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Design Guidelines for Low Energy Housing with Validated Effectiveness: Hot Humid Region Edition

-House Design to Achieve 50% Reduction in Energy Consumption-

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Foreword to English version

Building Research Institute and National Institute for Land and Infrastructure Management published the design guidelines for Japanese practitioners, who aim at substantial energy saving for residential buildings (detached houses) in mild climate regions (June 2005) and hot humid climate regions (August 2010). The guidelines were developed on the basis of the research outputs, especially experimental validation and prudent application of simulation programs, by the above-mentioned research institutes.

In Asia and Oceania regions, there are many countries, which have hot humid regions and are growing rapidly in population and economy. The fact means that energy consumption and resultant CO2 emission due to the use of houses and other kinds of buildings is increasing and there is a need to help practitioners and various decision makers with much more reliable information on how to design residential buildings. This is the reason why Building Research Institute decided to publish this English version of the design guidelines for energy-saving detached houses in hot humid regions, which was originally published in Japanese by Building Research Institute and National Institute for Land and Infrastructure Management.

As mentioned in the design guidelines, the optimized solution for a best possible energy saving house depends on its design conditions, such as detailed characteristics of the climate, surrounding outdoor conditions, lifestyle of the residents, economical aspect of building components and delivered energy and so on.Therefore, though the framework of this design guidelines and qualitative explanation can be universal, the detailed quantitative information should be carefully interpreted and applied to the situation other than Japanese ones.

I hope the English version of the design guidelines, entitled “Design Guidelines for Low Energy Housing with Validated Effectiveness; Hot Humid Region Edition”, will be utilized by practitioners and various decision makers when they aim at finding practical and economically feasible solutions for energy-saving houses in their countries.

December, 2010

Shuzo Murakami, Chief Executive
Building Research Institute
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Foreword

Japan aims to reduce CO_2 emissions by 80% compared to the emissions in 1990 by 2050 as a long-term goal in order to achieve a low-carbon society. In order to achieve this long-term goal, it is essential to make efforts toward controlling CO_2 emissions due to residential and commercial buildings through the promotion of energy conservation. Meanwhile, in terms of health promotion and improvement in convenience and comfort, houses in Japan still need improvement and quality enhancement. Therefore, it can be said that the establishment and spread of more rational building technology is in demand in order to solve the two tasks, energy conservation and quality enhancement, at the same time.

In June, 2005, the National Institute for Land and Infrastructure Management (NILIM) and the Building Research Institute (BRI) published the Design Guidelines for Low Energy Housing with Validated Effectiveness: House Design to Achieve 50% Reduction in Energy Consumption as a result of housing technology development research conducted between 2001 and 2004. After that, as energy-efficient technology development research, the National Institute for Land and Infrastructure Management has been conducting a research project named "Research on promoting technologies for improving energy efficiency of residential buildings (2005 – 2007)" and the Building Research Institute has also been implementing "Research on validated technologies for enhancing the energy performance in buildings and methods of application to existing stocks (2006– 2008)". This book, which contains the guidelines for hot and humid climate, was developed as one of the results of those research projects and summarizes the design technologies for low energy housing with validated effectiveness in hot and humid regions of Japan. The framework for evaluating energy performance was developed mainly by the NILIM, and energy-saving elemental technologies were validated and prescribed mainly by the BRI.

In the research and development, the "Low Energy Housing with Validated Effectiveness Development Committee" (Chairperson: Professor Yuzo Sakamoto, Graduate School of the University of Tokyo; Adviser: Professor Emeritus Kiyonori Miisho, Shibaura Institute of Technology), a study group in which experts from the fields of industry, universities and government were requested to participate, was established within the Institute of Building Environment and Energy Conservation. This committee has implemented measures for developing technology while seeking expertise and a wide range of knowledge from outside.

Lastly, we would like to sincerely pay our respects to the many researchers and engineers from research institutes, universities and companies, who were involved in the planning and writing of these guidelines, local practitioners who cooperated in the research on hot humid regions, and other people concerned for their efforts and cooperation. At the same time, we hope that these guidelines will help deepen the understanding of those readers involved in housing construction and contribute to the improvement in the energy efficiency, convenience and comfort of Japanese housing in the future.

August, 2010

Kenji Takai, Deputy Director General
National Institute for Land and Infrastructure Management
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Design Guidelines for Low Energy Housing with Validated Effectiveness: Hot Humid Region Edition

Table of Contents

Introduction
Objectives and Composition of the Design Guidelines

1. Objectives of the Design Guidelines

Low energy housing with validated effectiveness (LEHVE) is housing that uses as much natural energy as possible under the given conditions such as site characteristics and family forms, and is able to reduce energy consumption (CO_2 emissions) during occupancy by half compared to housing that was common around 2000, while increasing liveability and convenience (See Chapter 1). Therefore, when designing LEHVE two types of technologies are required: one that makes the most of the potential of nature, such as solar energy and wind, and utilizes it; and the other in which equipment technology is carefully selected, designed and installed, as typified by cooling and heating systems and domestic hot water systems, from the perspective of energy performance.

This document provides practical technical information for designing LEHVE to professionals working at construction and architect offices who are directly engaged in making houses, i.e. general housing architects who are not specialized in environment and equipment planning. It also aims to propagate and promote LEHVE by having these architects utilize this document. For that purpose, this document covers versatile technologies which can be made practical as a priority and explains the method for designing and applying such technologies in a specific, easy and straightforward fashion. It also evaluates the energy saving effects and cost effectiveness achieved by using these technologies.

2. Technology Covered in the Design Guidelines

Methods for designing and applying individual technologies that are effective for designing LEHVE (hereinafter referred to as "elemental technologies") are diverse and vary depending on design prerequisites such as regional and site conditions where the house is being built, the way the house is built and construction methods, and way of living.

In 2005, as the first step to propagate and promote LEHVE, we focused on elemental technologies related to detached wooden houses in relatively mild regions (Zone IV in the zone classification according to the energy conservation standard) and summarized them in the design guidelines. The present document targets the hot humid regions south of Zone V and discusses the elemental technologies related to houses designed under the following conditions.

- Construction region: Hot humid regions (Zones VI and V* in the zone classification according to the energy conservation standard)
- Housing construction: Detached house
- Construction methods: Reinforced concrete house for Zone VI
  Wooden house for Zone V (including traditional construction methods)

A diverse and wide range of elemental technologies are involved even under these specific conditions. However, in cases such as where site shapes and sizes as well as forms of the housing are unusual, it may be difficult to apply some elemental technologies, and if this is the case architects are required to exercise their own ingenuity for planning.

Moreover, some elemental technologies covered in this document are applicable to multi-family residential buildings or for house renovation.

* See "Appendix 1: Zone Classification Data" on p.384 for the zone classification based on the energy conservation standard. Zone VI belongs to Okinawa and Zone V extends to mainly South Kyushu and the Pacific coast west of Tokyo.

3. Composition of the Design Guidelines

This document is composed of the following six chapters:

Chapter 1 Low Energy Housing with Validated Effectiveness and Energy Conservation
It defines LEHVE and explains the significance of working on LEHVE as well as the indoor environment performance that LEHVE aims for.

Chapter 2 Design Process of Low Energy Housing with Validated Effectiveness and Outline of Elemental Technologies
From the perspective of both the natural energy application and energy-efficient equipment technology, it illustrates the design procedures for LEHVE and explains the overview of effective elemental technologies for designing. It also outlines the items to be considered that are peculiar to hot humid regions, such as heavy wind and rain as well as termites.

Chapter 3 Natural Energy Application Technology (Elemental Technology Application Method 1)
It covers elemental technologies that use natural energy such as wind, sunlight and solar heat as alternatives to fossil fuel energy, and explains their objectives, reduction targets of energy consumption, and specific design methods.

Chapter 4 Heat Control Technology of Building Envelopes (Elemental Technology Application Method 2)
It covers energy-efficient technologies using heat control measures for building envelopes including solar shading and thermal insulation and explains their objectives, reduction targets of energy consumption, and specific design methods. The details of these technologies differ between Zone VI and Zone V.

Chapter 5 Energy-efficient Equipment Technology (Elemental Technology Application Method 3)
It covers energy-efficient technologies related to the planning of the cooling and heating, ventilation and domestic hot water systems as well as selection of energy-efficient consumer electronics. It also explains their objectives, reduction targets of energy consumption, and specific design methods such as methods for selecting systems and devices.

Chapter 6 Energy Saving Effect Evaluation and its Utilization in Design
It summarizes the energy saving effects achieved by elemental technologies discussed in Chapters 3 to 5 and shows the evaluation results of energy consumption, CO_2 emissions and costs (initial and running). It also shows simplified estimation methods for energy-saving effects and introduces calculation examples of energy-efficient design using these methods.

The ideal of the low energy housing with validated effectiveness (LEHVE) is self-sufficiency that does not receive energy required for living from others. It aims to reduce energy consumption thereby controlling CO_2 emissions while maintaining the quality of the indoor environment.

1

Chapter 1 : Low Energy Housing with Validated Effectiveness and Energy Conservation

1.1 What is Low Energy Housing with Validated Effectiveness?

As part of efforts to improve sanitary conditions, measures have been implemented to develop environment-friendly housing technology in Japan since the Meiji period (1868-1912) when even the causes of many diseases were unknown. For example, various efforts have been made to achieve houses that provide coolness in summer and warmth in winter, bright rooms, high-quality water and other functions such as being able to use hot water freely. Time passed, and in the 1970's, there was rising concern that the impact of society on the environment could not be ignored. Since the 1980's, man-made climate change such as global warming have been recognized as international issues. The Kyoto Protocol was created in 1997 and came into effect internationally in 2005. While the first commitment period of the Kyoto Protocol started in January 2008, proactive actions have been taken such as the review of Japan's Kyoto Protocol Target Achievement Plan and the international measures regarding the framework of steps taken after the Kyoto Protocol.

Since the 1990's, in the housing field, measures have been promoted to tackle the issue of environmental friendliness at different stages; construction, occupancy and demolition. Furthermore, recently, technology used for traditional housing in Japan has been re-evaluated, and methods for indoor climate control, which enable the realization of housing that is cool in summer and warm in winter, have been discussed in order to deal with the Japanese hot, humid climate with high solar radiation. Low energy housing with validated effectiveness (LEHVE) can be positioned as one such effort.

The ideal of LEHVE is to achieve housing with an established self-contained energy reception and consumption system that does not receive energy required for living from others. However, while considering this as a long-term goal, we firstly aim to develop and spread technology which contributes to the reduction of CO_2 emissions from the standpoint of housing by the deadline around 2010 adopted by the Kyoto Protocol.

Based on this, we define LEHVE as follows.

Low energy housing with validated effectiveness is housing that uses as much natural energy as possible according to the way of living and housing site conditions, such as climate and site characteristics, while increasing the standards of livability and convenience by carefully designing and selecting buildings, equipment and appliances. Thereby, such housing is able to reduce energy consumption (CO_2 emissions) during occupancy by up to 50% compared to housing that was common around 2000, and it will be able to be put to practical use by 2010.

In addition, various technologies used for LEHVE explained in this document are not the technologies that will be feasible in some distant future but the ones that are already in practical use and commercialized. They are mainly economical, highly valid and accessible technologies that should be updated and improved over time.

●International Trends and Efforts Made by Japan Regarding Global Environmental Issues

In the late 20th century, supplying a large amount of energy became possible thanks to low-priced oil and artificial environmental technology, as typified by heating and cooling technology, spread rapidly. However, the corresponding increase in energy consumption caused an increase in greenhouse gas emissions, which became recognized as the cause of environmental impact including global warming. Since the 1970's, the following measures have been implemented to reduce environmental impact

1972	"The Limits to Growth" by the Club of Rome presented the necessity for a change from growth to equilibrium. Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration) was adopted.
1978 onward	Specific measures for energy conservation accelerated due to soaring oil prices caused by oil crisis.
1979	Energy Conservation Law (Act on the Rational Use of Energy) took effect in Japan. Various standards for promoting the energy conservation for housing and other buildings were established.
1988	World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) Intergovernmental Panel on Climate Change (IPCC)
1992	Earth Summit was held. United Nations Framework Convention on Climate Change was adopted in order to control the emissions of greenhouse gas such as CO_2.
1997	Kyoto Protocol was created. Japan set target values for reducing greenhouse gas emissions by 6%, compared to those in 1990, by around 2010.
2002	Outline for Promotion Effects to Prevent Global Warming Japan declared target values for reducing greenhouse gas emissions in the private sector by 2%, by around 2010.
2005	Kyoto Protocol came into effect as 143 countries, which hold approximately 62% of the CO_2 emissions caused by developed countries, ratified it.
2007	The Prime Minister Abe proposed Cool Earth 50 (Beautiful Star 50). A long-term goal to reduce greenhouse gas in the entire world by half by 2050 was proposed. The 13th Conference of Parties (COP 13) of the United Nations Framework Convention on Climate Change was held in Bali, Indonesia. It was decided that the framework after the first commitment period of the Kyoto Protocol would be adopted with consent by 2009.
2008	The first commitment period of the Kyoto Protocol started as of January 1.

●Change in CO_2 Emissions in Japan

We will look at the change in CO_2 emissions in Japan by sector (Fig. 1). The increase in CO_2 emissions in the private sector (caused by energy consumption by businesses and homes) is remarkable. For example, the CO_2 emissions from the household energy consumption sector increased by 36.4% between 1990 and 2005. This shows that an approximately 22% reduction must be achieved during the first commitment period in order to control the emissions within the range of an 8.5% to 10.9% increase※, which is the goal set for the sector in question in the Kyoto Protocol Target Achievement Plan.

※ The Kyoto Protocol Target Achievement Plan created in March 2005 was revised in March 2008. Regarding the household sector, it is stated in the revision that the goal is to reduce rate of increase for CO_2 emissions by the year 2010 from the current level to an 8.5 – 10.9% increase compared to the year 1990.

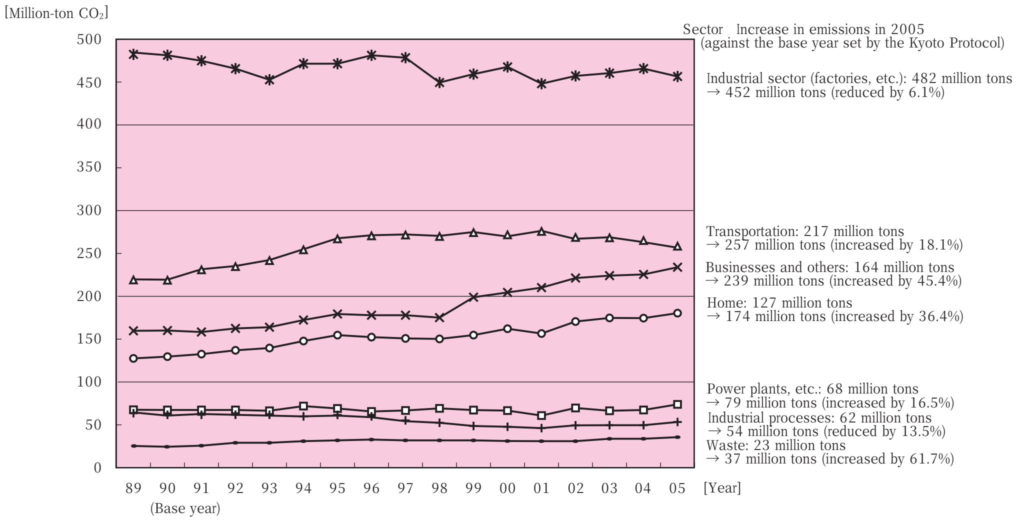


Fig. 1 Change in CO_2 emissions in each sector between 1990 and 2005

●Research Project on Low Energy Housing with Validated Effectiveness

The National Institute for Land and Infrastructure Management and the Building Research Institute implemented a research and development project on low energy housing with validated effectiveness for four years starting 2001. In June 2005, its results were summarized in the "Design Guidelines for Low Energy Housing with Validated Effectiveness" for detached houses in warm regions and are utilized by many people in the field. The project was followed by a subsequent project in and after 2005, which led to the creation of these guidelines for detached houses in hot humid regions.

Glossary: GJ
GJ is pronounced as "gigajoule", and joule (J) is a unit of energy amount. Since giga means one billion, 1 GJ is 1 billion joules

1.2 Actual Situation of Energy Consumption during Occupancy and Tasks

The actual situation of energy consumption during occupancy of housing is shown roughly in Fig. 2. Weather conditions are reflected in the situation. In Hokkaido and the Tohoku district, heating energy consumption is high. In warm regions in Honshu and Kyushu, the ratio of domestic hot water energy and cooling energy tends to be high.

Fig. 2
Actual situation of energy consumption in housing: Comparison of detached houses in eight urban regions

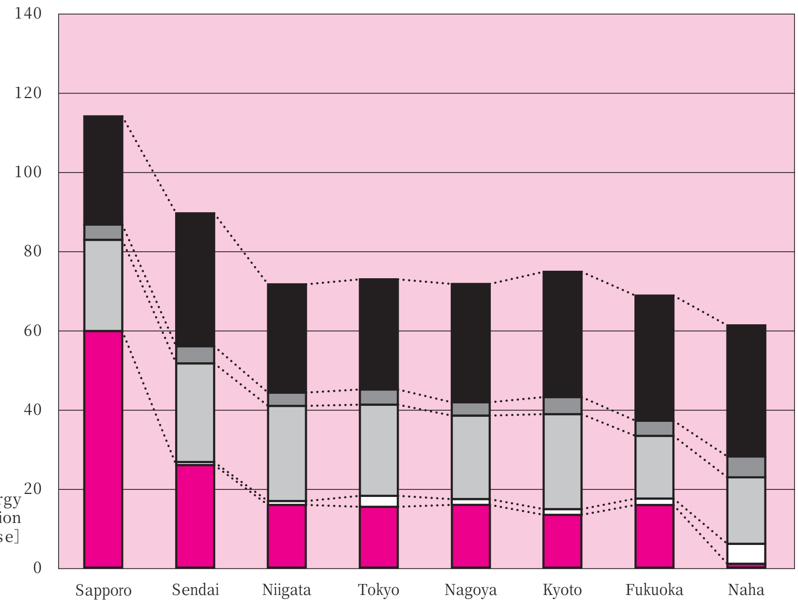
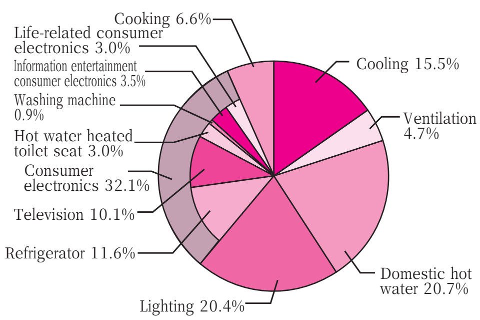
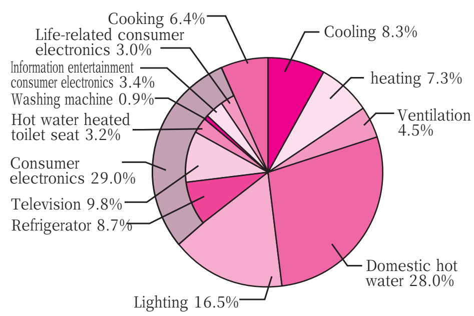


Fig. 3 shows the results of detailed analysis of the composition of energy consumption at detached houses in hot humid regions. In Naha located in Zone VI, its annual total consumption is: "16% for cooling", "5% for ventilation", "21% for domestic hot water", "20% for lighting", "32% for consumer electronics" and "7% for cooking" (0% for heating). In Kagoshima located in Zone V, the Fig. shows "8% for cooling", "7% for heating", "5% for ventilation", "28% for domestic hot water", "17% for lighting", "29% for consumer electronics" and "6% for cooking". As for the breakdown of consumer electronics, you can see that the ratios of refrigerators and televisions are high in both regions.

In order to achieve a great energy conservation effect as a whole, implementing a measure for a single use only is not sufficient. It is necessary to take measures for various uses of energy.



In the case of reinforced concrete house in Naha
Total primary energy consumption per year: 66.6 GJ



In the case of wooden house in Kagoshima
Total primary energy consumption per year: 68.6 GJ

Fig. 3
Ratio of annual primary energy consumption at detached houses in hot humid regions

1.3 Indoor Environment Performance that Low Energy Housing with Validated Effectiveness Aims for

While the goal of LEHVE is to reduce energy consumption during occupancy, we cannot forget that it should aim for creating a pleasant environment where occupants can feel “comfortable” at the same time. The quality of the environment that feels “comfortable” varies depending on the occupant’s living history, age and preferences. In addition, environmental quality that the same occupant seeks may be different depending on the housing site conditions. In other words, the “comfortable” environment that each occupant seeks is unique yet changes. Therefore, the complete removal of physiological stress (physiological unpleasantness caused by the gap between the quality that an occupant seeks and the actual quality), such as coldness, heat and darkness, is not necessarily the ultimate goal of LEHVE.

How much an occupant seeks environmental quality varies. Some occupants’ standards are flexible and they tolerate changes, while others have high standards and seek stability. Naturally, occupants have freedom to select the environment they seek. LEHVE secures such freedom for each occupant and accepts a wide range of ideas, aiming to realize the housing equipped with environmental quality suitable for the occupant.

Instead of relying only on machinery and equipment as well as commercial energy, LEHVE offers architectural ingenuity and natural energy application as preconditions. This is precisely why LEHVE does not always offer excessive standards for comfort by ignoring the occupant’s request. Instead, it values the active attitudes that occupants have toward creating environment. To achieve this, LEHVE is required to provide specifications and architectural arrangements that will accommodate the occupant’s creative ideas and measures. It is important to creatively design LEHVE in a way that allows the occupant to operate and adjust the following as he or she likes: finely-tuned operation of heating and cooling devices according to room temperature and outside air temperature; opening and closing of windows according to wind; adjusting solar radiation by installing solar shading devices; and turning on and off lighting fixtures according to places and actions.

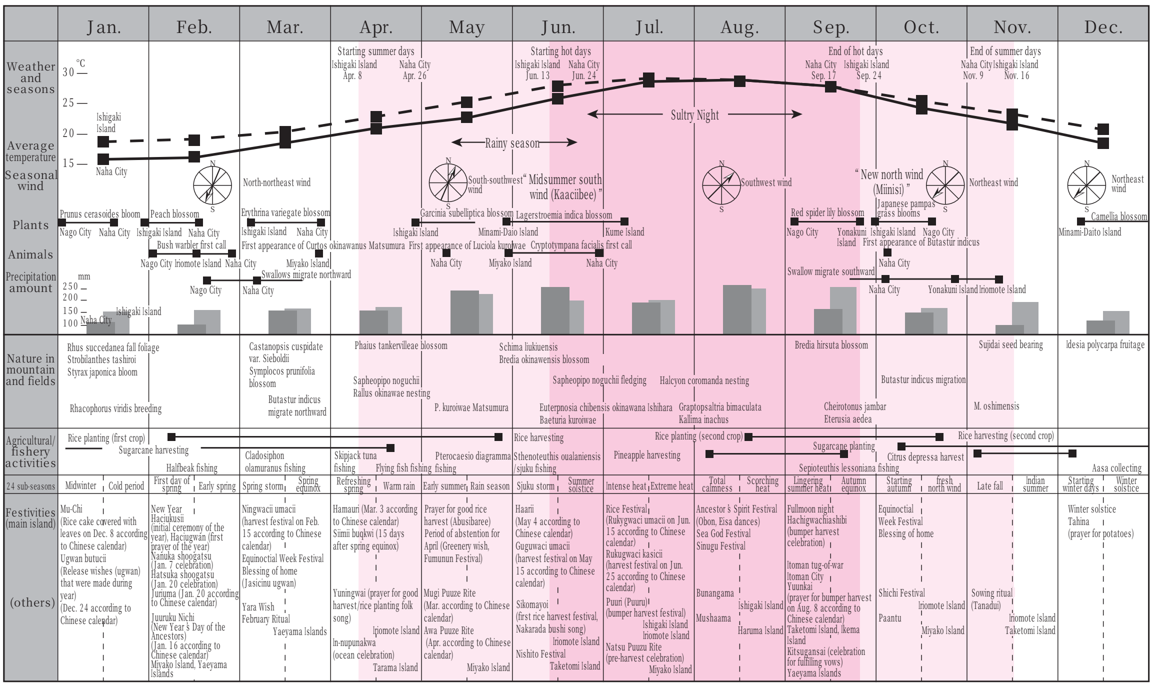


Fig. 4
Lifestyle in Okinawa that coexists with seasonal changes

Source: Okinawa Prefectural Basic Plan for Environmentally Symbiotic Housing, Housing Division, Department of Civil Engineering & Construction, Okinawa Prefectural Government

1.4 Climate and Housing Characteristics in Hot Humid Regions

1.4.1 Target Hot Humid Regions and Climate Characteristics

This document targets the following two regions. Zone VI is Okinawa Prefecture including the minor islands, and Zone V is the region along the Pacific coast west of Tokyo such as Southern Kyushu and the south of Shikoku (Table 1). The list of municipalities for each region is in “Supplement 1: Zone Classification Materials” (p.384).

The climate of each Zone varies, but general characteristics are described below (Table 2).

- Zone VI belongs to subtropical marine climate. It is hot and humid there with small temperature differences throughout the year. It is warm even in winter with a temperature around 16°C, and the temperature rarely falls below 10°C. In summer, on the other hand, it is rare for the temperature to significantly exceed 30°C. Although relative humidity is high, you may even feel cool thanks to high wind speed. In this region which gets hit by typhoons frequently, wind is strong throughout the year and rainfall is relatively high even when it is not the rainy season. Because this region is located at low latitudes, solar altitude is high with strong UV rays reaching the ground.
- Zone V covers a wide area. It is warm and humid throughout the year with high rainfall. In the rainy season and the typhoon season, concentrated heavy rain and extremely gusty winds occur in some areas. In general, sunshine hours are long in this region with high global solar radiation.

Table 1 Main hot humid regions

Zone VI	Okinawa (Okinawa Island and approximately 160 large and small islands including Miyako Island, Ishigaki Island, etc.)	
Zone V (16 prefectures)	Kagoshima (excluding the north mountain area) Miyazaki (excluding the west mountain area) Oita (part of the southwest coastal area) Kumamoto (the southwest plain area, large and small islands) Nagasaki (part of the east area, excluding Tsushima and Iki islands) Fukuoka (part of Fukuoka City) Kochi (most of the south coastal area) Ehime (part of the west coastal area)	Tokushima (part of the southwest coastal area) Yamaguchi (Shimonoseki City) Wakayama (part of the south area and west area) Mie (part of the south coastal area) Shizuoka (south area of Izu Peninsula) Tokyo (Izu Islands, Ogasawara Islands) Chiba (Choshi City) Ibaraki (Hasaki-machi)

Table 2 Weather data of major cities in hot humid regions (normal values)

Major cities		Temperature (°C) Annual average (January)	Precipitation amount (mm) Annual total	Relative humidity (%) Annual average	Wind speed (m/s) Annual average	Most frequent wind direction through the year (August)	Sunshine hours (h) Annual total	Global solar radiation (MJ/m²) Average
Zone VI	Naha	22.7 (16.6)	2036.9	75	5.3	North-northeast (Southeast)	1820.9	13.9
	Miyako Island	23.3 (17.7)	2019.3	79	4.8	North-northeast (South)	1768.5	14.6
	Ishigaki Island	24.0 (18.3)	2061.0	77	4.7	North-northeast (South-southwest)	1852.6	15.0
Zone V	Kagoshima	18.3 (8.3)	2279.0	71	3.4	Northwest (Northeast)	1918.9	13.5
	Miyazaki	17.2 (7.6)	2457.0	75	3.2	Northwest (Northwest)	2108.4	13.9
	Kochi	16.6 (6.1)	2627.0	68	1.8	West (West)	2120.1	14.0
Zone IV (Reference)	Tokyo	15.9 (5.8)	1466.7	63	3.3	North-northwest (South)	1847.2	11.6

※Created based on Japan Meteorological Agency's website

1.4.2 Characteristics of Housing in Hot Humid Regions

The statistics of housing built in hot humid regions show that trends in terms of structure and construction differ between Zone VI and Zone V (Table 3).

- In Zone VI (Okinawa Prefecture), multi-family residential buildings account for more than half of the total number of housing, slightly exceeding the number of detached houses. As for the detached houses, more than 80% of them are reinforced concrete houses. While the ratios of one-story houses and two-story houses are almost the same, two-story houses have been on the increase in recent years. In addition, average total floor area is around 110 m^2.
- According to the data on the three Prefectures (Kagoshima, Miyazaki, and Kochi) in Zone V, detached houses account for 70% of the total number of housing. Among them, more than 90% are wooden houses. As for the number of stories, ratios are different in each prefecture. However, the ratio of houses with two or more stories has been increasing in recent years, accounting for 50% in Kagoshima and Miyazaki Prefectures and more than 80% in Kochi Prefecture. In addition, the average total floor area is between 100 m^2 and over 110 m^2.

Table 3　Construction and structure of housing in hot humid regions

Region/Prefecture		Total number of houses (household)	Construction (%)		Structure of detached house (%)		Number of stories (%)	
			Detached house	Multi-family residential building	Fire-retardant wood Wood	Reinforced/ Steel framed concrete	One-storied house	Two stories or more
Zone VI	Okinawa	465,000	45.9	50.3	13.7	82.4	48.6	51.4
			34.5	63.8	4.4	89.1	35.6	64.4
Zone V	Kagoshima	699,700	72.9	24.0	92.8	5.3	68.8	31.2
			59.9	38.5	90.0	6.0	53.9	46.1
	Miyazaki	435,300	72.7	24.0	95.7	2.7	62.1	37.9
			61.4	37.9	93.0	4.2	49.0	51.0
	Kochi	318,400	70.7	25.1	92.7	4.0	25.2	74.8
			55.7	41.2	88.9	5.6	14.7	85.3

※Created based on the data on 2003 housing/land statistical research by Statistics Bureau, Ministry of Internal Affairs and Communications
The upper rows show overall ratios and the lower rows show ratios of houses built between 1999 and 2003.
The number of stories for detached houses is that of the reinforced/steel framed concrete houses for Zone VI and wooden houses for Zone V.

Fig. 5
Average residential area in Naha City, Okinawa

Based on what has been described above, this document targets reinforced concrete house in Zone VI and wooden house in Zone V. Energy consumed during occupancy varies between houses in Zone VI and those in Zone V. With regard to elemental technologies effective in designing LEHVE, some are described in separate chapters for each region and others can be described in the same chapter for both regions without any problems. We will describe the details in Chapter 3 onward.

Natural energy utilization, building envelope performance and system efficiency should be taken into account when aiming to design LEHVE. Architects are required to proficiently combine these three elements according to the given design conditions including the building site and lifestyle of occupants, enhancing these elements rather than impairing them.

2

Chapter 2 : Design Process of Low Energy Housing with Validated Effectiveness and Outline of Elemental Technologies

2

Chapter 2
Design Process of Low Energy Housing with Validated Effectiveness and Outline of Elemental Technologies

2.1 Design Flow of Low Energy Housing with Validated Effectiveness

In order to "reduce energy consumption during occupancy" and "create a comfortable indoor environment", which is the goal of low energy housing with validated effectiveness (LEHVE), it is necessary to combine "architectural techniques" through the use of natural energy and heat control of building envelopes with "mechanical techniques" by introducing high-efficiency mechanical systems, according to the characteristics of the home to be designed. It is important for architects to reach an appropriate and comprehensive design solution by combining different methods and to proceed with design work by taking into consideration the priorities of items to be studied and the context of design procedures. **Fig. 1** illustrates the design procedures for LEHVE as well as the essential stages and items to be studied in order to reduce as many design changes as possible and achieve the goal of LEHVE.

The design procedures of LEHVE are based on the standard design procedures for housing. This document views the standard design procedures for housing in four stages: "understanding given conditions and requirements", "setting design goals and principles", "developing design models", and "analyzing design models and verifying their effectiveness". **Fig. 1** presents the design flow of LEHVE according to these four stages, including the design and details to be studied for LEHVE and specific items to be studied.

The outline of the design procedures for LEHVE is explained below:

◆ Procedure 1　Understanding design requirements of LEHVE (i. Understanding given conditions and requirements)

This stage focuses on and identifies the "possibility of natural energy utilization at the building site" and "lifestyle orientation" which determines the feasible characteristics of LEHVE among the given design conditions.

◆ Procedure 2　Setting target design model for LEHVE (ii. Setting design goals and principles)

Based on Procedure 1, this stage sets the target design model for LEHVE. It is effective to study the possibility of applying elemental technologies and their levels in relation to the target design model. See Section 2.3.2 on p.029 for the types of houses that are considered typical target design models.

◆ Procedure 3　Basic items to be considered for designing LEHVE (iii. Developing design models – 1)

This stage refers to the early planning and design stage, such as building layout planning, floor planning, sectional and elevation planning, and examines the basic items to be considered for designing LEHVE. Please confirm and examine these basic items listed in Section 2.3.3 on p.034 prior to determining design specifics.

◆ Procedure 4　Examining the application of elemental technologies (iii. Developing design models – 2)

This stage studies in detail the application of elemental technologies, which determine the specifics of LEHVE, and integrates the design model. As shown in Table 1, this document covers 13 elemental technologies related to the thermal, air, light and other environmental planning fields, which are classified into the three categories of "natural energy application technology", "heat control technology of building envelopes", and "energy-efficient equipment technology".

Table 1　Elemental technologies discussed in this document

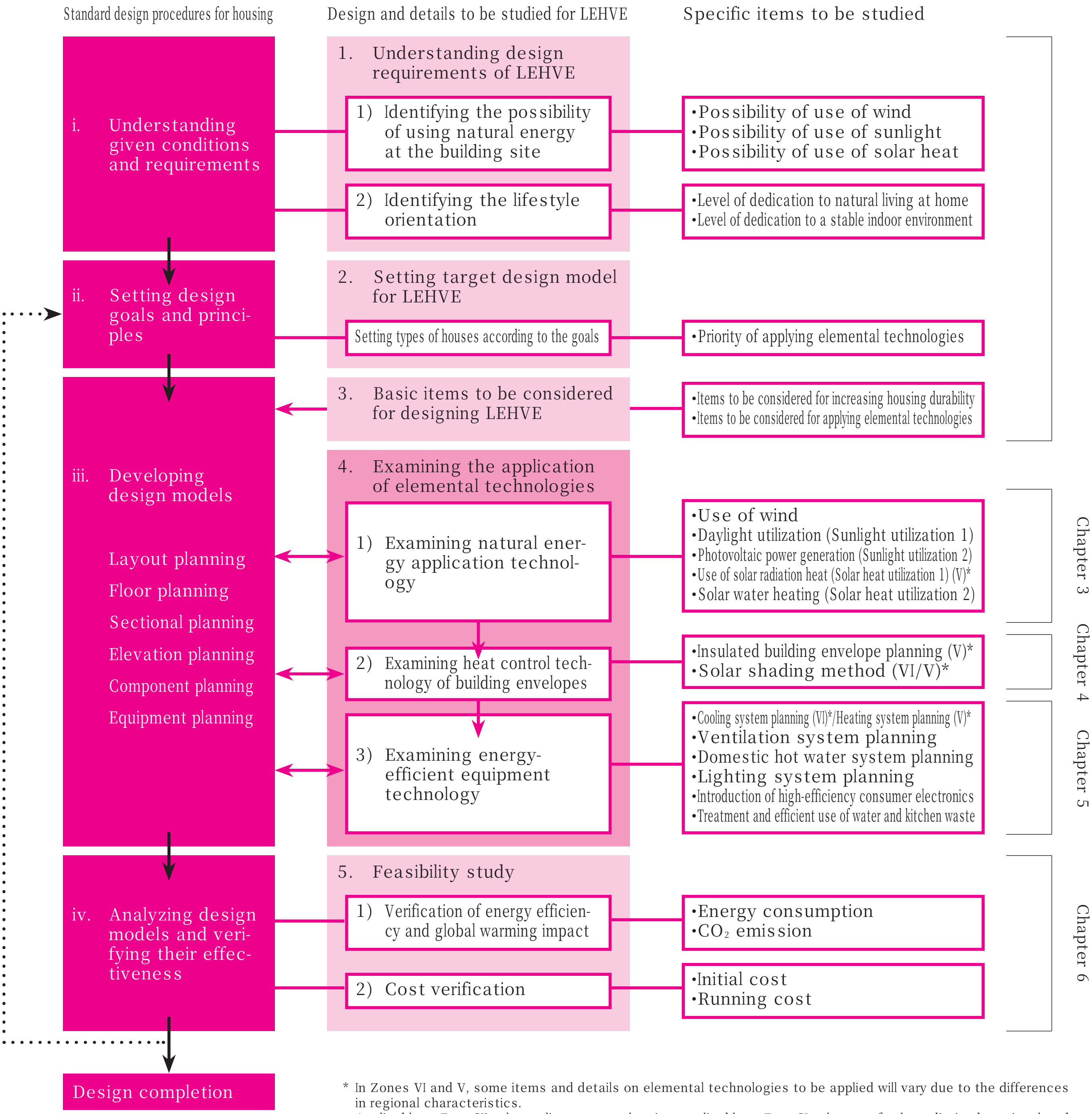
		Field of thermal environment	Field of air environment	Field of light environment	Other
Natural energy application technology	Technology that replaces fuel energy with natural energy such as wind, solar heat, sunlight	Use of solar radiation heat (Solar heat utilization 1) Solar water heating (Solar heat utilization 2)	Use/control of wind	Daylight utilization (Sunlight utilization 1) Photovoltaic power generation (Sunlight utilization 2)	
Heat control technology of building envelopes	Technology that controls heat transfer and maintains an appropriate indoor environment using architectural solutions for building envelopes including insulation and solar shading	Insulated building envelope planning Solar shading method			
Energy-efficient equipment technology	Technology that uses select energy efficient equipment and systems, reduces energy, and increases comfort	Cooling/heating system planning Domestic hot water system planning	Ventilation system planning	Lighting system planning	Introduction of high-efficiency consumer electronics Treatment and efficient use of water and kitchen waste

The prerequisite of LEHVE is to make optimum use of the natural potential of the building site. It is recommended to first examine the "natural energy application technology" and "heat control technology of building envelopes" as the priority before studying the "energy-efficient equipment technology". In order to create a "pleasant" indoor environment while reducing energy consumption, it is important to select elemental technologies that meet the design conditions from the various ones available, as well as to properly combine those technologies.

♦ Procedure 5 Feasibility study (iv. Analyzing design models and verifying their effectiveness)

This stage verifies the energy consumption (CO_2 emission) and cost of the design model that has been studied.

If the goal has not been achieved, go back to Procedure 2 and re-examine the design model.



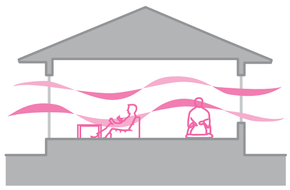
* In Zones VI and V, some items and details on elemental technologies to be applied will vary due to the differences in regional characteristics.
Applicable to Zone VI only: cooling system planning; applicable to Zone V only: use of solar radiation heat, insulated building envelope planning, heating and cooling system planning; details are different between Zones VI and V: solar shading method. Other elemental technologies are applicable to both zones.

Fig. 1 Design flow of low energy housing with validated effectiveness

2.2 Outline of Elemental Technologies

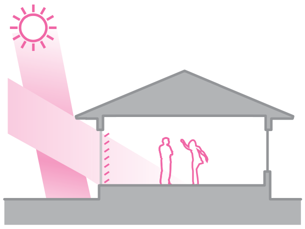
Natural energy application technology

01 Use and control of wind (3.1)



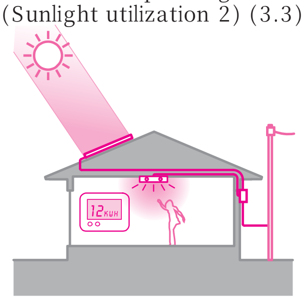
Method 1 Securing the opening area for the cross ventilation route
Method 2 Positioning the opening area according to the prevailing wind direction
Method 3 Use of high windows

02 Daylight utilization (Sunlight utilization 1) (3.2)



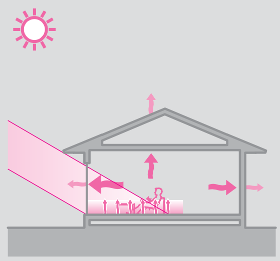
Method 1 Direct daylight utilization method (daylighting method)
Method 2 Indirect daylight utilization method (daylight guiding method)

03 Photovoltaic power generation (Sunlight utilization 2) (3.3)



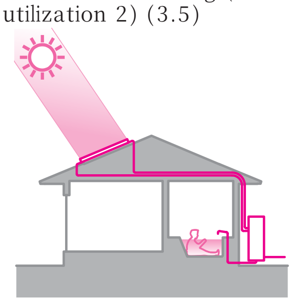
(Covers whether or not to install a photovoltaic power generation system and its capacity, etc. Methods have not been specified.)

04 Solar radiation heat utilization (Solar heat utilization 1) (3.4)



Method 1 Method for insulating openings
Method 2 Method for collecting heat from openings
Method 3 Heat storage method

05 Solar water heating (Solar heat utilization 2) (3.5)



Method 1 Securing heat collection area, etc.
Method 2 Proper connection to the auxiliary heat source
Method 3 Adoption of energy-efficient circulating pump

Key

- Elemental technologies effective for both Zones VI and V
- Elemental technologies effective for Zone VI
- Elemental technologies effective for Zone V

Numbers in parentheses refer to the section numbers in Chapters 3 and 5 in which the elemental technologies are explained.

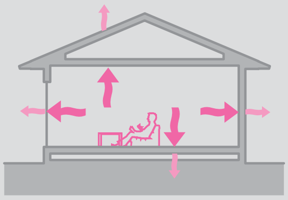
2.2.1 List of Elemental Technologies and Methods

There are 13 elemental technologies covered in this document for designing LEHVE: five types of "natural energy application technology"; two types of "heat control technology of building envelopes"; and six types of "energy-efficient equipment technology". Please note that some items and details of elemental technologies to be applied vary in the hot humid zones VI and V due to the differences in regional characteristics.

Recommended design methods (hereinafter referred to as "methods") that offer energy saving effects are specified for the elemental technologies. (Methods are not specified for some elemental technologies.)

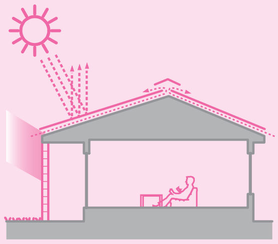
Heat control technology of building envelopes

06 Insulated building envelope planning (Zone V) (4.1)



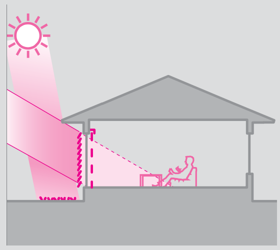
(It covers the insulation material thickness, opening specifications, airflow blocking for junction areas, condensation control, etc. Methods have not been specified.)

07-1 Solar shading method (Zone VI) (4.2)



Method 1 Solar shading method using outside shading device
Method 2 Solar shading method using building envelope

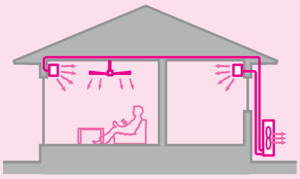
07-2 Solar shading method (Zone V) (4.3)



Method 1 Solar shading method of opening areas
Method 2 Solar shading method of roofs
Method 3 Solar shading method of exterior walls
Method 4 Other solar shading methods

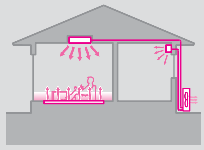
Energy-efficient equipment technology

08-1 Cooling system planning (Zone VI) (5.1)



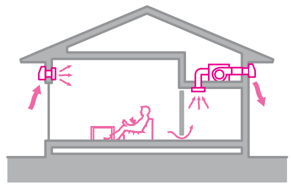
Method 1 Introduction of high-efficiency air-conditioner
Method 2 Adoption of electric and ceiling fans

08-2 Heating and cooling system planning (Zone V) (5.2)



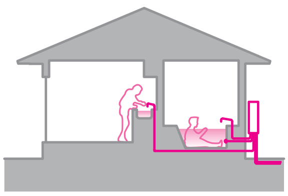
Type 1 Individual heating and cooling
Type 2 Gas/oil hot water heating
Type 3 Forced flue (FF) heating
Type 4 Duct central heating and cooling

09 Ventilation system planning (5.3)



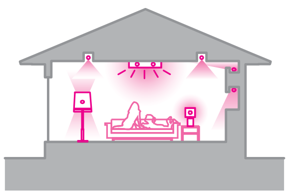
Type 1 Duct ventilation system
Method 1 Reduction of pressure loss of ducts, etc.
Method 2 Introduction of high-efficiency devices
Type 2 Through-the-wall ventilation system
Method 1 Proper combination of fan and outside air terminal

10 Domestic hot water system planning (5.4)



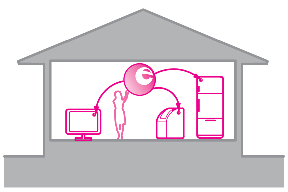
Method 1 Solar heat utilization
Method 2 Introduction of high-efficiency water heater
Method 3 Energy saving design/construction methods, etc., for each component of domestic hot water system

11 Lighting system planning (5.5)



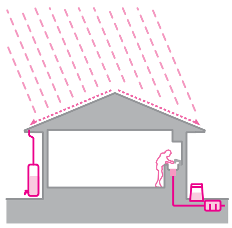
Method 1 Method using devices
Method 2 Method by lighting operation and control
Method 3 Method by design

12 Introduction of high-efficiency consumer electronics (5.6)



(Covers high-efficiency prime consumer electronics and priority consumer electronics, etc. Methods have not been specified.)

13 Treatment and efficient use of water and kitchen waste (5.7)



Method 1 Use of water saving devices
Method 2 Adoption of rainwater and wastewater reuse system
Method 3 Adoption of rainwater seepage pit, etc.
Method 4 Adoption of advanced wastewater treatment technology
Method 5 Adoption of efficient kitchen waste disposal technology

2.2.2 Uses of Energy to be Reduced

1. Uses of energy to be reduced by means of elemental technologies

This document classifies uses of energy that are consumed by occupants of a house into eight categories, which are cooling, heating, ventilation, domestic hot water, lighting, home electronics, cooking and water. The table below shows the uses of energy that can be reduced by using elemental technologies, and factors such as cooling and heating energy are influenced by multiple elemental technologies (Table 2).

Table 2 Relationship between uses of energy at houses and elemental technologies

Elemental technologies	Uses of energy to be reduced (marked with a circle)							
	Cooling	Heating	Ventilation	Domestic hot water	Lighting	Home electronics	Cooking	Water
1) Use/control of wind	○		○					
2) Daylight utilization					○			
3) Photovoltaic power generation								
4) Use of solar radiation heat (V)		○						
5) Solar water heating				○				
6) Insulated building envelope planning (V)	○	○						
7) Solar shading method (VI/V)	○							
8) Cooling system (VI)/ Heating and cooling system planning (V)	○	○						
9) Ventilation system planning			○					
10) Domestic hot water system planning				○				
11) Lighting system planning					○			
12) Introduction of high-efficiency consumer electronics						○		
13) Treatment and efficient use of water and kitchen waste								○

The following section focuses on the cooling, heating, domestic hot water and lighting energy and explains its relation with the elemental technologies.

1) Cooling energy

Related elemental technologies: Use and control of wind, insulated building envelope planning, solar shading method, cooling system/heating and cooling system planning (cooling)

- **In order to maintain a cool indoor environment without relying solely on the cooling system in the summer and in-between seasons, it is critical to achieve both cross ventilation and solar shading (including insulated building envelope planning for Zone V). These are all related to the provision of windows, overhangs and other features. When using accessories for solar shading the windows such as louvers and curtains, it is necessary to arrange them so that they will not hinder cross ventilation. On the other hand, it is possible not only to shade solar radiation but also to protect windows from heavy wind and rain by choosing the right sizes and shapes of overhangs and side walls (See Sections 3.1, 4.2 and 4.3).**

2) Heating energy

Related elemental technologies: Use of solar radiation heat, insulated building envelope planning, heating and cooling system planning (heating)

- **Energy that can be reduced by using solar radiation heat and planning the heating system is largely affected by the insulation level. In order to control the heating load by effectively using the solar radiation heat obtained indoors from windows in winter, it is necessary to increase the insulation performance of the openings, in particular, to reduce heat loss from the windows (See Sections 3.4 and 4.1).**
- **Low insulation levels lead to a significant temperature difference between the heated and unheated rooms and require a long heating operation time for maintaining a certain room temperature. In particular, if the lifestyle requires an extensive, long-hour heating operation system, as represented by a central heating system, it is critical to reduce running costs by enhancing the insulation level (See Sections 4.1 and 5.2).**

3) Domestic hot water energy

Related elemental technologies: solar water heating, domestic hot water system planning

- **Solar water heating and domestic hot water system planning involve different domestic hot water system heat sources. The former uses solar heat and the latter uses gas, oil or electricity as a heat source. When solar water heating is used, its planning generally incorporates a water heater as an auxiliary heat source. It is necessary to consider which combination of solar water heating system to be used and auxiliary heat source type is appropriate (See Sections 3.5 and 5.4).**

4) Lighting energy

Related elemental technologies: daylight utilization, lighting system planning

- **It is desirable to make an integrated examination of the daylight utilization and lighting system planning, which are related to lighting energy consumption. For example, if you want to actively introduce daylight utilization, use light fixtures with controlled lighting in the specific areas so that the lighting can be easily switched on and off during the daytime according to the availability of natural daylight. This will further increase the effect of lighting energy reduction (See Sections 3.2 and 5.5).**

2. Interaction of elemental technologies

Some elemental technologies are influenced by other elemental technologies and show different energy efficiencies when they are evaluated alone. In order to fully demonstrate the anticipated energy efficiency, it is necessary to examine individual elemental technologies as well as reviewing them as a group.

For example, even under the same living and environmental conditions, the cooling energy reduction effect obtained by the "use and control of wind" varies depending on the level of solar shading measures and the fluctuations of the internal heat generation caused by the use of lighting systems and devices as well as home electronics.

The influence of one elemental technology on the energy efficiency of another elemental technology is referred to as "interaction" in this document. Interactions are classified into synergic action, which increases the effect, and antagonistic action, which decreases the effect, in relation to other elemental technologies.

When estimating the overall energy efficiency of a house, we need to consider these interactions so that we can evaluate the energy saving effect more accurately.

2.3 Outline of Design Procedures

2.3.1 Understanding Design Requirements of Low Energy Housing with Validated Effectiveness

1. Possibility of natural energy utilization at the building site

The target design model of LEHVE varies depending on how much of nature's potential, such as solar heat and light energy and wind, can be utilized at building site. For this reason, architects need to confirm the local weather conditions and site conditions (building density and other surrounding conditions of the building site) and identify the possibility of natural energy utilization.

When discussing the overall natural potential the building site possesses, two points can be understood; a suburban location in which natural energy can be relatively easily utilized and an urban location in which natural energy can be utilized with some effort or is hard to utilize (Table 3).

Based on these points, specific site conditions need to be evaluated, particularly when adopting natural energy application technology (See Table 5 on p.027).

Table 3　Classification of location and possibility of natural energy utilization

Classification of location	Possibility of natural energy utilization
Suburban location	Building site in which natural energy can be easily utilized It is desirable to actively adopt natural energy application technology as its expected effects are high.
↕	Building site in which natural energy can be utilized with some effort Design ingenuity is required for adopting natural energy application technology.
Urban location	Building site in which natural energy is hard to utilize Effects of adopting natural energy application technology are considered low.

The following outlines the influences of weather and site conditions.

1) Influences of weather conditions

There is a relationship between the possibility of wind utilization and the outside wind characteristics in in-between seasons and summer, between the possibility of sunlight utilization and the solar radiation level, and between the possibility of solar heat utilization and the solar radiation level and outside air temperature particularly in winter. These relationships are summarized below according to each elemental technology with natural energy application (Table 4).

Table 4　Factors influencing possibility of natural energy utilization 1 (Weather conditions)

Elemental technologies	Major influential factors	Common influences
Use/control of wind	Outside wind speed	The higher the outside wind speed, the greater the possibility of wind utilization.
	Outside wind direction	Outside wind direction varies widely, but wind can be effectively utilized by taking into account the relationship between the direction which is frequently windward during the day or night and the openings.
Photovoltaic power generation	Annual solar radiation level	The higher the solar radiation level, the higher the photovoltaic power generation level (However, regional differences are not very significant in Japan).
Use of solar radiation heat	Solar radiation level in winter Outside air temperature in winter (PSP classification)	The higher the solar radiation level and outside air temperature in winter, the greater the possibility of utilizing solar radiation heat.
Solar water heating	Solar radiation level Outside air temperature in winter Snowfall and snow cover	The higher the solar radiation level in general, the higher the outside air temperature in winter and the lower the snowfall and snow cover, the greater the possibility of solar heat utilization for water heating (However, differences within the hot humid region are small).

Chapter 3 explains the details of how weather conditions influence each elemental technology and how to understand weather conditions.

2) Influences of site conditions

Major factors that influence site conditions include the density of buildings around the building site, height of adjacent buildings, and noise and other factors that impair the environment of the building site. These influential factors are categorized by elemental technologies related to natural energy application as shown in the table below (Table 5). Since it is desirable to quantitatively evaluate these site conditions when verifying the energy saving effects of applied elemental technology, simple evaluation methods are recommended for some elemental technologies (See Chapter 3 for details).

Moreover, in the hot humid region where solar shading is particularly important in the summer and in-between seasons, buildings around the building site may be effective for solar shading. The "solar shading method" in Zone VI takes into account the solar shading effect of buildings around the building site when evaluating the site conditions.

Table 5　Factors influencing possibility of natural energy utilization 2 (Site conditions)

Elemental technologies	Major influential factors	Common influences	Evaluation index (Classification of location for evaluation, etc.)
Use/control of wind	Building density around the site	The lower the density of buildings around the building site, the higher the possibility of wind utilization.	Building coverage ratio of adjacent area (Locations 1 – 2)
Daylight utilization	Level of obstruction of sunlight	The smaller the influence of the shade caused by buildings around the building site, the higher the possibility of daylight utilization.	— (Locations 1 – 3)
Photovoltaic power generation	Level of obstruction of sunlight	The smaller the influence of the shade caused by the topography of the building site and buildings around the building site, the larger the amount of photovoltaic power generation.	—
Use of solar radiation heat	Level of obstruction of sunlight	The smaller the influence of the shade caused by buildings around the building site in winter, the higher the possibility of utilizing solar radiation heat.	Sunshine hours in winter (Locations 1 – 3)
Solar water heating	Level of obstruction of sunlight (mainly on the roof)	The smaller the influence of buildings that obstruct solar radiation mainly on the roof, the higher the possibility of solar heat utilization for water heating.	—
Solar shading method (reference)	Building density around the site	The higher the density of buildings around the building site, the higher the solar shading effect expected from this.	Horizontal distance from surrounding buildings (Locations 1 – 3) * Zone VI

* The locations in the evaluation index column indicate that natural energy utilization is easier in the order of Locations 1, 2 and 3 (with 3 as easiest).

Chapter 3 explains the details of how site conditions influence each elemental technology.

2. Lifestyle orientation

The target design model of LEHVE varies according to how much the occupants are involved with nature in their everyday life as well as how they value environmental stability. Therefore, it is necessary to understand their awareness of natural energy utilization and equipment technology introduction in their lifestyle.

This section focuses on the "level of dedication to natural living" as the awareness of natural energy utilization and the "level of dedication to a stable indoor environment free of unpleasantness" as the awareness of equipment introduction. As shown in Table 6, these two types of awareness are classified into three levels.

Table 6 Items to be confirmed regarding lifestyle orientation

Items to be confirmed	Description	Level of awarenes
Level of dedication to natural living	Level of awareness of enjoying the changing environment such as strong /weak wind, moderate coldness/hotness, and brightness/darkness	High Moderate Low
Level of dedication to a stable indoor environment free of unpleasantness	Level of seeking a stable indoor environment that is free of unpleasantness or physiological stress, such as hotness, coldness and darkness, as much as possible	High Moderate Low

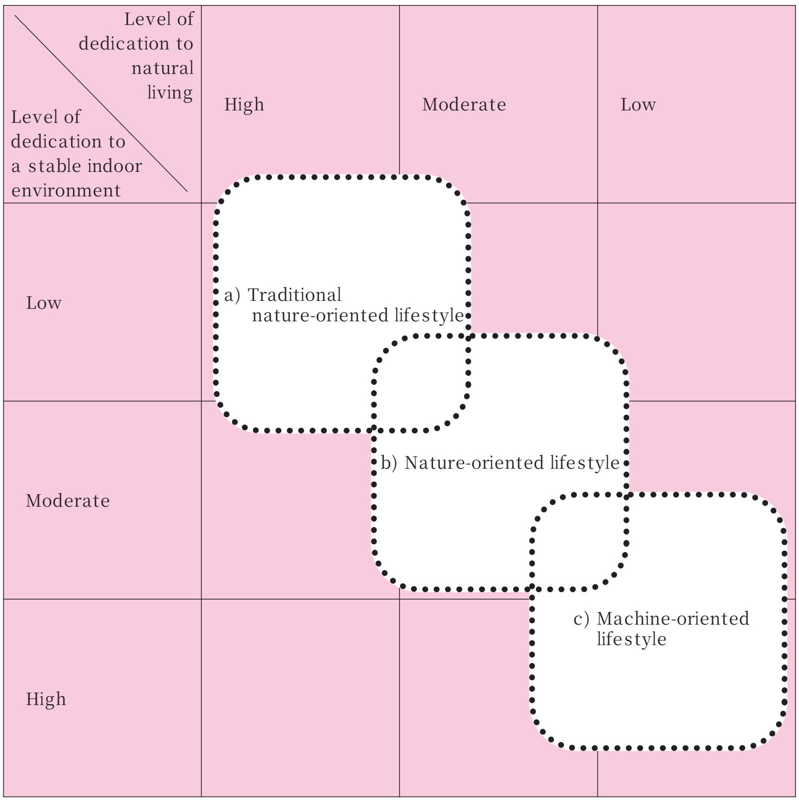
By combining the level of dedication to natural living and level of dedication to an indoor environment, we can identify the lifestyle orientation of the occupants. Here are three possible typical types of lifestyle orientation for reference (Table 7).

a) Traditional nature-oriented lifestyle: …… **Values the enjoyment of the changing environment and optimizes the utilization of natural energy.**

b) Nature-oriented lifestyle: …………………… **Utilizes energy efficient equipment while utilizing natural energy.**

c) Machine-oriented lifestyle: ……………… **Seeks a stable indoor environment and uses energy saving equipment as a priority.**

Table 7 Classification of lifestyle orientation



2.3.2 Setting Target Design Model of Low Energy Housing with Validated Effectiveness

Set the target design models of LEHVE after identifying the "possibility of natural energy utilization at the building site" and "lifestyle orientation" shown in Section 2.3.1.

There are three possible typical housing types for the target design models of LEHVE, Types I, II and III, as illustrated in the design example in Table 8 and the following pages. These types of housing correspond to the three lifestyle orientation types and are listed for reference purposes. Since which elemental technologies should be used as a priority will depend on the housing type, architects can effectively set the target design model by referring to these types and consider the priority of elemental technology application when examining specific architectural techniques.

We can assume various housing models within the three housing types. Set the appropriate target design model according to the site conditions and the way of living.

Table 8 Target design models of LEHVE (typical types) and examples of elemental technology application

Design requirements of LEHVE: Possibility of natural energy utilization at the building site	Design requirements of LEHVE: Lifestyle orientation	Target design models of LEHVE (Typical types)	Examples of elemental technology application: Classification of elemental technologies	Priority of application	Overview
Suburban location Location in which natural energy can be relatively easily utilized	Traditional nature-oriented lifestyle Optimizing the utilization of natural energy	Housing type I House that mainly uses natural energy to achieve comfort	Natural energy application technology	◎	Make maximum use of wind, daylight, etc. Take sufficient architectural measures to control the indoor environment according to hotness, coldness, etc.
			Heat control technology of building envelope	◎	Take sufficient measures to prevent penetration of solar radiation heat and install insulation to maintain constant temperatures according to regional climate characteristics, etc., in an effort to reduce cooling and heating loads.
			Energy-efficient equipment technology	△	Introduce mechanical measures such as cooling and heating systems and lighting systems as needed. Introduce as much energy-efficient equipment as possible.
	Nature-oriented lifestyle Utilizing energy efficient equipment while utilizing natural energy	Housing type II House that uses natural energy as well as equipment to achieve comfort	Natural energy application technology	○	Use as much wind and daylight as possible through design ingenuity, etc. Take as many architectural measures as possible to control the indoor environment according to hotness, coldness, etc.
			Heat control technology of building envelope	◎	Take sufficient measures to prevent penetration of solar radiation heat and install insulation to maintain constant temperatures according to regional climate characteristics, etc., in an effort to reduce cooling and heating loads.
			Energy-efficient equipment technology	○	Use mechanical measures such as cooling and heating systems and lighting systems to control the indoor environment. Introduce as much energy-efficient equipment as possible.
Urban location Location in which natural energy can be utilized with some effort (or is hard to utilize)	Machine-oriented lifestyle Using energy saving equipment as a priority	Housing type III House that mainly uses equipment to achieve comfort	Natural energy application technology	△	Use as much wind and daylight as possible as an auxiliary energy source.
			Heat control technology of building envelope	◎	Take sufficient measures to prevent penetration of solar radiation heat and install insulation to maintain constant temperatures according to regional climate characteristics, etc., in an effort to reduce cooling and heating loads.
			Energy-efficient equipment technology	◎	Use mechanical measures such as cooling and heating systems and lighting systems as a priority to control the indoor environment. Actively introduce energy-efficient equipment.

Priority of elemental technology application: ◎ high, ○ moderate, △ low

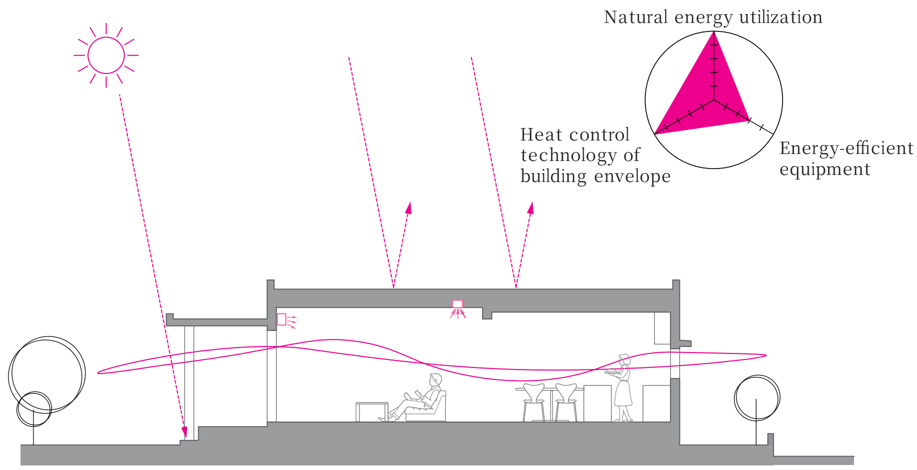
Design example of LEHVE (reinforced concrete house) in Zone VI

■Housing type Ⅰ　Traditional nature-oriented lifestyle

Example of house and lifestyle

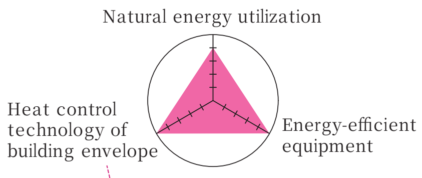
A single-storey house for a four-person family built on a large suburban site.
It has a wide frontage and an open layout with a series of rooms surrounding the living and dining rooms at the center. *Amahaji* (semi-outdoor space with a deep overhang) is installed along the south east corner of the house.
The bathroom, washing room and laundry area are located on the west side where it has a cloth drying area built with blocks with decorative openings to increase the solar shading effect.
The outdoor spot garden is in the shaded area, contributing to improved cross ventilation and heat exhaust of the rooms facing it.

- **Lot area: 432.0 m² (4,650.0 ft²)**
- **Building area: 185.5 m² (1,996.7 ft²)**
- **Total floor area: 145.3 m² (1,564.0 ft²)**



■Conceptual section rendering

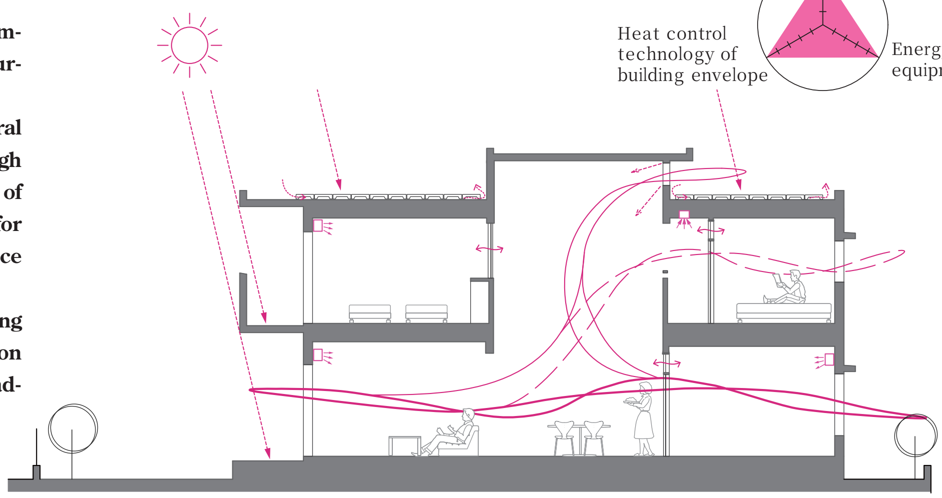
■Housing type Ⅱ　Nature-oriented lifestyle



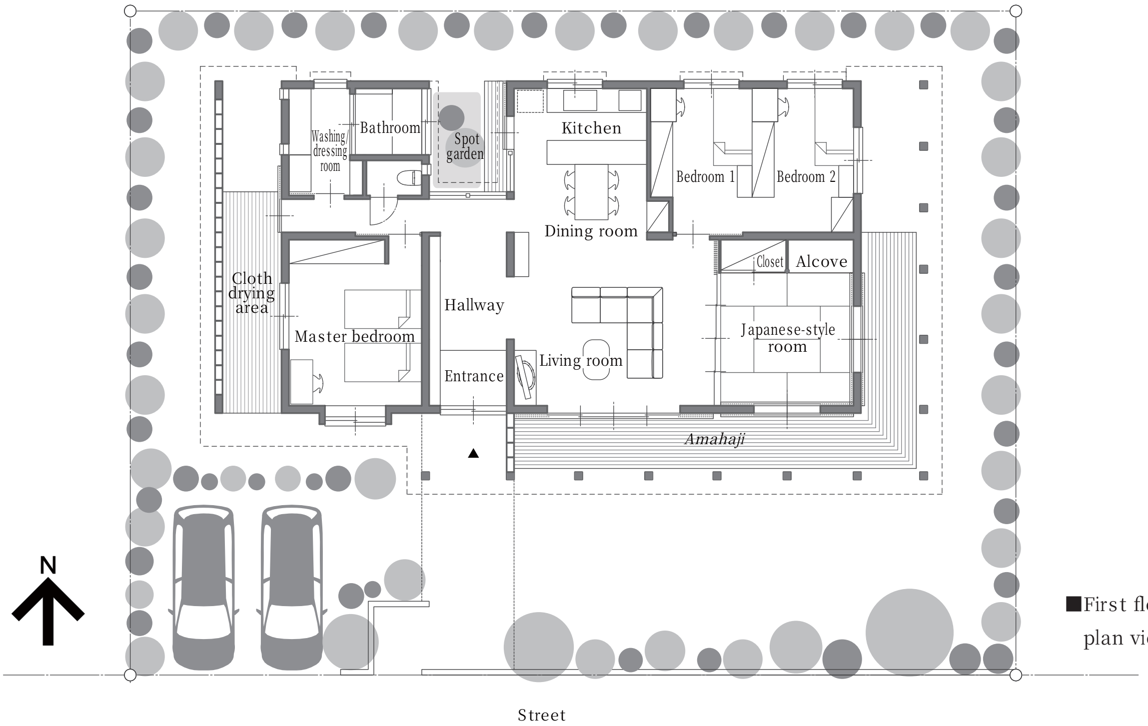
Example of house and lifestyle

A two-storey house for a four-person family built on a relatively small, yet long urban site stretching south and north.
It has an open structure with a central void space surrounded by rooms. A high window is installed in the upper area of the void space to release indoor air for better cross ventilation. The void space also secures the privacy of each room.
The bathroom, laundry area, washing room and cloth drying area are located on the west side to increase the solar shading effect.

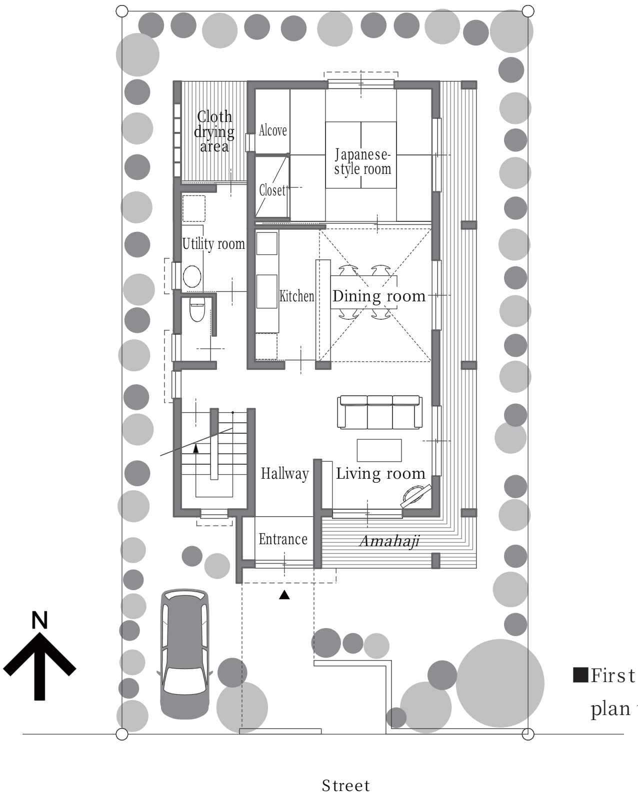
- **Lot area: 215.6 m² (2,320.7 ft²)**
- **Building area: 102.3 m² (1,101.1 ft²)**
- **Total floor area: 147.8 m² (1,590.9 ft²)**



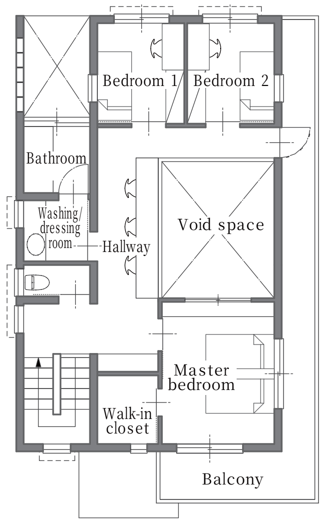
■Conceptual section rendering



■First floor plan view



■First floor plan view



■Second floor plan view

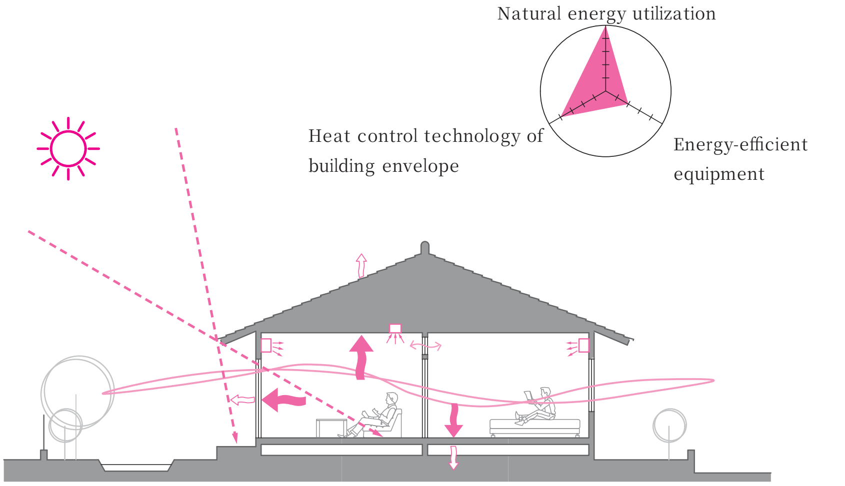
Design example of LEHVE (wooden house) in Zone V

■Housing type I　Traditional nature-oriented lifestyle

Example of house and lifestyle

A single-storey house built on a large sub-urban site in a medium-sized city.
It has an open layout with a series of rooms surrounding the living and dining rooms at the center. It is designed to efficiently utilize wind and solar radiation heat.
The deck and long overhangs on the south east corner are intended to increase the solar shading effect in summer.

- **Lot area: 274.5 m² (2,954.7 ft²)**
- **Building area: 94.8 m² (1,020.4 ft²)**
- **Total floor area: 73.7 m² (793.3 ft²)**



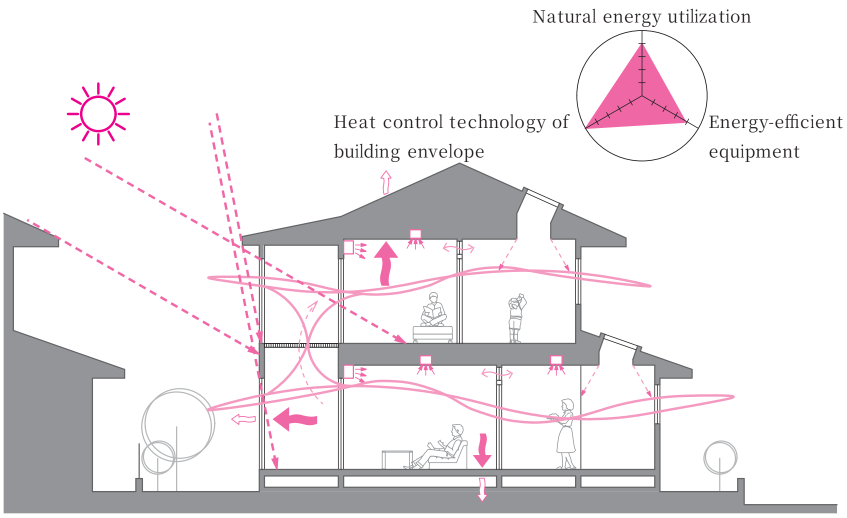
■Conceptual section rendering

■Housing type II　Nature-oriented lifestyle

Example of house and lifestyle

A two-storey house for a four-person family built on a relatively large site close to a city.
The terrace on the first and second floors, a family room located in the shared area in front of each room, and sliding doors are designed to promote wind in summer and solar heat gain and its active utilization in winter. The skylight on the north side of the roof facilitates daylight utilization.

- **Lot area: 210.0 m² (2,260.4 ft²)**
- **Building area: 77.8 m² (837.4 ft²)**
- **Total floor area: 128.3 m² (1,381.0 ft²)**



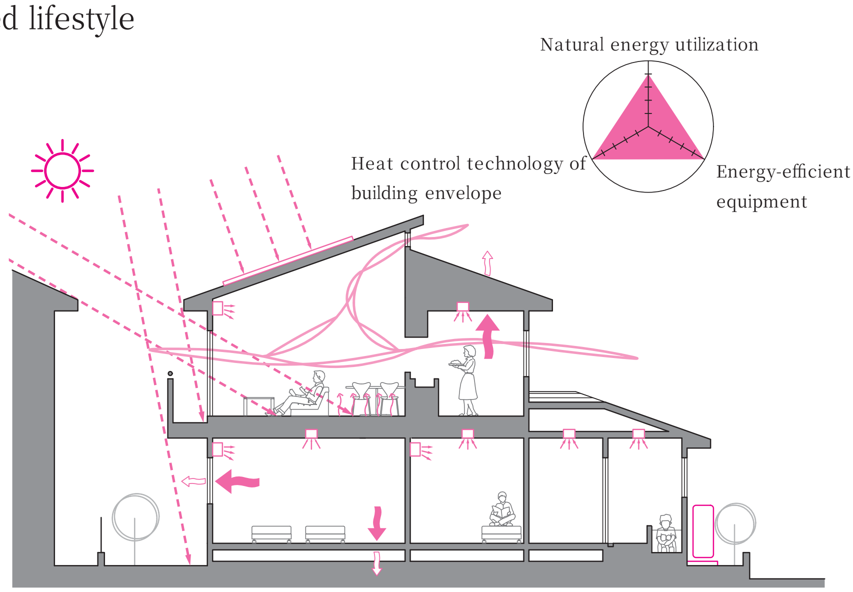
■Conceptual section rendering

■Housing type III　Machine-oriented lifestyle

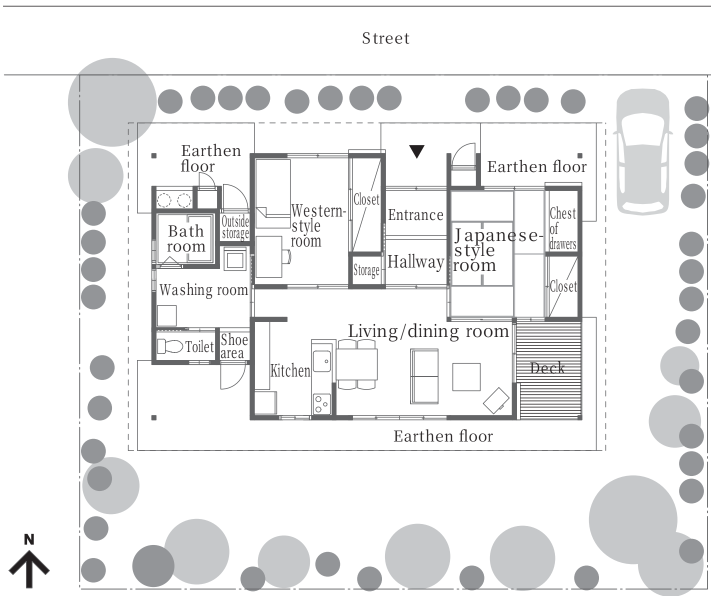
Example of house and lifestyle

A two-storey house for a four-person family built on a relatively large urban site.
The second floor living room and high windows are designed to promote as much as possible the utilization of the wind in summer and solar radiation heat and daylight in winter.
Rooms on the first floor are intended to control and maintain the indoor thermal environment using equipment during the night.

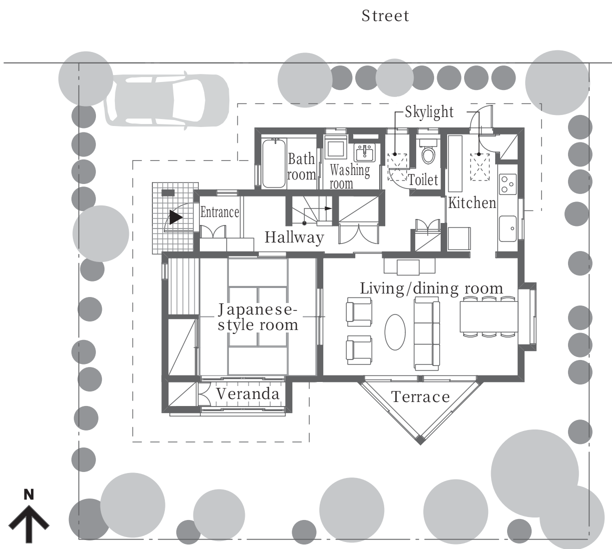
- **Lot area: 135.0 m² (1,453.1 ft²)**
- **Building area: 71.2 m² (766.39 ft²)**
- **Total floor area: 122.1 m² (1,314.3 ft²)**



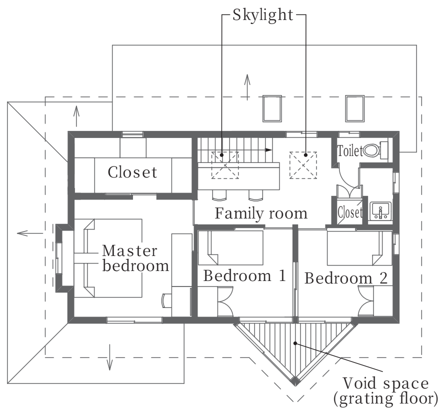
■Conceptual section rendering



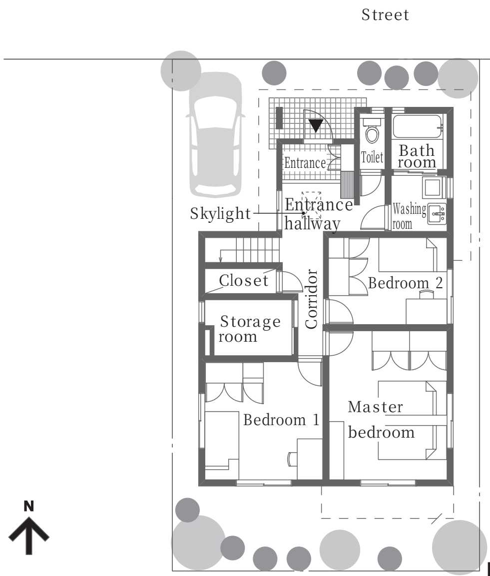
■First floor plan view



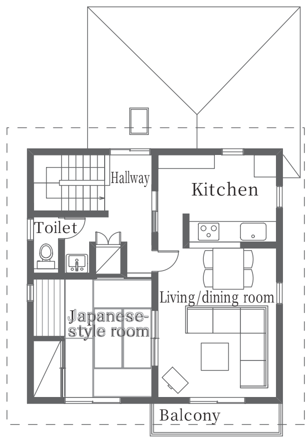
■First floor plan view



■Second floor plan view



■First floor plan view



■Second floor plan view

2.3.3 Basic Items to be Considered for Designing Low Energy Housing with Validated Effectiveness

1. Items to be considered for increasing housing durability

The hot humid region faces harsh natural environmental conditions such as high temperature and humidity, frequent typhoons, etc. In order to maintain long-term livability of housing in this region, it is essential to take countermeasures for the challenges brought by Mother Nature including heavy wind and rain, termites and salt damage. LEHVE aims to maintain long-term comfort and energy efficiency. Its fundamental principle is to plan for ensuring long-term livability and durability of housing by taking proper countermeasures to cope with these challenges.

The following shows examples of the possible factors influencing the durability of housing which are related to the natural environmental conditions of the hot humid region and their countermeasures for reference purposes (Table 9).

Table 9 Factors influencing housing durability and countermeasures

Influential factors	Description	Examples of countermeasures
Heavy wind and rain	The region faces frequent typhoons which often bring extremely heavy wind and rain. This may cause deterioration and water damage to the exterior of the house and broken windows due to flying objects.	• Install deep eaves, overhangs and flashing. • Use water-tight materials on the exterior openings. • Install storm doors, shutters or window bars on the exterior openings. • Make sure that roofing materials are securely fastened and fixed to the roof. • Bolt equipment frames to the envelope and securely fasten the main unit to the frame. • Install an evergreen hedge and plant trees (Choose varieties that are resistant to salt damage).
Termites	It is a warm humid region where termites are prevalent.	• Maintain good cross ventilation in the crawl space, attic, etc., to avoid retention of heat and humidity. • Place the right inspection spots in the crawl space, attic, etc., for easy inspection. • Ensure the concrete envelope and concrete slabs on earth or scarcement are cast as a single structure to prevent cracks and gaps. • Use lumber of termite resistant species. • Apply preservative and termite repellent to all the wooden components such as the timber frame. • Moisture control in the crawl space (adoption of slab on grade foundation or soil treatment, insulated foundation construction, etc.)
Salt damage	Places near the beach are influenced by the sea breeze throughout the year. During the typhoon season, seawater is fanned by a strong wind and mixed in the air. This can result in salt damage, causing the concrete envelope to crack or break away. Additionally, metal products used outside, such as sashes, railings and outside units, tend to rust.	• Finish the concrete surface with a paint, tiles, etc. • Make sure that there is a sufficient thickness of concrete covering. • Lay concrete with a low water-cement ratio to ensure solidity. • Apply surface treatment to metal components to increase corrosion resistance (hot dip galvanizing, etc.). • Apply weatherproof coating to metal components to increase corrosion resistance (fluorocarbon resin coating, etc.). • Rigorously inspect metal products. If rust is found remove it as early as possible and apply rust-proofing. • After typhoons have passed, wash the exterior walls and metal components with water.
UV light	Because of being located in the low latitude, the solar altitude is high and the UV light is intense. As such, paint work on the exterior finish, water proofing, sealants and other materials tend to deteriorate.	• Regularly reapply the coating of the exterior finish. • Cover the waterproofing material with top coating or a concrete or other protective layer. • Apply coating to the surface of the sealant and replace it regularly.

2. Items to be considered for applying elemental technologies

Lack of consideration in the early planning and design stage may lead to difficulty in applying elemental technologies or prevent the expected effects even if elemental technologies are applied. To avoid this, it is necessary to pay attention to the relationship between the planning and design items to be examined and the elemental technologies discussed in this document in the relatively early planning and design stage. Although there are various items to be examined in each stage of planning and design examination, the table below explains examples of major items to be discussed related to the layout, floor, sectional and component planning (material/specifications planning) and their relevance to the elemental technologies for reference purposes (Table 10).

Table 10 Relationship between planning and design items to be examined and elemental technologies

Type of planning/design	Items to be examined	Elemental technology							
		Use/control of wind	Daylight utilization	Photovoltaic generation	Use of solar radiation heat	Solar water heating	Insulated building envelope planning	Solar shading method	Energy-efficient equipment technologies (Commonly applicable)
Layout planning	Building position (distance from adjacent buildings, etc.)	◎	◎	○	◎	○		◎	
	Layout of major garden	◎	○		◎				
	Design of outer perimeter of the site	○	○						
	Planting layout	○						○	
	Outside equipment spacing								◎
Floor planning	Layout of major rooms	◎	○				○	○	○
	Kitchen and bathroom layout					○	○	○	○
	Layout/style of exterior openings	◎	◎		◎		◎		
	Layout/style of interior openings	◎	○						
	Exterior wall perimeter (overhangs, exterior floors, etc.)	○	◎		○		○	◎	
	Service yard layout					○			○
Sectional planning	Basic layer composition	○							○
	Roof composition			◎		◎	○		
	Ceiling composition		○				○		○
	Crawl space composition						○		
	Position/height of exterior openings	◎	◎		○		○		
	Exterior wall perimeter (overhangs, exterior floors, etc.)	○	◎		○		○	◎	
	Height of interior openings	○							
Component planning (materials/specifications)	Building envelope materials/construction methods				○	○	◎	◎	
	Roof materials/construction methods			○	○	○	○	◎	
	Exterior wall materials/construction methods				○		○	◎	
	Specifications of exterior openings				◎		◎	◎	
	Interior materials		○		◎				
	Exterior materials		○					○	

Note: ◎ Particularly highly related, ○ Highly related
Items to be examined include those which are considered to be related to elemental technologies.

2.3.4 Examining Application of Elemental Technologies

As described above, it is considered desirable to examine the priority of the elemental technologies and decide the possibility and level of application after conceiving the target design model of LEHVE based on the site conditions and lifestyle orientations. Moreover, when deciding to adopt a certain elemental technology, it is necessary to verify both initial and running costs in addition to energy saving effects.

Details of the 13 elemental technologies are explained respectively in Chapters 3 to 5. The key information is as follows:

- **Purposes of elemental technology application and key points for design**
- **Energy saving effects of applied elemental technologies and how to achieve them**
- **Steps for examining elemental technology application**
- **Specific methods and details for applying elemental technologies**

2.3.5 Feasibility Study

Glossary:
Feasibility study
It refers to the process of verifying in advance the effectiveness and feasibility of the elemental technologies adopted.

It is beneficial to estimate the overall energy saving effects and costs of the house once the design work of LEHVE has progressed and the adoption of elemental technologies has been finalized to some extent.

It is difficult to set a general calculation method for energy saving effects and costs, however, Chapter 6 of this document evaluates under certain given conditions the energy efficiency (reduction level of primary energy consumption), global warming impact (CO_2 emissions reductions), and costs (initial and running costs) for reference purposes (See Sections 6.1 and 6.2).

Chapter 6 also shows simplified estimation methods for energy consumption based on this evaluation result. Use this information for estimating the energy consumption of LEHVE you design (See Section 6.3).

If the energy consumption reduction target has not been reached after completing the estimation, it is necessary to review the design (reexamine the details of elemental technology application) to the extent possible under given design conditions.

2.4 Energy Efficiency Indication Method

2.4.1 Meaning of Levels

Several energy conservation target levels (hereinafter referred to as the "level") are set for elemental technologies to show the differences in the level of energy saving measures.

- **Level 0 or design details not discussed in this document refer to the conventional design method (reference level of energy efficiency) that does not reach the standard of LEHVE.**
- **Level 1 or higher refers to the design details suitable for LEHVE. Countermeasures are set for each elemental technology according to the target level. The higher the number of the level, the higher the level of measures, indicating that higher energy saving effects can be achieved.**

The relationship between the uses of energy consumed during occupancy and the elemental technologies that can reduce them is shown in Table 2 of Section 2.2.2 on p.024. The explanation section of elemental technologies in Chapters 3 – 5 sets target levels and clearly illustrates the measures (e.g. methods) for achieving each level. It also shows how much energy saving effect (reduction ratio of primary energy consumption) can be expected using specific values regarding the uses of energy that can be reduced by implementing the measures for each level.

If the target design model of LEHVE is set and the priority of applying elemental technologies is considered, it is possible to efficiently increase energy efficiency by introducing the high level methods to the high priority elemental technologies.

2.4.2 Energy Saving Effects and Levels of Elemental Technologies

The uses of energy that can be reduced by applying elemental technologies and their energy saving effects and levels are summarized in Tables 11 and 12. See each section of Chapters 3 – 5 for details.

Table 11 Energy saving effects and levels of elemental technologies (Zone VI, reinforced concrete house)

Elemental technology		Uses of energy to be reduced	Energy saving effects and levels
Natural energy application technology	Use/control of wind	Cooling	4 – 12% reduction (Levels 1 – 3)
	Daylight utilization	Lighting	2 – 10% reduction (Levels 1 – 3)
	Photovoltaic power generation	Electricity	33.7 – 45.0 GJ reduction (Levels 1 – 2)
	Solar water heating	Domestic hot water	10 – 70% or higher reduction (Levels 1 – 4)
Heat control technology of building envelopes	Solar shading method	Cooling	10 – 30% reduction (Levels 1 – 4)
Energy-efficient equipment technology	Cooling system planning	Cooling	Individual cooling 10 – 35% reduction (Levels 1 – 3)
	Ventilation system planning	Ventilation	Duct ventilation 30 – 50% reduction (Levels 1 – 2)
			Through-the-wall ventilation 20% reduction (Level 1)
	Domestic hot water system planning	Domestic hot water	10 – 40% or higher reduction (Levels 1 – 4)
	Lighting system planning	Lighting	30 – 50% (Levels 1 – 3)
	Introduction of high-efficiency consumer electronics	Consumer electronics	20 – 40% reduction (Levels 1 – 2)
	Treatment and efficient use of water and kitchen waste	Water	Water saving device 10 – 40% reduction (Levels 1 – 2)

Table 12　Energy saving effects and levels of elemental technologies (Zone V, wooden house)

<table>
<tr><th colspan="2">Elemental technology</th><th>Uses of energy to be reduced</th><th>Energy saving effects and levels</th></tr>
<tr><td rowspan="5">Natural energy application technology</td><td>Use/control of wind</td><td>Cooling</td><td>5 – 18% reduction (Levels 1 – 3)</td></tr>
<tr><td>Daylight utilization</td><td>Lighting</td><td>2 – 10% reduction (Levels 1 – 3)</td></tr>
<tr><td>Photovoltaic power generation</td><td>Electricity</td><td>32.7 – 43.6 GJ reduction (Levels 1 – 2)</td></tr>
<tr><td>Use of solar radiation heat</td><td>Heating</td><td>5 – 35% reduction (Levels 1 – 4)</td></tr>
<tr><td>Solar water heating</td><td>Domestic hot water</td><td>10 – 70% or higher reduction (Levels 1 – 4)</td></tr>
<tr><td rowspan="3">Heat control technology of building envelopes</td><td rowspan="2">Insulated building envelope planning</td><td rowspan="2">Heating</td><td>Partial intermittent heating 20 – 55% reduction (Levels 1 – 4)</td></tr>
<tr><td>Whole-building continuous heating 40 – 70% reduction (Levels 1 – 4)</td></tr>
<tr><td>Solar shading method</td><td>Cooling</td><td>15 – 45% reduction (Levels 1 – 3)</td></tr>
<tr><td rowspan="10">Energy-efficient equipment technology</td><td rowspan="4">Heating and cooling system planning</td><td rowspan="2">Cooling</td><td>Individual cooling 5 – 35% reduction (Levels 1 – 4)</td></tr>
<tr><td>Central cooling 25 – 40% reduction (Levels 1 – 2)</td></tr>
<tr><td rowspan="2">Heating</td><td>Individual heating 5 – 30% reduction (Levels 1 – 4)</td></tr>
<tr><td>Central heating 20 – 45% reduction (Levels 1 – 2)</td></tr>
<tr><td rowspan="2">Ventilation system planning</td><td rowspan="2">Ventilation</td><td>Duct ventilation 30 – 50% reduction (Levels 1 – 2)</td></tr>
<tr><td>Through-the-wall ventilation 20% reduction (Level 1)</td></tr>
<tr><td>Domestic hot water system planning</td><td>Domestic hot water</td><td>10 – 40% or higher reduction (Levels 1 – 4)</td></tr>
<tr><td>Lighting system planning</td><td>Lighting</td><td>30 – 50% reduction (Levels 1 – 3)</td></tr>
<tr><td>Introduction of high-efficiency consumer electronics</td><td>Consumer electronics</td><td>20 – 40% reduction (Levels 1 – 2)</td></tr>
<tr><td>Treatment and efficient use of water and kitchen waste</td><td>Water</td><td>Water saving device 10 – 40% reduction (Levels 1 – 2)</td></tr>
</table>

There are various regional characteristics and types of houses in Zones VI and V, and a universal method for calculating the overall energy efficiency of housing has yet to be established. For this reason, this document calculates energy consumption using specific regions, family structures and housing conditions that are considered generic. Based on the calculation results, it illustrates energy saving effects and their estimation methods. Therefore, the values of energy saving effects shown in this document should be treated as a reference only. The energy consumption calculation was performed using the prerequisites of a detached reinforced concrete house in the suburb of Naha City, Okinawa for Zone VI and a detached wooden house in the suburb of Kagoshima City, Kagoshima for Zone V, in addition to a four-person family with standard lifestyle for both zones (Details will be explained in Chapter 6).

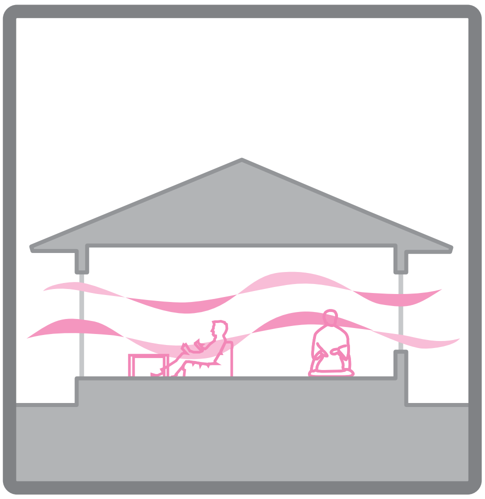
Methods described in this document and their energy saving effects are endorsed by reliable evaluation methods and validation experiments. Nevertheless, the development of method for more accurately estimating energy saving effects will continue to be a critical task.

In hot humid regions which are generally very hot in summer, a diversity of climatic and environmental conditions are found particularly between suburbs and cities, and between coastal and inland areas. The fundamental of LEHVE is to maximize and make the most efficient use of natural energy such as cool winds, daylight and winter sun at individual building sites.

3

Chapter 3 : Natural Energy Application Technology

3.1 Use and Control of Wind



Wind utilization is a technology that aims to reduce cooling energy consumption and improve comfort, by actively introducing outdoor air into the building through cross ventilation when weather conditions are effective for improving thermal sensation such as during summer nights and in-between seasons. In order to effectively take in wind, it is necessary to skillfully integrate both methods for contriving building shapes and floor plan with methods for contriving window shapes and opening and closing operations of windows.

However, installing openings for wind utilization may lead to negative consequences in terms of security, noise and wind resistance. It is important to plan so that the security and comfort of the house will be maintained.

Furthermore, by combining methods for controlling internal heat generation through use of high-efficiency consumer electronics and methods for solar shading, we can achieve higher energy saving effects.

3.1.1 Purpose and Key Points of Wind Utilization

- **Wind utilization is a technology that aims to realize a pleasant indoor thermal environment and reduce cooling energy consumption without relying too much on air conditioning through active introduction of outdoor air into the building and heat exhaust to the outside during the summer (particularly nighttime) and in-between seasons.**
- **Possibility of wind utilization largely depends on the region in which the house is built and the surrounding environment of the house. For locations with open surroundings, the layout planning of openings based on the prevailing wind direction (wind direction which is peculiar to the region, season and time of day) is especially effective. On the other hand, as the surroundings become more crowded, the outside wind speed becomes lower due to the surrounding buildings, resulting in unstable wind direction. Landscaping such as trees and fences surrounding the house may also affect the wind flow around the house. In a highly dense residential area where it is difficult to position the openings based on the wind direction, it is effective to secure a large opening area, position openings that enable multiple cross ventilation routes and use high windows.**
- **An “entrance” and “exit” for the air is required in order to effectively introduce outside air into the building. Openings in the exterior walls in more than two different directions more effectively utilize wind. If openings in the exterior walls are only available in one direction, you can secure the “entrance” and “exit” of wind by installing openings in the exterior walls in the adjacent space via openings in the partition walls (e.g. transom windows and sliding doors).**
- **The use of landscaping ingenuity to block solar radiation, such as planting trees around the house, can keep down the temperature of wind introduced into the room. Such solar shading controls the reflected solar radiation and the heat radiation from the heated ground surface and inhibits the heat from entering through openings, etc.**
- **Wind utilization technology consists of methods for contriving building shapes and floor plans and landscaping planning, as well as methods for contriving the positions, shapes, and opening and closing operations of the openings.**
- **The prerequisite of this technology is that the occupants appropriately open the openings. That is why we also need to exercise ingenuity to encourage the opening and closing of the openings. For example, we must make security measures so that the occupants can feel safe to leave the openings open.**
- **It is necessary to use opening parts with high wind resistance in preparation for storms. Even if there is heavy wind, wind utilization may be still possible by controlling and adjusting the wind.**

3.1.2 Energy Conservation Target Levels for Wind Utilization

1. Definition of target levels

- Energy conservation target levels by wind utilization refer to the following levels 1 to 3. These levels indicate the reduction rates of energy consumed by cooling systems are indicated for Zones VI and V.
- The target levels provided for Zone VI are based on the reinforced concrete house and for Zone V are based on the wooden house.

			Zone VI	Zone V
Level − 1	:	Cooling energy increase rate	Approx. 4%	Approx. 6%
Level 0	:	Cooling energy reduction rate	None	None
Level 1	:	Cooling energy reduction rate	Approx. 4%	Approx. 5%
Level 2	:	Cooling energy reduction rate	Approx. 9%	Approx. 12%
Level 3	:	Cooling energy reduction rate	Approx. 12%	Approx. 18%

- **The typical cooling energy consumption in 2000 was 10.3 GJ (approximately 16% of total energy consumption) for Zone VI and 5.7 GJ (approximately 8% of total energy consumption) for Zone V (See Section 6.1 on p.339).**
- **Level –1 refers to the case of "not utilizing wind at all without opening windows" and Level 0 refers to the case of "occupants opening the windows only when they are at home without design ingenuity in wind utilization".**
- **The cooling energy reduction rate by wind utilization is set using the air change rate of the house that is obtained through wind utilization as an index. The above-mentioned energy reduction rates are the values obtained assuming a similar air change rate in each room. If the air change rate significantly varies between rooms, set the target level based on the air change rate of the living room and other major rooms (where cooling energy consumption is the largest). Meanwhile, Section 3.1.6 Calculation Method for Cooling Energy Reduction Rate by Room on p.064 explains a more accurate method for calculating the energy reduction rate which reflects the differences in the air change rates by room.**

2. Requirements for achieving target levels

1) Zone classification

- **As the cooling energy reduction rate by wind utilization differs between Zone VI and Zone V, it is necessary to confirm the applicable zone classification first.**
- **For the zone classification, check it in Appendix 1: Zone Classification Data on p.384.**

2) Weather conditions (outside wind direction and speed)

- **Weather conditions of the construction site, such as temperature, humidity, wind speed and direction, influence the possibility of wind utilization, but the outside wind direction and speed is particularly important. The outside wind direction and speed usually changes according to the season and time of day and have regional characteristics.**
- **The amount of cross ventilation allowed into the room is directly influenced by the outside wind speed. There is a tendency for the outside wind speed and the air change rate (i.e. amount of cross ventilation) to be proportional with one another.**
- **For building sites with open surroundings, the outside wind direction is of particular importance as the installation of openings in the prevailing wind direction secures an airflow rate. Even in a highly dense residential area, the effectiveness of cross ventilation varies depending on the position of high windows in the outside wind direction if high windows (e.g. top side windows) are used as the cross ventilation route.**

Key Point

Outside wind speed in hot humid regions

- **The table below shows the average outside wind speed of four representative cities in Zones VI and V in the summer for waking hours, sleeping hours and the entire day.**
- **The outside wind speed varies according to the height from the ground. The wind speed shown in the table has been converted to the value at 6.5 m above the ground (equivalent to the eaves height of a two-storied house).**

Table: Average outside wind speed in major cities
(June – September)
Waking hours: 7:00 – 22:00
Sleeping hours: 23:00 – 6:00

City	Average outside wind speed [m/s]		
	Waking hours	Sleeping hours	Entire day
Naha	3.5	2.8	3.3
Kagoshima	2.2	1.6	2.0
Miyazaki	2.5	1.6	2.2
Kochi	1.6	1.1	1.5

* The average outside wind speed includes the wind speed of typhoons, but their influence on the average value is considered minor.
* Created based on the expanded AMeDAS weather data (for 20 years) from Expanded AMeDAS Weather Data 1981 – 2000 issued by the Architectural Institute of Japan (published in 2005).

Key Point

Outside wind direction in hot humid regions

- **The table below shows the trend of outside wind direction of four representative cities in Zones VI and V during the summer. The frequency of becoming windward and leeward is shown by direction of the exterior wall (16 directions) and by time of day (waking hours and sleeping hours).**
- **The trends of these cities is shown below:**
  - **a. Naha: Openings facing east to south have a high frequency of becoming windward both night and day.**
  - **b. Kagoshima: As the prevailing wind direction is unclear during waking hours, the direction of the openings is hardly influential. During the sleeping hours, openings facing west-northwest to north to northeast become windward.**
  - **c. Miyazaki: Both the east and west sides may become windward during waking hours. The west to north side becomes windward during sleeping hours.**
  - **d. Kochi: The exterior wall facing east to south often becomes windward during waking hours. The direction of southwest to north-northwest dominates the windward side during sleeping hours.**
- **It is considered effective to place a room in which occupants spend time during the day (e.g. living room) in the direction which frequently becomes windward during waking hours and locate a bedroom in the direction which frequently becomes windward during sleeping hours.**
- **The weather station is usually built in an area with open surroundings representative of the region. However, if the topography around the building site is peculiar, the wind direction does not necessary correspond to that of the nearest weather station. If this is the case, it is necessary to gather closer observational data or check the wind direction on the site.**

Table: Frequency of becoming windward and leeward by direction in major cities (June – September)

a. Naha

Direction of exterior wall		North	North-northeast	Northeast	East-northeast	East	East-southeast	Southeast	South-southeast	South	South-southwest	Southwest	West-southwest	West	West-northwest	Northwest	North-northwest
Windward	Waking hours	×	△	△	○	○	◎	◎	◎	◎	○	○	○	△	×	×	×
	Sleeping hours	×	△	△	○	◎	◎	◎	◎	◎	○	○	△	×	×	×	×
Leeward	Waking hours	◎	○	○	○	△	×	×	×	×	△	△	○	○	◎	◎	◎
	Sleeping hours	◎	○	○	△	×	×	×	×	×	△	△	○	◎	◎	◎	◎

b. Kagoshima

Direction of exterior wall		North	North-northeast	Northeast	East-northeast	East	East-southeast	Southeast	South-southeast	South	South-southwest	Southwest	West-southwest	West	West-northwest	Northwest	North-northwest
Windward	Waking hours	△	△	△	△	○	○	○	○	○	△	△	○	○	○	○	△
	Sleeping hours	◎	◎	○	△	△	×	×	×	×	×	×	△	○	◎	◎	◎
Leeward	Waking hours	○	△	△	○	○	○	○	△	△	△	△	△	○	○	○	○
	Sleeping hours	×	×	×	△	○	◎	◎	◎	◎	◎	○	△	△	×	×	×

c. Miyazaki

Direction of exterior wall		North	North-northeast	Northeast	East-northeast	East	East-southeast	Southeast	South-southeast	South	South-southwest	Southwest	West-southwest	West	West-northwest	Northwest	North-northwest
Windward	Waking hours	△	△	○	◎	◎	○	○	△	×	△	△	○	○	○	△	△
	Sleeping hours	○	×	×	×	×	×	×	×	×	×	△	◎	◎	◎	◎	◎
Leeward	Waking hours	×	△	△	○	○	○	△	△	△	△	○	◎	◎	○	○	△
	Sleeping hours	×	×	△	◎	◎	◎	◎	◎	○	×	×	×	×	×	×	×

d. Kochi

Direction of exterior wall		North	North-northeast	Northeast	East-northeast	East	East-southeast	Southeast	South-southeast	South	South-southwest	Southwest	West-southwest	West	West-northwest	Northwest	North-northwest
Windward	Waking hours	×	×	△	△	○	◎	◎	◎	○	△	△	△	△	△	△	×
	Sleeping hours	×	×	×	×	×	×	×	×	×	×	○	◎	◎	◎	◎	○
Leeward	Waking hours	○	△	△	△	△	△	△	×	×	×	△	△	○	◎	◎	◎
	Sleeping hours	×	×	○	◎	◎	◎	◎	○	×	×	×	×	×	×	×	×

Key: Frequency of the exterior wall direction to become windward and leeward; ◎: Over 40%, ○: 30 - 40%, △: 20 - 30%, ×: under 20%

* Created based on the expanded AMeDAS weather data (for 20 years) from *Expanded AMeDAS Weather Data 1981 – 2000* issued by the Architectural Institute of Japan (published in 2005).

3

Chapter 3
Natural Energy Application Technology (Elemental Technology Application Method 1)

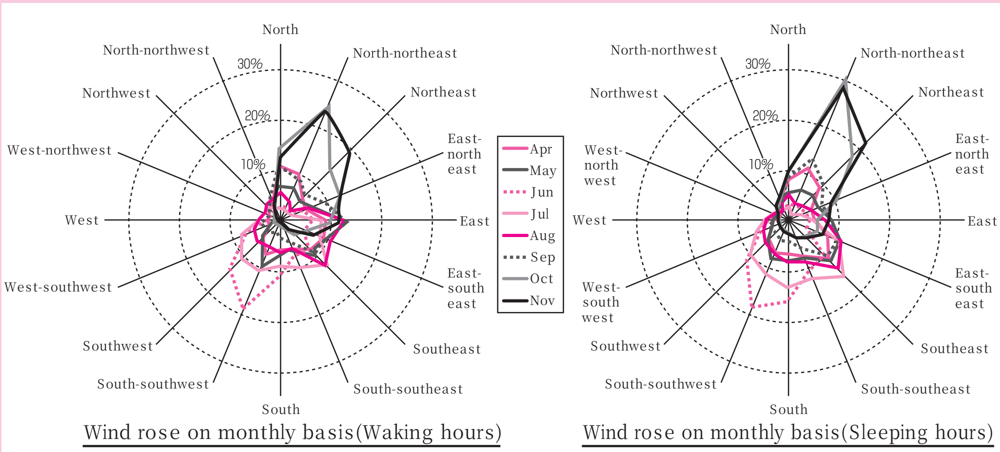
Glossary: Weather data
Weather data can be checked using the Chronological Scientific Tables (National Astronomical Observatory of Japan, Ministry of Education, Culture, Sports, Science and Technology) and the Japan Meteorological Agency's website (http://www.jma.go.jp).

Comment ● Publication of weather data

You can refer to the LEHVE's website (http://www.jjj-design.org) for the weather data information (for 842 locations in Japan) that has been compiled for studying wind utilization methods. In addition to the tables shown above for these locations (average outside wind speed, frequency of becoming windward and leeward by direction), the website also provides tables showing temperature, relative humidity, wind speed, and wind direction (wind rose). Take the following into consideration when using this information:

- The weather data is available in pdf format.
- The weather data is created based on the expanded AMeDAS weather data (for 20 years) from Expanded AMeDAS Weather Data 1981 – 2000 issued by the Architectural Institute of Japan (published in 2005, http://www.metds.co.jp/). For how to use the data and the data creation methods employed , check "How to use this data" and "Data creation method" Sections in the PDF file.
- Permission has been obtained from the Research Committee on Environment Engineering of the Architectural Institute of Japan and Meteorological Data System Co., Ltd to publish the weather data on the above-mentioned website only. Please refrain from reproducing this information or employing it for uses other than the design methods described in this document.

Fig. Data available on the website (part of Naha)



Monthly weather data table

		April		May		June		July		August		September		October		November	
		Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours
Average temperature (℃)		21.9	20.3	24.5	22.7	27.3	25.6	29.4	27.5	29.1	27.3	28.0	26.3	25.6	23.9	22.4	21.0
Average relative humidity (%)		75	81	77	84	81	89	76	85	77	85	74	81	70	77	67	73
Average wind speed (m/s)		3.4	2.8	3.4	2.7	3.7	3.0	3.4	2.7	3.6	3.0	3.4	2.7	3.5	2.8	3.6	3.1
Wind direction	First direction	North 11%	Southeast 12%	East 13%	East-southeast 12%	South-southwest 20%	South-southwest 18%	Southeast 13%	Southeast 16%	Southeast 12%	Southeast 15%	East 13%	North-northeast 14%	North-northeast 25%	North-northeast 31%	North-northeast 24%	North-northeast 29%
	Second direction	North-northeast 10%	North-northeast 12%	East-southeast 10%	Southeast 12%	Southwest 15%	South 16%	Southwest 11%	South 13%	East 12%	East-southeast 13%	North 11%	East-southeast 12%	North 14%	Northeast 19%	Northeast 19%	Northeast 23%
	Third direction	East-southeast 10%	Northeast 11%	South-southwest 9%	East 10%	South 11%	South-southeast 11%	South-southwest 11%	South-southeast 12%	East-southeast 11%	East 8%	Southeast 10%	Northeast 11%	Northeast 14%	East-northeast 11%	North 13%	East-northeast 10%

- The wind rose in the upper figure shows the frequency of becoming windward by wind direction and allows you to see which direction the wind comes from on a monthly basis by waking and sleeping hours. The lower table shows the monthly data on temperature, relative humidity, wind speed, and wind direction by waking and sleeping hours.

3) Site conditions (building density around the site))

- **The possibility of wind utilization significantly depends on how crowded the area surrounding the construction site is.**
- **For a location that has open surroundings, such as a suburb, it is easy to maintain the wind pressure difference (driving force of cross ventilation) that acts on the building, which is effective for wind utilization. On the other hand, for a highly dense residential area in the city, it is difficult to utilize wind as the outside wind speed declines due to the surrounding buildings, which causes the wind pressure difference to decrease.**

・Generally, how the wind pressure acts on the building is evaluated by the wind pressure coefficient. In this section, we classify the site conditions (building density around the site) into the following two categories according to the differences in the wind pressure coefficient characteristics.

Location 1: Urban location (building coverage ratio of adjacent area = over 20%)
Location 2: Suburban location (building coverage ratio of adjacent area = 20% or below)

・An average residential area is classified as Location 1. Location 2 is supposed to be a suburban location with 20% or below of the building coverage ratio of adjacent area (ratio of total building area of the buildings in the adjacent area (surroundings) to the relevant adjacent area (dimensions)) within a 50 m diameter surrounding the planned building. For definition and calculation of the building coverage ratio of adjacent area, see the Key Point on the next page.

Key Point

Characteristics of wind pressure coefficient

- Since the wind pressure coefficient varies significantly depending on the shapes and surrounding conditions of the house, accurate estimation is difficult, particularly in dense residential areas.
- If the building density around the site is low (in the case of Location 2), the wind pressure coefficient varies significantly depending on the direction of the building in relation to the wind direction. If the wall is facing perpendicular to the wind direction, the surface which the wind hits generates a positive pressure and the remaining surfaces generates a negative pressure (Fig. a). Since the ease of maintaining cross ventilation depends on the wind pressure coefficient difference, it is not always necessary to install two openings in opposite walls in the case of Fig. a.
- If there is a wall tilting the building is at an angle of 45° to the wind direction, the two surfaces walls which the wind hits generate a positive pressure and the remaining surfaces generate a negative pressure (Fig. b). In the case of Fig. b, although the wind pressure on the windward side decreases by nearly 60 – 70% of Fig. a, it is easy to install effective openings for cross ventilation because the wind pressure coefficient difference between the windward and leeward side is not significantly different from that of Fig. a.
- In the case of a residential area with high building density (i.e. Location 1), the influence of the outside wind is small and the wind pressure coefficient decreases. The airflow around the building becomes complex and the wind pressure on the wall at the downstream end may become positive. The wind pressure coefficient difference obtained is approximately 0.05 – 0.1.
- The wind pressure coefficient is also influenced by trees, fences and other landscaping. Even if the site has a low building density (in the case of Location 2), the wind pressure coefficient difference obtained is usually small if there are dense trees on the windward side that block the wind.

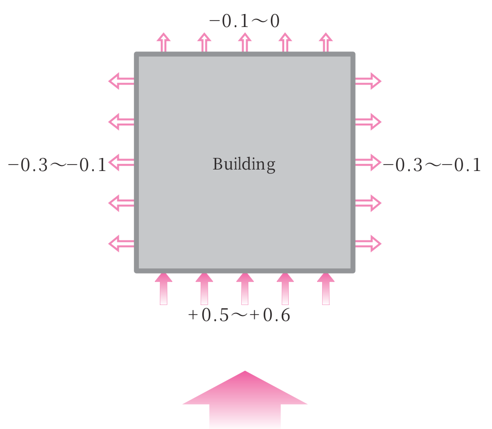


Fig. a Wind pressure coefficient on the wall perpendicular to the prevailing wind direction (in the case of low surrounding density)

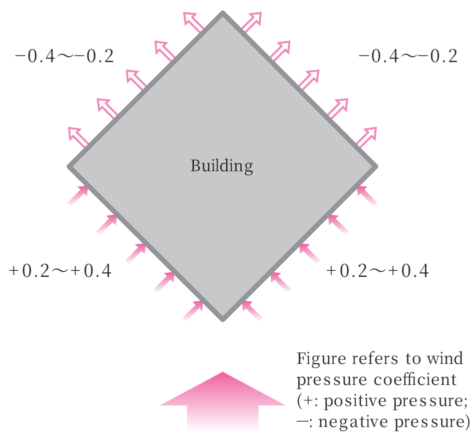


Figure refers to wind pressure coefficient (+: positive pressure; —: negative pressure)

Fig. b Wind pressure coefficient on the wall tiltinga building at an angle of 45° to the prevailing wind direction (in the case of low surrounding density)

Glossary: Wind pressure coefficient

Wind pressure coefficient refers to the ratio of the pressure that acts on the building surface to the wind's own pressure (dynamic pressure). It is used for estimation of the wind pressure (driving force of cross ventilation) that acts on the building. For example, a wind pressure coefficient of 0.5 means that a half of the pressure acts as a pressure that pushes the building surface. Generally, the wind pressure is positive on the windward side and negative on the leeward side. Cross ventilation can be easily achieved by installing two openings at locations where there is a major difference in the positive and negative pressures (wind pressure coefficient difference).

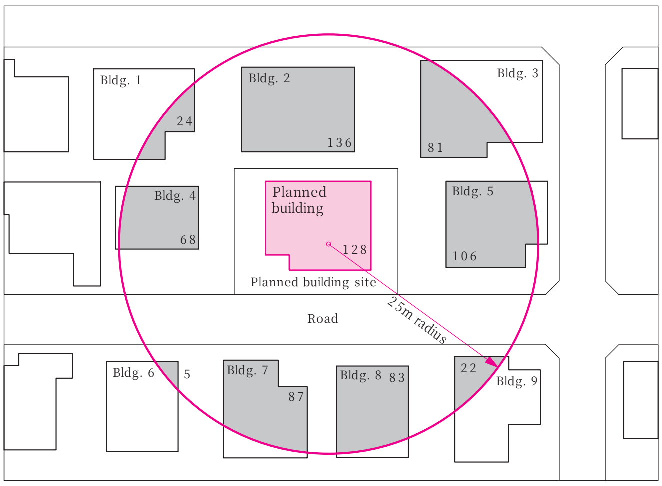
3

Chapter 3
Natural Energy
Application Technology
(Elemental Technology
Application Method 1)

Key Point

What is building coverage ratio of adjacent area?

- **The "building coverage ratio of adjacent area" is an indicator that has been defined in this document to judge the density around the site which is related to the possibility of wind utilization. It has been modified and adapted from the "building coverage ratio" used in the Building Standard Law of Japan. While the building coverage ratio stipulated in the Building Standard Law refers to the "ratio of the building area of the building to the site area", the building coverage ratio of adjacent area refers to the "ratio of the total building area of the buildings in a certain adjacent area (surroundings) to the relevant adjacent area (dimensions)" in the surrounding area of the construction site that is assumed to influence the wind pressure which acts on the building . The adjacent area (dimensions) includes an area of roads, parks, waterways and elements outside the site at which the building is constructed, and the building area includes surrounding buildings in addition to the building area of the planned building. Considering the influences on the possibility of wind utilization, this design method defines an area 50 m in diameter surrounding the planned building as the area to be calculated as the relevant adjacent area (dimensions).**
- **The following shows how to obtain the "building coverage ratio of adjacent area":**
  (1) Draw a circle with 50 m diameter (25 m radius) around the construction site on the residential map according to the reduced scale.
  (2) Make a rough estimate of the building area from the outlines of buildings that exist inside the circle drawn in (1) and calculate the total value (For buildings that are partially within this circle, only the portion within the circle is included).
  (3) Add the building area (assumed value can be used) of the planned building to the value obtained in (2). This value is regarded as the building area of the buildings in the adjacent area (surroundings) for obtaining the "building coverage ratio of adjacent area.
  (4) Determine the ratio of the area obtained in (3) to the adjacent area (dimensions) (1963.5 m2). This value is the "building coverage ratio of adjacent area".



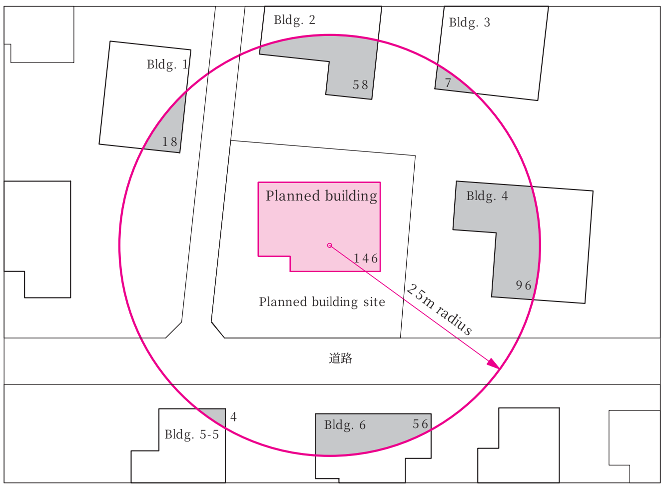
* Figures in the diagram refer to the area (m²) to be calculated for buildings in the adjacent area (surroundings).

Building area of buildings in adjacent area (surroundings)
= building area of Bldgs. 1 to 9 + building area of planned building
= (24+136+81+68+106+5+87+83+22) + 128
= 740 m²

Adjacent area (dimensions) = 1963.5 m²

Building coverage ratio of adjacent area
= building area of buildings in adjacent area (surroundings) / adjacent area (dimensions)
= 740 / 1963.50
= 0.3769
= 37.7% > 20% (therefore, Location 1)

Fig. a Example of residential area in urban location (Location 1)



* Figures in the diagram refer to the area (m²) to be calculated for buildings in the adjacent area (surroundings).

Building area of buildings in adjacent area (surroundings)
= building area of Bldgs.-1 to -6 + building area of planned building
= (18+58+7+96+4+56) + 146
= 385 m²

Adjacent area (dimensions) = 1963.5 m²

Building coverage ratio of adjacent area
= building area of buildings in adjacent area (surroundings) / adjacent area (dimensions)
= 385 / 1963.50
= 0.1961
= 19.6% ≦ 20% (therefore, Location 2)

Fig. b Example of residential area in suburban location (Location 2)

Fig. Calculation example of building coverage ratio of adjacent area in a residential area

4) Lifestyle orientation of occupants and use of rooms

Cooling energy consumption varies depending on how the occupants like to utilize wind and cooling systems. The different uses of wind and cooling systems according to the use of rooms in the house also affect cooling energy consumption.

For that reason, it is desirable to confirm and examine the use of wind and cooling systems in the rooms that are used mainly during the day (e.g. living and dining rooms) and the rooms that are used mainly at night (e.g. master bedrooms and children's rooms). This enables one to estimate the air change rate and examine the cooling energy consumption (See Section 3.1.6 on p.064).

5) Wind utilization method

- **The following is a list of wind utilization methods discussed in this document, which are expected to provide energy saving effects:**

Method 1: Securing opening area on cross ventilation route	1a: Combination of small opening areas
	1b: Combination of large opening areas
Method 2: Opening layout according to prevailing wind direction	
Method 3: Use of high windows	3a: Combination of small opening areas
	3b: Combination of large opening areas

- **For wind utilization, it is necessary to install a combination of openings which serve as the "entrance" and the "exit". Methods 1 and 3 are designed to examine the opening area of the room into which wind is introduced and are classified into a and b according to the size of the opening area.**
- **Method 2 increases the effect of wind utilization by taking full advantage of the prevailing wind direction, and is only applicable to Location 2 (suburban location).**
- **Section 3.1.4 Wind Utilization Methods explains the details of each method.**

Comment ● Night ventilation and cold storage

The fundamental idea of passive solar heating is to introduce the solar radiation heat during a winter day into the house and store heat so that a heating effect can be obtained throughout the night. The area used for heat storage is an interior component with a large heat capacity and is called a heat storage component. Conversely, in summer, a large amount of ventilation is performed during the night when the temperature is low to cool down the building so that a cooling effect can be obtained during the hot daytime hours the next day. In Japan, probably because of the traditional prevalence of wooden houses with small heat capacity, cross ventilation is the most well known method for achieving a cooling sensation using wind. Cross ventilation can also provide an intentional cold storage effect and this effect is larger in regions with greater daily temperature range .

How about in the hot and humid regions? Generally, it is believed to be difficult to obtain cold storage effects in the hot humid regions as the daily temperature range is smaller, and even if it is possible, condensation on the surface of the heat storage component is a concern. However, this does not mean there is no cold storage effect and we can prevent condensation damage by using appropriate materials or taking preventive measures for the surface of the heat storage component. In fact, we can experience the cold storage effect in brick buildings in South East Asia and cold storage is well established in these buildings as they do not cause condensation damage.

In Okinawa, the number of concrete houses has rapidly increased after World War II. Can we obtain a cooling effect by utilizing its heat capacity? To achieve this, we must fully shade the concrete building envelope so that it does not receive solar radiation. There are an increasing number of cases in which night ventilation and cold storage are intentionally combined in the design and it will not be long before this becomes an established design method for the LEHVE in the hot humid regions.

3

Chapter 3
Natural Energy Application Technology (Elemental Technology Application Method 1)

3. How to achieve target levels

- **The energy conservation target levels for wind utilization are set using the air change rate of the house that is obtained through wind utilization as an index. The corresponding relationship between the target levels and the air change rate is as shown in Table 1.**

Table 1 Corresponding relationship between the target levels of wind utilization and the air change rate

Target level	Energy saving effect (Cooling energy reduction rate)		Air change rate of house
	Zone VI	Zone V	
Level −1	Approx. 4% increase	Approx. 6% increase	0 ACH
Level 0	No reduction	No reduction	At least 2 ACH
Level 1	Approx. 4%	Approx. 5%	At least 5 ACH
Level 2	Approx. 9%	Approx. 12%	At least 10 ACH
Level 3	Approx. 12%	Approx. 18%	At least 20 ACH

- **The air change rate of a house is generally determined by the wind utilization methods adopted and outside wind speed. The air change rate changes according to the site conditions even under the same method and outside wind speed. Table 2 shows the air change rate obtained from a combination of different methods and outside wind speeds.**
- **For the outside wind speed, search the weather data of the construction site (or its vicinity) on the website (See Comment on p.044) and obtain the full-day mean wind speed (at 6.5 m from the ground). In the case of estimating the air change rate by room according to Section 3.1.6 Calculation Method for Cooling Energy Reduction Rate by Room on p.064, see the mean outside wind speed during the time of day when the room is mainly used (waking or sleeping hours). When checking the air change rate, as shown in Table 2, the outside wind speed should be studied in three phases; below 1 m/s, 1 – 1.9 m/s, and 2 m/s or above.**

Glossary: Air change rate
A value that expresses the number of times the indoor air is exchanged with the outdoor air per hour. This value is calculated by the amount of ventilation (amount of cross ventilation) divided by the volume of the room, and the units are measured in air changes per hour (ACH). (h)

Table 2 Air change rate obtained in the combination of wind utilization methods and outside wind speed
(1) Location 1

Method	Outside wind speed		
	Below 1 m/s	1 – 1.9 m/s	2 m/s or above
Method 1a or 3a	2 ACH	5 ACH	8 ACH
Method 1b or 3b	3 ACH	10 ACH	17 ACH

(2) Location 2

Method	Outside wind speed		
	Below 1 m/s	1 – 1.9 m/s	2 m/s or above
Method 1a or 3a	3 ACH	10 ACH	17 ACH
Method 1a + 2 or Method 3a + 2 or 3b	5 ACH	15 ACH	25 ACH
Method 1b or 3b	7 ACH	20 ACH	33 ACH
Method 1b + 2 or Method 3b + 2	10 ACH	30 ACH	50 ACH

* Calculation of air change rate was performed based on a room with the ceiling height of 2.4 m.

- **In the case of Location 1 with an outside wind speed of below 1 m/s or Location 2 with an outside wind speed of below 1 m/s adopting Method 1a or 3a (combination of small opening areas), the expected air change rate is small and cooling energy reduction cannot be anticipated (Level 0). In order to reduce cooling energy, it is necessary to examine the adoption of other methods (in the case of Location 2) and the application of other elemental technologies.**
- **At Location 2, an extremely high air change rate can be achieved through certain methods. If the air change rate is in the order of tens of air changes per hour , the airflow velocity near the window may instantaneously exceed 1 m/s.**

Glossary: Difference between ventilation and cross ventilation
Ventilation and cross ventilation are the same in terms of introducing outdoor air into the room, but are clearly different in the amount of air introduced (air change rate). The aim of ventilation is to improve the indoor air environment and exchange the air at the rate of 0.5 ACH throughout the year. In the meantime, cross ventilation exchanges the air at the late of at least 2 ACH and aims to contain room temperature increases and reduce cooling consumption energy. Section 5.3 Ventilation System Planning explains ventilation.

3.1.3 Steps for Examining Wind Utilization Technology

- **As a prerequisite of examining methods, it is necessary to check the zone classification, weather conditions and site conditions. The possibility of wind utilization is examined by confirming the outside wind speed and prevailing wind direction at the construction site during the wind utilization period as well as the conditions such as the topography related to local winds in the surrounding area and density around the site.**
- **Next examine the adoption of wind utilization methods.**
- **For security, noise control and wind resistance, examine them equally in all types of houses regardless of the location.**

Step 1 Checking weather conditions, site conditions, lifestyle orientation of occupants, etc.

1) Check zone classification (Zone VI, Zone V)
2) Check weather conditions (outside wind speed and direction)
3) Check site conditions (building density around the site)
4) Check lifestyle orientation of occupants and use of rooms

▼

Step 2 Examining the securing of opening areas in the cross ventilation route (Method 1)

1) Examine the installation of cross ventilation routes and openings
2) Examine openings in the exterior wall
3) Examine openings in the partition wall

▼

Step 3 Examining the securing of wind pressure coefficient difference

1) Examine the position of openings according to the prevailing wind direction (Method 2): Location 2 only
2) Examine the use of high windows such as top side windows (Method 3)

▼

Step 4 Considerations for security, heavy wind and rain, noise, etc.

1) Examine security measures
2) Examine measures for heavy wind and rain
3) Examine noise control measures

3.1.4 Wind Utilization Methods

Method 1 : Securing opening area on cross ventilation route

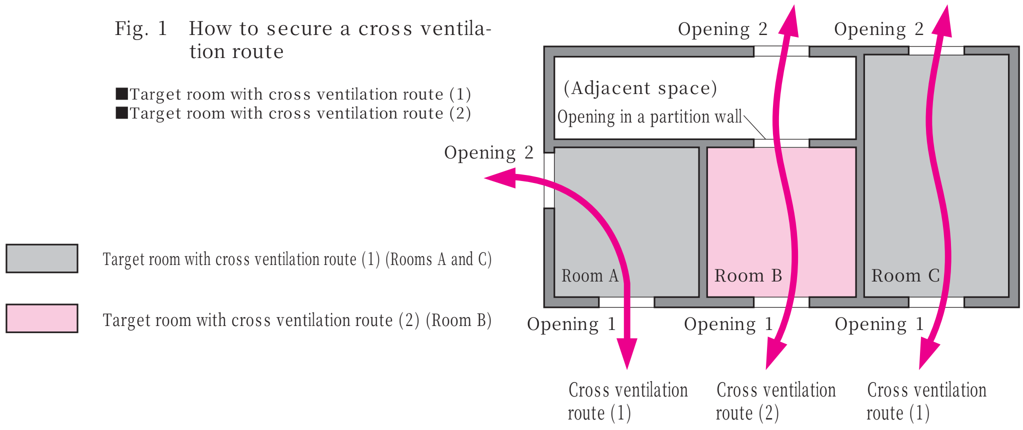
1. Cross ventilation route and opening area

In order to effectively introduce outside air into the building, we need to install openings, which serve as the "entrances" and "exits" for the air, in the walls in more than two different directions. Method 1 involves the following two techniques for installing two openings and cross ventilation routes (Fig. 1).

Cross ventilation route (1) in Fig. 1 is a technique for ensuring cross ventilation by installing an opening in two exterior walls facing different directions in a room. If an opening can only be placed in one of the exterior walls of the room, consider cross ventilation route (2). This technique ensures cross ventilation by installing an opening in the exterior wall of the adjacent space which shares the same opening in the partition wall with the room.

Fig. 1 How to secure a cross ventilation route

■Target room with cross ventilation route (1)
■Target room with cross ventilation route (2)



The larger the opening area on cross ventilation routes (1) and (2), the greater the expected amount of cross ventilation (air change rate) as well as the energy saving effect, in general.

Requirements for the opening area on cross ventilation routes (1) and (2) needed for Method 1 are classified into two levels, respectively (Table 3). Method 1a is intended for a small opening area and Method 1b is for an opening area twice as large as the opening area of Method 1a.

Table 3 Requirements for opening area on cross ventilation route (Method 1)

Method		Ratio of opening area to floor area		
		Opening 1	Opening in a partition wall	Opening 2
Method 1a (Combination of small opening areas)	Cross ventilation route (1)	at least 1/35	–	at least 1/35
	Cross ventilation route (2)	at least 1/20	at least 1/50	at least 1/20
Method 1b (Combination of large opening areas)	Cross ventilation route (1)	at least 1/17	–	at least 1/17
	Cross ventilation route (2)	at least 1/10	at least 1/25	at least 1/10

Although it is desirable to use the net floor area of the relevant room as the floor area shown in Table 3, you can use the floor area measured from the center line of the wall to simplify the calculation. In both cases of cross ventilation routes (1) and (2), the floor area of the target room should be examined.

The opening area refers to an area that can be open for cross ventilation for a certain period of time (an area calculated from the inside dimensions of the open area). If there are multiple openings in the same direction in the exterior wall, all the opening areas can be (included) added together as a single opening in the calculation. In addition to securing the proper opening area, it is necessary to ensure the security of the openings during the night (Section 3.1.5 explains security measures).

Comment ● Method for judging Method 1 by calculating the combined effective opening area in the cross ventilation route

Requirements of the opening area shown in Table 3 are based on the assumption that openings 1 and 2 in the exterior wall have the same area. If the area of the two openings in the cross ventilation route is unequal and the area of either opening does not satisfy the requirements in **Table 3**, the table below can be used to calculate whether or not requirements of Method 1 are met (When examining cross ventilation route (1), keep the Opening in a partition wall column blank).

Example of calculation and steps thereof

Step	Entry item and other factors	Opening 1	Opening in a partition wall	Opening 2
1	Width (m)	a_1	a_i	a_2
2	Height (m)	b_1	b_i	b_2
3	Discharge coefficient	c_1	c_i	c_2
4	Effective opening area (m^2)	$d_1 \leftarrow c_1 \times (a_1 \times b_1)$	$d_i \leftarrow c_i \times (a_1 \times b_1)$	$d_2 \leftarrow c_2 \times (a_2 \times b_2)$
5	$\left(\frac{1}{\text{Effective opening area}}\right)^2$	$e_1 \leftarrow 1/d_1^2$	$e_i \leftarrow 1/d_i^2$	$e_2 \leftarrow 1/d_2^2$
6	$\Sigma \left(\frac{1}{\text{Effective opening area}}\right)^2$	$f \leftarrow e_1+e_i+e_2$		
7	Combined effective opening area (m^2)	$g \leftarrow 1/\sqrt{f}$		
8	Floor area (m^2)	h		
9	Combined effective opening area / floor area	$i \leftarrow g/h$		
10	Determination	i≥0.006: Satisfies Method 3a i≥0.006: Satisfies Method 3a i≥0.012: Satisfies Method 3b i≥0.012: Satisfies Method 3b		

Steps 1, 2: Enter width and height of each opening. Note that inside dimensions of the actual opening, instead of sash nominal dimensions, should be used for the width and height of the opening. Similar to the examination using Table 3, if there are multiple openings in the same direction in the exterior wall it is possible to use their combined area as a single effective opening area.
Step 3: Enter discharge coefficient (See p.054) of each opening. Although the discharge coefficient varies depending on the angle of airflow and opening coverings, use the following as a reference.
Opening in a partition wall: approx. 0.6; double sliding window (with a screen): approx. 0.5; projected window, inward/outward-opening window: approx. 0.3
Steps 4 – 7: Calculate using the formula in the column (shown on the right of the arrow)
Steps 8 – 9: Enter the floor area of the target room and obtain the ratio of the combined effective opening area to the floor area.
Step 10: Based on the calculated figures and value for determination (e.g. 0.01, 0.02), check which method (Method 1a, 1b, 3a or 3b) the opening satisfies.

Calculation example: Example of calculating cross ventilation route (2) of the 8-tatami-mat room (13.2 m^2)
Opening 1: Double sliding window; sash inside size 1,650 mm (width) x 1,100 mm (height)
→If the overlap of the glazed sliding door is 70 mm, the opening size is 755 mm (width) x 1,100 mm (height).
Opening in a partition wall: Transom window opening above the door to the hallway; inside size 800 mm (width) x 450 mm (height)
Opening 2: Vertical projected window (triple window); sash inside size 160 mm (width) x 1,300 (height)

Step	Entry item and other factors	Opening 1	Opening in a partition wall	Opening 2
1	Width (m)	a_1 0.755	a_i 0.8	a_2 0.16 x 3
2	Height (m)	b_1 1.1	b_i 0.45	b_2 1.3
3	Discharge coefficient	c_1 0.5	c_i 0.6	c_2 0.3
4	Effective opening area (m^2)	$d_1 \leftarrow c_1 \times (a_1 \times b_1)$ $0.42 \leftarrow 0.5 \times (0.755 \times 1.1)$	$d_i \leftarrow c_i \times (a_1 \times b_1)$ $0.22 \leftarrow 0.6 \times (0.8 \times 0.45))$	$d_2 \leftarrow c_2 \times (a_2 \times b_2)$ $0.19 \leftarrow 0.3 \times (0.48 \times 0.13)$
5	$\left(\frac{1}{\text{Effective opening area}}\right)^2$	$e_1 \leftarrow 1/d_1^2$ $5.67 \leftarrow 1/0.42^2$	$e_i \leftarrow 1/d_i^2$ $20.66 \leftarrow 1/0.22^2$	$e_2 \leftarrow 1/d_2^2$ $27.7 \leftarrow 1/0.19^2$
6	$\Sigma \left(\frac{1}{\text{Effective opening area}}\right)^2$	$f \leftarrow e_1+e_i+e_2$ 54.03		
7	Combined effective opening area (m^2)	$g \leftarrow 1/\sqrt{f}$ 0.136		
8	Floor area (m^2)	h 13.2		
9	Combined effective opening area / floor area	$i \leftarrow g/h$ 0.01		
10	Determination	ii≥0.01: Satisfies Method 1a → Satisfies Method 1a i≥0.02: Satisfies Method 1b i≥0.006: Satisfies Method 3a i≥0.012: Satisfies Method 3b		

3

Key Point

Controlling the indoor environment through landscape planning

- **The use of landscaping ingenuity to block solar radiation, such as planting shrubs and trees around the house, can keep down the temperature of wind introduced into the room. This also controls the reflected solar radiation and the heat radiation from the heated ground surface and inhibits the heat from entering through windows and other means. On the other hand, if a tiled terrace or paved parking lot that is exposed to solar radiation is facing a large window, deterioration of the external thermal environment affects the indoor environment.**

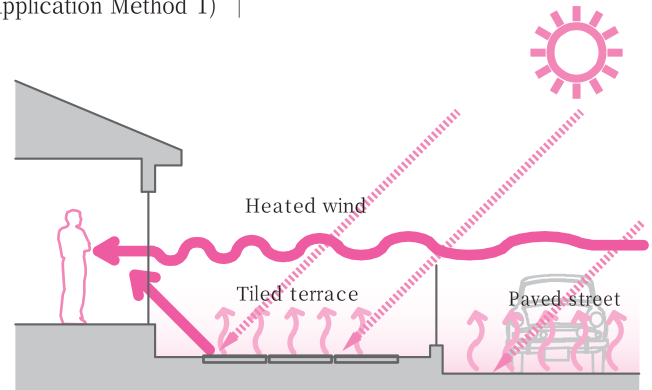


Fig. a Example of landscape planning that increases temperature of wind to be introduced

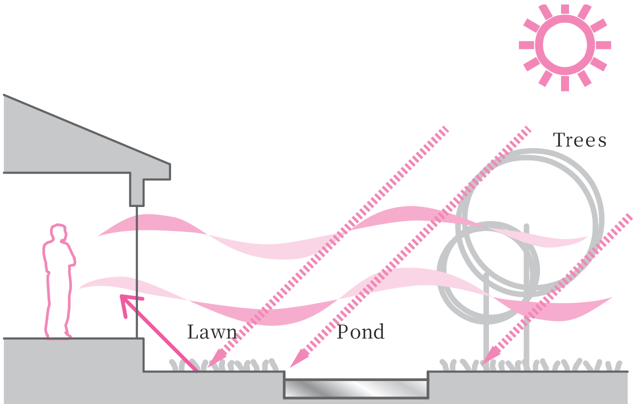


Fig. b Example of landscape planning that keeps down temperature of wind to be introduced

Comment ● Size of opening and cross ventilation quality

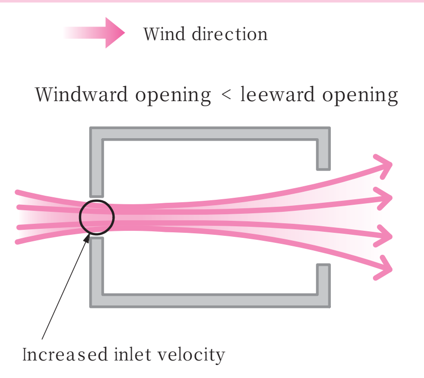


Fig. a Cross ventilation with a small windward opening area

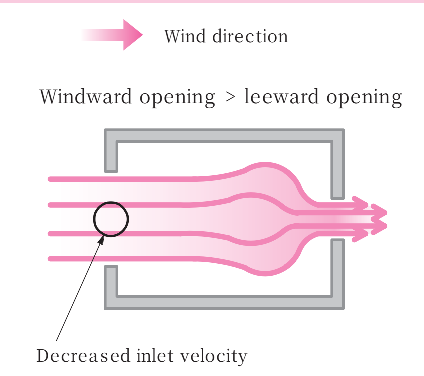


Fig. b Cross ventilation with a small leeward opening area

Ventilation quality depends on the relationship of the size between the “entrance” and “exit” of the wind.

(1) Opening area and amount of cross ventilation

- The larger the opening area the higher the cross ventilation effect. Nevertheless, halving the area of one of the openings in the cross ventilation route that passes through multiple openings does not mean the amount of cross ventilation is reduced by half.
- Having either a couple of large opening areas or multiple openings of equal area in total does not provide any significant difference in cross ventilation effects. In short, even if a large opening cannot be installed, a similar amount of cross ventilation can be obtained by securing a similar opening area with a combination of small openings.

(2) Difference in windward and leeward opening areas and cross ventilation effects

- When planning two openings in one room, as long as both openings are large enough you can obtain a large amount of cross ventilation. However, if there is a size difference in the two openings, the windward and leeward windows, the indoor airflow patterns can change depending on which is larger (**Fig. a and Fig. b**).
- When the windward opening is small, the inlet velocity increases and a person standing in the wind passage can feel very cool (**Fig. a**). Careful attention needs to be paid, as placing a bed near the small windward opening can cause airflow to directly hit the occupants during sleep, which may negatively affect their health.
- When the leeward opening is small, it results in a decrease in the inlet velocity, but mild breeze (with gentle airflow velocity) can be expected in the wide area of the room (**Fig. b**).

2. Planning openings in the exterior wall

It is important to install an opening area that effectively allows outside wind into the room while paying attention to securing sunshine, view and privacy.

1) Securing exterior opening areas

It is necessary to secure two exterior openings in the cross ventilation route that satisfy the area requirements for Method 1 shown in Table 3 on p.050. Examples of dimensions of the exterior opening that satisfy the requirements are shown below for reference purposes (Table 4).

Table 4 Examples of dimensions of exterior openings that satisfy Method 1 requirements

Type of opening	Area ratio	Room size				
		6 *tatami* mats(10 m²)	8 *tatami* ats(13 m²)	10 *tatami* mats(16 m²)	12 *tatami* mats(20 m²)	15 *tatami* mats(25 m²)
Waist-level window (Height: 1.1 m)	1/35	Width: 0.26m	Width: 0.34m	Width: 0.43m	Width: 0.51m	Width: 0.64m
	1/20	Width: 0.45m	Width: 0.6m	Width: 0.75m	Width: 0.9m	Width: 1.13m
	1/17	Width: 0.53m	Width: 0.71m	Width: 0.88m	Width: 1.06m	Width: 1.32m
	1/10	Width: 0.9m	Width: 1.2m	Width: 1.5m	Width: 1.8m	Width: 2.25m
Patio door (Height: 1.8 m)	1/35	Width: 0.16m	Width: 0.21m	Width: 0.26m	Width: 0.31m	Width: 0.39m
	1/20	Width: 0.28m	Width: 0.37m	Width: 0.46m	Width: 0.55m	Width: 0.69m
	1/17	Width: 0.32m	Width: 0.43m	Width: 0.54m	Width: 0.65m	Width: 0.81m
	1/10	Width: 0.55m	Width: 0.73m	Width: 0.92m	Width: 1.1m	Width: 1.38m

* The width and height of the opening are inside dimensions.
The area ratio refers to a ratio of the opening area to the floor area of the room.

Windows you can use vary according to the required opening area. It is necessary in particular to consider security aspects when planning openings. For example, if a 0.26 m wide opening is needed, installing double windows with 0.13 m wide effective opening each on the same wall is acceptable and this may be more advantageous for security reasons.

Pay attention to the following when selecting window sashes:

- **When using a regular double sliding window sash, an openable area is less than the one side of the glazed sliding door. Additionally, although it is necessary to install window bars for increased security, if only a moderate level of security is required, a metal lock can be used to lock the sliding door frame at the middle.**
- **Bottom-hinged inswinging windows and projected windows are suitable for securing a relatively small opening area. However, it is possible to secure a large opening area by installing more than two windows on the same wall.**

Fig. 2 Example of secured open area with security considerations
Combination of a waist-level window and a small floor-level window. A wooden window bar is installed for the small floor-level window (double sliding window).

2) Planning opening coverings

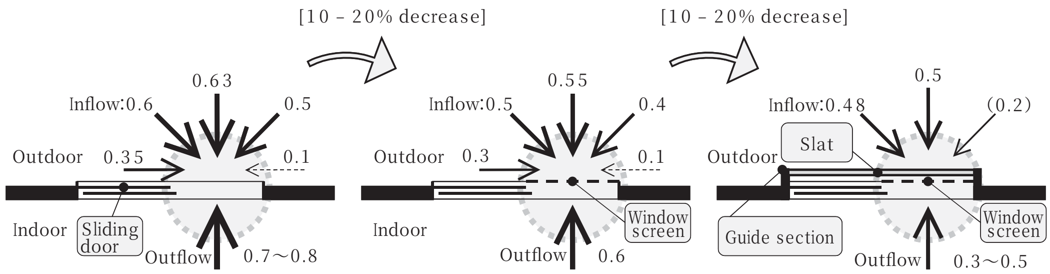
Coverings are usually installed on the openings. It is necessary to recognize how much effect coverings have on cross ventilation and take it into consideration when planning openings.

Key Point

Cross ventilation disturbance by window screens and shutters

- **Changes in inflow due to the direction of incoming wind are shown using discharge coefficient values (Fig.). The discharge coefficient is a value that indicates the ease of passage of wind. As shown in the figure, the discharge coefficient that receives wind from the front of the opening is 0.63 for "a. Double sliding window only" whereas it is 0.55 for "b. Double sliding window + window screen", indicating a 10 – 20% decrease with the use of window screens. It decreases a further 10 – 20% if blind shutters are also used as shown in c.**
- **Using a window screen only during the daytime when the temperature is high to let in ample wind and a window screen and a blind shutter at night is a rational way in terms of efficient cross ventilation as well as security and privacy protection.**
- **A combination of a window screen and a curtain significantly prevents cross ventilation as the curtain adheres closely to the window screen when wind flows out of the window. Even with a sheer curtain, if it adheres closely to the window screen the discharge coefficient decreases to approximately 0.2 (1/3 of normal condition). Bamboo and other blinds may also adhere to the window screen, depending on the wind direction and speed, thus careful attention is required when using them.**

Glossary: Discharge coefficient
This refers to a ratio of the effective area of cross ventilation to the actual opening area. For example, as shown in Fig. a on the right, even when wind flows perpendicular into the opening the discharge coefficient is 0.63 and an effective area of cross ventilation is approximately 60% of the actual opening area. A value obtained from multiplying a discharge coefficient with an actual opening area is referred to as an effective opening area, which is an effective area of cross ventilation.



a. Double sliding window only

b. Double sliding window + window screen

c. Double sliding window + window screen + blind shutter (slat angle of 30°)

Fig. Easing passage of wind through combination of opening coverings

Comment ● Wind introducing effects of side walls and other means

If there is an airflow parallel to the wall surface in the space between the house and the adjacent building, placing a fence, plants and a side wall will increase the wind pressure in that area and introduce wind into the room.

If this is the case, it is important to install a fence and other elements that are large enough for the opening, and the height and width of the fence and other elements need to be equal to or greater than that of the opening. The figure shows a calculation example using a side wall to introduce wind into the room, which results in an approximately 2.5-fold amount of cross ventilation compared to no side wall.

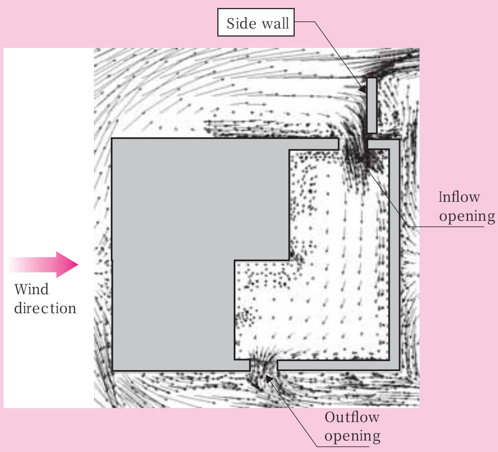


Fig. Introducing wind into a room with a side wall

2. Planning opening in a partition wall

Even if an "entrance" and "exit" for the wind has been installed, sufficient cross ventilation cannot be achieved unless there is a passage of wind in the house. To realize this, it is necessary to use an open concept floor plan with as few partition walls as possible and choose the right interior fittings and fixtures.

1) Area of opening in a partition wall

In the case of cross ventilation route (2), it requires openings in the partition wall in the cross ventilation route that satisfy the area requirements for Method 1 shown in Table 3 on p.050. Examples of dimensions of the interior opening that satisfy the requirements are shown below for reference purposes (Table 5).

Table 5 Examples of dimensions for interior openings that satisfy Method 1 requirements

Type of opening in partition wall	Area ratio	Room size				
		6 *tatami* mats (10 m²)	8 *tatami* mats (13 m²)	10 *tatami* mats (16 m²)	12 *tatami* mats (20 m²)	15 *tatami* mats (25 m²)
Opening equivalent to door (Height: 1.8 m)	1/50	W: 0.11m	W: 0.15m	W: 0.18m	W: 0.22m	W: 0.28m
	1/25	W: 0.22m	W: 0.29m	W: 0.37m	W: 0.44m	W: 0.55m
Transom window opening above door (Width: 0.8 m)	1/50	H: 0.25m	H: 0.33m	H: 0.41m	H: 0.5m	H: 0.62m
	1/25	H: 0.5m	H: 0.66m	H: 0.83m	H: 0.99m	H: 1.24m

* The width and height of the opening are inside dimensions.
The area ratio refers to a ratio of the opening area to the floor area of the room.

- **The easiest way to ensure cross ventilation by an opening in the partition wall is to leave the door open. However, as this makes it difficult to protect privacy and the door may close due to a sudden gust of wind, it may be difficult to leave the door open to ensure appropriate cross ventilation. Therefore, in this section, standard doors lacking any of the appropriate measures for cross ventilation are not regarded as openings in the partition wall in the cross ventilation route (2). The prerequisite is to exercise ingenuity for ensuring cross ventilation such as adopting a sliding door shown below (Fig. 3) and installing a door stopper (Fig. 6).**
- **For openings other than the openings in the partition wall in the cross ventilation route, it is important to ensure that they can be opened as needed using such ingenuity to increase the cross ventilation performance of the room.**

2) Adoption of sliding doors

Compared to single swing doors, sliding doors make effective fixtures for cross ventilation as not only do they prevent movement from being hindered when open, but also the extent to which they are open can be freely adjusted. Furthermore, installing a sliding door that is as high as the ceiling allows for a movable partition wall-like fixture with high flexibility, thereby achieving an open space (Fig. 3).

Fig. 3
Example of sliding door
(effective opening area: approx. 1.3 m²)

Use and Control of Wind 3.1

3

Chapter 3
Natural Energy Application Technology (Elemental Technology Application Method 1)

3) Adoption of transom windows

A Japanese traditional ranma transom is an excellent tool for ensuring air flow while providing a clear visual division. This idea can be fully applied to modern houses (Fig. 4). Single swing fixtures with top-mounted transom windows are now available on the market.

Fig. 4
Example of transom windows
(effective opening area: approx. 0.1 m²)

4) Adoption of lattice doors

Depending on the spacing of the lattice, lattice doors can block other people's gaze to some extent as well as being effective for cross ventilation. By combining lattice doors with wooden and other types of sliding doors that do not let air through, it is possible to reduce heating load in winter as well as achieve active cross ventilation in summer (Fig. 5).

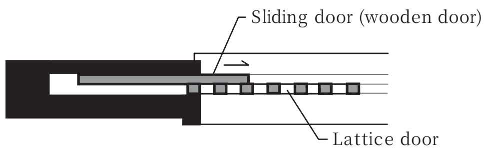


Fig. 5
Example of lattice door
(effective opening area: approx. 0.4 m²)

5) Adoption of door with opening

If a sliding door cannot be used and a hinged door has to be installed, as is the case for a hallway, bathroom or washing room, and if it is difficult to leave the door open, it is effective to adopt a door that has an opening which can be opened and closed such as a double hang window.

6) Installation of door stopper

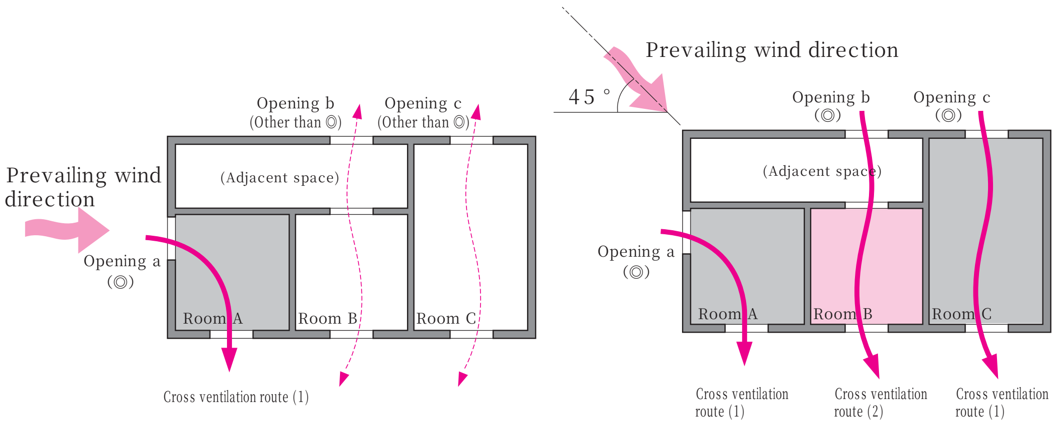
When installing a hinged door in the hallway, bathroom or washing room, the use of a door stopper (Fig. 6) allows the door to be left open for cross ventilation. It is recommended to select a door stopper that does not extrude from the floor to avoid hindering movement.

Fig. 6
Example of door stopper

Method 2 : Opening layout according to prevailing wind direction

At a site with open surroundings (Location 2: suburban location), installing openings on one side in the prevailing wind direction (windward) ensures a significant wind pressure coefficient difference between the inflow and outflow openings, which allows for a large amount of cross ventilation.

Method 2 has two requirements (Fig. 7). If the prevailing wind direction is known, the direction of one side of the openings in the cross ventilation route must be within 45° of the prevailing wind direction. If it needs to be determined from the table of Key Point Outside wind direction in hot humid regions on p.043, the frequency of the direction of one side of the openings in the cross ventilation route to become windward must be at least 40% (indicated with ◎ in Table on p.043). Method 2 cannot be applied to Location 1 (urban location).



Pattern 1: Method 2 is applicable to Room A

◎: Frequency of direction of one side of openings in cross ventilation route to become windward is at least 40% (See Table on p.043)

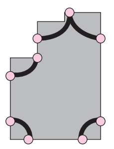
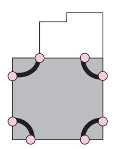
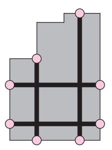
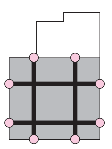
Fig. 7 Patterns for achieving Method 2 requirements

Key Point

Influence of housing density and wind direction on the wind pressure coefficient difference

- **Based on the wind tunnel test results for different housing densities, the relationship between the site conditions and the average wind pressure coefficient difference is summarized (Table). Assuming the linear cross ventilation route (opposite openings) and the right-angled cross ventilation route (openings in the corners), the table shows the average wind pressure coefficient difference in cases where the openings are on the windward side (i.e. there is an opening facing within 45° of the prevailing wind direction) and where they are not.**
- **At sites with open surroundings (Location 2), an average wind pressure coefficient difference of approximately 0.5 – 0.8 can be obtained if there is an opening on the windward side. However, if there is no opening on the windward side, only approximately 0.1 – 0.4 of wind pressure coefficient difference can be anticipated.**
- **Meanwhile, at sites with high surrounding density (Location 1), the influence of whether or not openings are on the windward side is small, and there is a wind pressure coefficient difference of approximately 0.05 – 0.2 regardless of the direction of the openings.**

Table Average wind pressure coefficient difference of each cross ventilation route obtained from wind tunnel test

Site onditions	Relationship of opening location and wind direction (Assumed relationship of cross ventilation routes (Plan view))	 1st floor (corner)	 2nd floor (corner)	 1st floor (opposite)	 2nd floor (opposite)	Value used in this examination
Location 1 (Urban location)	In the case of windward opening	0.1~0.14	0.08~0.21	0.08~0.15	0.08~0.23	0.05
	In the case of no windward opening	0.05~0.07	0.06~0.08	0.08~0.13	0.08~0.14	0.05
Location 2 (Suburban location)	In the case of windward opening	0.55	0.77	0.62	0.78	0.5
	In the case of no windward opening	0.14	0.19	0.36	0.37	0.2

* For verification of energy saving effects by wind utilization in this document, a wind pressure coefficient difference of 0.05 is used for Location 1, 0.5 for Location 2 with openings on the windward side, and 0.2 for Location 2 without openings on the windward side

Method 3 : Use of high windows

1. Cross ventilation routes and opening area

The use of high windows (e.g. top side windows in the wall near the top of the building, skylights in the roof) can ensure cross ventilation. In this case, openings in the exterior wall and high windows often serve as the entrance and exit for wind, respectively. Method 3 discusses how to use the following two techniques (Fig. 8).

- **Since high windows on the leeward side allow for a significant wind pressure coefficient difference, it is effective to install them even if the area of the window is small. Furthermore, installing windows in a high position can effectively ensure a stable amount of cross ventilation by taking advantage of the air density difference caused by the inside and outside temperature difference. This is also effective from the perspective of security considerations at night.**

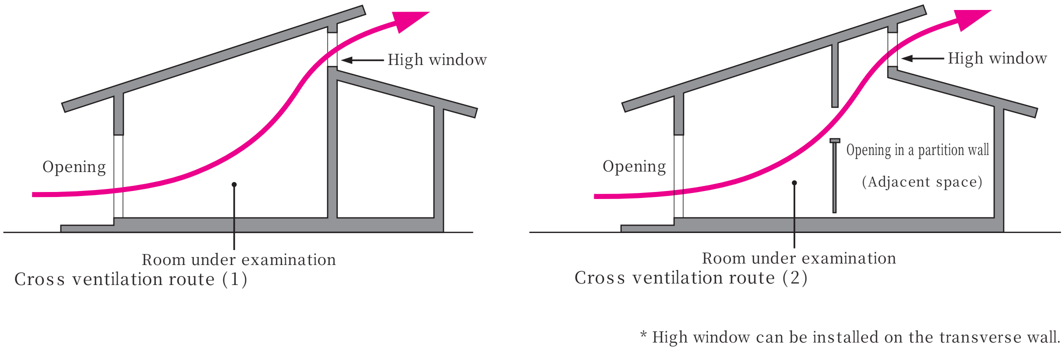


Fig. 8 How to secure a cross ventilation route using a high window

Method 3 assumes high windows installed on the leeward side. If the prevailing wind direction is known, the direction of the high windows must be within 45° of the leeward side of the prevailing wind direction. If it needs to be determined from the table of Key Point Outside wind direction in hot humid regions on p.043, the frequency of the direction of the high windows to face leeward must be at least 40% (indicated with ◎ in Table on p.043).

Similar to Method 1, the larger the opening area in cross ventilation routes (1) and (2), the greater the expected amount of cross ventilation (air change rate) as well as the energy saving effect. Requirements for the opening area in cross ventilation routes (1) and (2) needed for Method 3 are classified into two levels, respectively (Table 6). Method 3a is intended for a small opening area and Method 3b is for an opening area twice as large as the opening area of Method 3a. Method 3a and Method 1a have an equal expected amount of cross ventilation (air change rate), as do Method 3b and Method 1b. Compared to the opening of Method 1 (See Table 3 on p.050), the use of high windows can achieve a similar effect with a small window area.

See Method 1 for other items that require careful attention. The opening area ratio in Table 6 is a value calculated with an assumption that a high window is installed at the leeward side of the roof in a room with a ceiling height of 2.4 m

Table 6 Requirements for opening area on cross ventilation route using high window (Method 3)

Method		Ratio of opening area to floor area		
		Opening in exterior wall	Opening in partition wall	High window
Method 3a (Combination of small opening areas)	Cross ventilation route (1)	at least 1/35	—	at least 1/80
	Cross ventilation route (2)	at least 1/20	at least 1/50	at least 1/70
Method 3b (Combination of large opening areas)	Cross ventilation route (1)	at least 1/17	—	at least 1/40
	Cross ventilation route (2)	at least 1/10	at least 1/25	at least 1/35

Similar to Method 1, it is also possible for Method 3 to examine whether the opening satisfies Method 3a or 3b based on the area of each opening. When making this judgment, replace the last judgment criteria in the table on p.051 of Comment ● Method for judging Method 1 by calculating the combined effective opening area in the cross ventilation route according to the following criteria:

$i \geq 0.006$: Satisfies Method 3a

$i \geq 0.012$: Satisfies Method 3b

It is necessary to secure high windows in the cross ventilation route that satisfy the area requirements of Method 3 shown in Table 6. Examples of dimensions for high window that satisfy the requirements are shown below for reference purposes (Table 7).

Table 7 Examples of opening dimensions for high windows that satisfy Method 1 requirements

Type of high window	Area ratio	Room size				
		6 *tatami* mats(10 m²)	8 *tatami* mats(13 m²)	10 *tatami* mats(16 m²)	12 *tatami* mats(20 m²)	15 *tatami* mats(25 m²)
Top side window (Height: 0.4 m)	1/80	W: 0.31m	W: 0.41m	W: 0.52m	W: 0.62m	W: 0.77m
	1/70	W: 0.35m	W: 0.47m	W: 0.59m	W: 0.71m	W: 0.88m
	1/40	W: 0.62m	W: 0.83m	W: 1.03m	W: 1.24m	W: 1.55m
	1/35	W: 0.71m	W: 0.94m	W: 1.18m	W: 1.41m	W: 1.77m
Top side window (Height: 0.6 m)	1/80	W: 0.21m	W: 0.28m	W: 0.34m	W: 0.41m	W: 0.52m
	1/70	W: 0.24m	W: 0.31m	W: 0.39m	W: 0.47m	W: 0.59m
	1/40	W: 0.41m	W: 0.55m	W: 0.69m	W: 0.83m	W: 1.03m
	1/35	W: 0.47m	W: 0.63m	W: 0.79m	W: 0.94m	W: 1.18m
Skylight (Square)	1/80	0.35x0.35 m	0.41x0.41 m	0.45x0.45 m	0.5x0.5 m	0.56x0.56 m
	1/70	0.38x0.38 m	0.43x0.43 m	0.49x0.49 m	0.53x0.53 m	0.59x0.59 m
	1/40	0.5x0.5 m	0.57x0.57 m	0.64x0.64 m	0.7x0.7 m	0.79x0.79 m
	1/35	0.53x0.53 m	0.61x0.61 m	0.69x0.69 m	0.75x0.75 m	0.84x0.84 m

* The width and height of the opening are inside dimensions.
The area ratio refers to a ratio of the opening area to the floor area of the room.

- **In the case of using a top side window, the opening can satisfy Method 3 as long as a relatively long width is maintained even if the height is low.**
- **When a top side window or skylight is installed, excessive solar radiation enters into the room, which may result in an increase in cooling energy consumption. In addition to studying the right direction and angle of elevation of the top side window and skylight, it is necessary to take measures such as solar shading considerations for the top side window and thorough solar shading of the skylight.**

2. Planning high windows

1) Installing top side windows and other means (in the case of a roof with a pitch of 15° or greater)

Cross ventilation can be ensured by installing top side windows and other means in the roof where the wind pressure coefficient is negative (Fig. 9).

- **If the roof pitch is 15° or greater, there is a spot on the leeward side of the building where the wind pressure is negative. Installing a window in this spot creates an effective opening for venting air.**
- **A wind tunnel test was performed on a house in a dense residential area that has a top side window on the leeward side. The result shows an approximately 0.15 of wind pressure coefficient difference between the wall and the top side window (approximately two- to three-fold of the expected wind pressure coefficient from the cross ventilation route between the walls (Method 1)).**

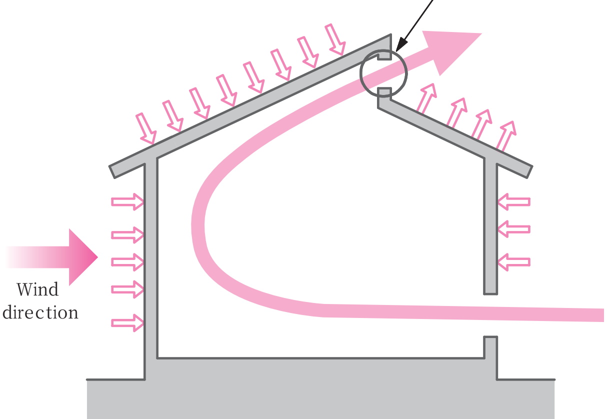


Fig. 9
Cross ventilation by top side window
(Roof pitch of 15° or greater)

2) Planning skylights and other means (in case of low pitch roof)

Installing skylights and other means in the roof where the wind pressure coefficient is negative can ensure cross ventilation.

- **If the roof receives a sufficient amount of wind, outside air can be efficiently introduced into the room by taking advantage of the blow-off force (negative pressure) generated on the roof. At Location 1 (urban location), the blow-off force is small as the roof does not receive sufficient amount of wind. Nevertheless, installing a skylight on the leeward side of the roof ensures approximately two- to three-fold (approximately 0.15) of the expected wind pressure coefficient from the cross ventilation route between the walls (Method 1). A larger wind pressure coefficient difference (driving force of cross ventilation) means that it can ensure the same amount of cross ventilation as Method 1 using a small area of high window.**

3

Chapter 3
Natural Energy Application Technology (Elemental Technology Application Method 1)

3.1.5 Considerations for Planning and Designing Openings

Consideration has to be given to security and noise issues when leaving the windows open for cross ventilation during the night. Openings require wind resistance and water tightness in preparation for rainstorms. Moreover, when utilizing wind during heavy wind it is necessary to control and adjust it.

1. Security measures

- **It is necessary to select a window that provides high security performance during cross ventilation as well as when closed (openable window with nighttime security).**
- **The security performance of windows significantly varies depending on the sash structures (opening and closing styles, locking mechanisms, window sizes, etc.), types of glazing, and the use of shutters and window bars, etc.**
- **Security should be ensured not only by windows but also by an overall security plan, such as combining security systems and devices as well as planning landscape with security considerations.**

* Inside dimensions
The Joint Government and Business Meeting on the Promotion and Development of High Performance Building Security Components considers that openings through which any blocks with the following dimensions cannot pass through are effective for preventing home invasion regardless of the structures and specifications.
- 400x250 mm rectangle →αA 0.06 m²
- 400x300 mm ellipse →αA 0.06 m²
- 350 mm diameter circle →αA 0.06 m²

Key Point

Example of ventilating windows considered effective for security

- **There are various tactics of burglars; however this section lists examples of windows that are considered to provide effective security measures against "cat burglars" who enter the house while hardly making noise using hands or a small screwdriver and other tools, as well as against "destructive burglars" who break the window to enter the house using tools.**

【Examples of windows with measures against cat burglars】

(1) Window with stopper

This type of window is often hinged and is available in a wide range of products. The moving part can be fixed so that the window stays slightly open but cannot be opened from outside.

Fig. a
Example of vertical projected window with stopper (partial image)

(2) Window with window bar

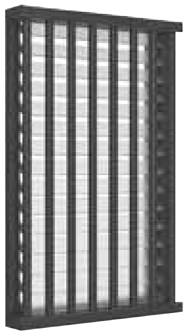


Fig. b
Example of louver window with window bar

(3) Ventilating storm door and window with ventilating storm shutter

Some storm doors and shutters allow cross ventilation while being closed. These products are used particularly with double sliding windows.

Fig. c
Example of ventilating shutter

The shutter section cannot be pulled up from outside during cross ventilation (Electric type is more common)

Fig. d
Example of ventilating storm door

【Examples of windows with measures against destructive burglars】

(1) Windows with security bars

Compared to regular window bars, security bars are designed so that they are more difficult to be destroyed. These windows have enhanced security features; for example, the screws are hidden, the bars are crossed for increased strength or integrated into the sash.

Fig. e
Example of combination of stainless window bar and double-hung window

(2) Slit windows

Windows with small inside dimensions of the frame that prevent people from going through provide high security. These long and narrow windows also ensure the required area of cross ventilation.

Fig. f
Example of slit vertical projected window

2. Measures for heavy wind and rain

- **Wind pressure resistance, water tightness and rustproof performance are required for sashes to cope with heavy wind and rain.**
- **In Okinawa, where typhoons frequently hit and reinforced concrete houses are common, sashes for reinforced concrete buildings are usually used. Since sashes for reinforced concrete buildings are intended for use on the upper floors of multi-family residential buildings as well, they have high wind pressure resistance and water tightness compared to regular sashes for wooden houses (Fig. 10).**
- **Select the thickness, types and area of the glazing for the sashes according to the required wind pressure resistance. If the resistance is insufficient, such measures as installing middle sash bars and dividing the opening into multiple sashes are required.**
- **From the perspective of rustproof performance and durability, aluminum window components including sashes, doors, window bars and shutters are commonly used. Additionally, glass fiber or resin mesh is used for window screens.**
- **In Okinawa, there are some examples of exercising architectural ingenuity in preventing wind and rain from entering the windows with poor water tightness. Fig. 11 shows the side walls that are placed on both sides of the high window for blocking cross wind and preventing rain drops from entering.**

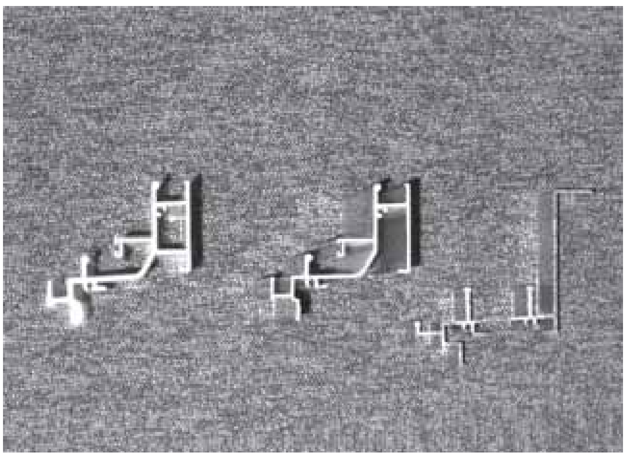


Fig. 10 Cross section example of the sash lower frame
(The frame on the far left is equipped with reinforced board and flashing.)

Fig. 11 Side walls installed on high window in the transverse wall

Glossary: Destructive burglar
This section refers to information from the Joint Government and Business Meeting on the Promotion and Development of High Performance Building Security Components on the website for the Japanese National Policy Agency (http://www.npa.go.jp/safetylife/seianki26/top.html).

Glossary: Measures against destructive burglars
These components are certified as "building security components (for which use of the CP sticker has been approved)" that are included on the list of building components with high security performance on the website managed by the Japan Crime Prevention Association (http://www.cp-bohan.jp). If security performance is a major priority, it is advisable to select the components that have the CP (crime prevention) sticker.

CP mark

3. Noise control measures

- When using cross ventilation in the bedroom during the night, it is necessary to make cross ventilation planning that introduces outside air directly into the bedroom. However, people are more sensitive about outside noise at night and it is highly possible that it will be too noisy to sleep with windows open even though this achieves cross ventilation. It is therefore necessary to exercise design ingenuity for openings so that outside noise is reduced while leaving the windows open for cross ventilation.
- Fig. 12 shows the average outdoor noise level in a residential area during the night and the recommended indoor noise level which takes into account the effect of noise on sleep. Even when the windows are open, if the sound insulation performance (indoor and outdoor noise level difference) is approximately 10 dB, it is possible to open windows during sleeping hours.
- The noise level depends on whether the window is facing the noise source. If the noise source is known from the beginning of the design stage, it is possible to address the noise concern by using sound insulating fittings and fixtures or reducing the size of openings which face the source. The selection of single swing windows that open on the opposite direction from the noise source (quiet direction) achieves a higher sound insulating effect. (Fig. 13).

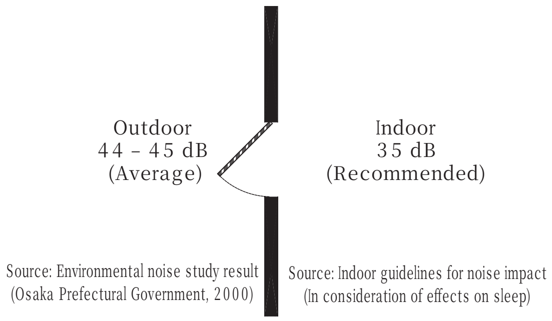


Fig. 12 Recommended indoor and outdoor noise level

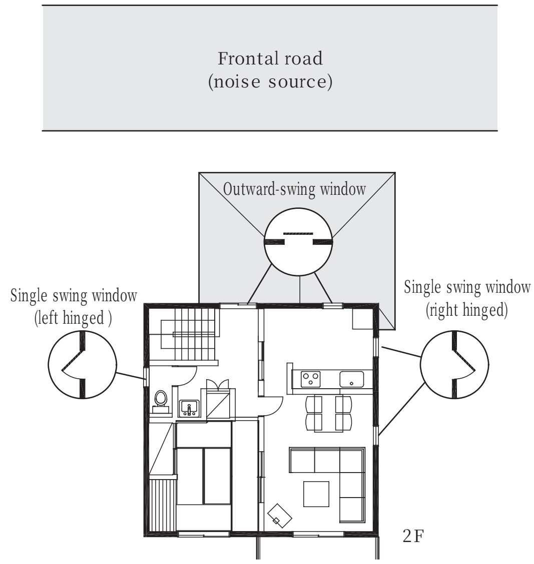


Fig. 13 Example of openings effective for sound insulation

Key Point

Sound insulation performance of open windows

- The figure below illustrates the sound insulation performance of the single swing window (width: 0.7 m, height: 1.3 m) based on the result of measuring the indoor noise level of the sound generated from the two outside directions.
- If the open width is 25 cm, the sound directly enters the room as shown with (1) even though it still provides approximately 10 dB of sound insulation. On the other hand, the result shows when the window serves as a wall blocking the sound as shown with (2), the sound insulation increases by approximately 5 dB to 15 dB.

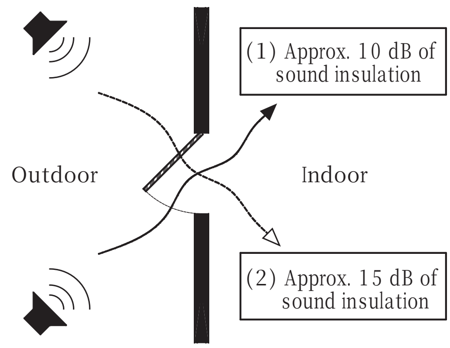


Fig.
Sound insulation performance of single swing window by opening direction

Comment ● Cautionary advice on high air change rate

If the air change rate is in the order of tens of air changes per hour and the indoor airflow velocity increases, a significant amount of heat is removed from the surface of the body, providing a cooling sensation even when the air temperature is relatively high. However, since this cools down the body too much when sleeping and increases the risk of catching a cold, openings need to be controlled according to the situation.

Comment ● Window opening habits of occupants

Even if considerable design ingenuity has been employed, cross ventilation cannot be obtained unless occupants actually open the windows. It is often the case that occupants do not open the windows, particularly during summer nights even when the outside air temperature decreases.

What is needed here is a system that informs occupants when the outside air temperature decreases. Compact outside air temperature thermometers are available on the market, and we recommend that you use these thermometers to encourage occupants to open the windows.

A simple way to do this is to stick a thermometer on the window (Fig. a). Placing a thermometer on the inside and outside of the window allows occupants to see both room temperature and outside air temperature. These thermometers typically cost between 1,000 and 2,000 yen.

Some digital thermometers can simultaneously measure the indoor and outdoor temperature by installing an external sensor on an extended cord from the indoor unit (Fig. b). One advantage of digital thermometers is that they catch people's eyes and are typically available between 3,000 and 5,000 yen.

Either type of thermometer requires careful attention to ensure that the temperature sensor (or the main thermometer body) is protected from rain or snow and is not exposed to direct sunlight.

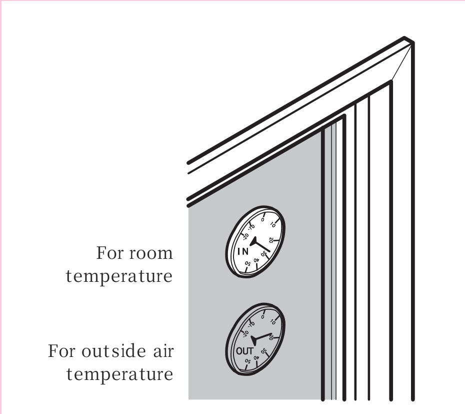


Fig. a Use of thermometers
A couple of analog thermometers are placed on the inside and outside of the window. The use of a thin outside air temperature thermometer does not hinder the opening and closing of window screens.

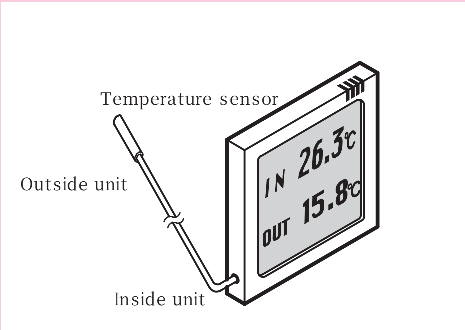


Fig. b Digital thermometer
A digital thermometer's sensor can be extended to the outside.

3.1.6 Calculation Method for Cooling Energy Reduction Rate by Room

Estimating an air change rate by room can calculate the cooling energy reduction rate more accurately. This section explains the calculation method.

The calculation procedures are as follows:

(1) Determine the method to be used for the living and dining rooms (used mainly during waking hours), master bedroom (used only during sleeping hours) and children's room (used from the evening till the morning), respectively, and estimate the air change rate based on Table 2 on p.048.

(2) Table a shows the cooling energy reduction (or increase) rate by room for each zone according to the different air change rate. Determine the energy consumption ratio (a consumption ratio, where reference energy consumption = 1.0) based on the cooling energy reduction (or increase) rate for each room given in Table a.
The cooling energy reduction rate varies slightly depending on the room in which wind is being utilized. This is due to the fact a room, which is more frequently used during hours when the outside air temperature is low (primarily during the night), achieves a higher wind utilization effect. Therefore, the cooling energy reduction rate of master bedrooms, which are used mostly during the night, is estimated to be higher than that of living, dining and children's rooms.

(3) For a room without an air conditioner, check the energy consumption during the period of using an electric fan according to Table b (Use 0 for energy consumption if electric fan is not used).

(4) Table c is a calculation table for the overall cooling energy reduction rate of the house. Calculate the cooling energy consumption by multiplying the reference cooling energy consumption by the energy consumption ratio obtained from Table a. For the period of using an electric fan, include the energy consumption listed in Table b. The overall energy reduction rate can be determined from these calculations.

Table a　Cooling energy reduction rate by room and air change rate

Air change rate (ACH)	Zone VI			Zone V		
	Living/Dining	Master bedroom	Children's room	Living/Dining	Master bedroom	Children's room
0	4% increase (1.04)	7% increase (1.07)	3% increase (1.03)	6% increase (1.06)	16% increase (1.16)	5% increase (1.05)
2	No reduction (1.0)	No reduction (1.0)	No reduction (1.0)	No reduction (1.0)	No reduction (1.0)	No reduction (1.0)
5	4% reduction (0.96)	7% reduction (0.93)	3% reduction (0.97)	4% reduction (0.96)	9% reduction (0.91)	6% reduction (0.94)
10	9% reduction (0.91)	15% reduction (0.85)	7% reduction (0.93)	10% reduction (0.9)	22% reduction (0.78)	12% reduction (0.88)
20	10% reduction (0.9)	22% reduction (0.78)	11% reduction (0.89)	16% reduction (0.84)	33% reduction (0.67)	18% reduction (0.82)

* Figures in parentheses refer to energy consumption ratio.

■Conditions of study
Set cooling temperature: 28 °C
Rated capacity of air conditioner: Living/Dining rooms 5 kW; master bedroom 2.8 kW; children's room 3.6 kW (Zone VI) / 2.2 kW x 2 units (Zone V)
Rated COP of air conditioner: Approx. 3

Table b Primary energy consumption during the period of using an electric fan (Unit: GJ)

Air change rate (ACH)	Zone VI			Zone V		
	Living/Dining	Master bedroom	Children's room	Living/Dining	Master bedroom	Children's room
0	0.57	0.26	0.41	0.41	0.15	0.53
2	0.52	0.23	0.36	0.38	0.13	0.47
5	0.47	0.19	0.31	0.35	0.11	0.41
10	0.4	0.16	0.26	0.31	0.08	0.35
20	0.35	0.13	0.22	0.27	0.06	0.29

■Conditions of study
Power consumption of electric fan: 30 W (low setting; oscillation)
The calculations assume that an electric fan is being used when an occupant is in the room, a temperature of 28 ° C or greater, and that a cooling system is not being used.
Primary energy conversion factor: Electricity 9,760 (kJ/kWh; value based on the revised 2006 building energy conservation standard)

Table c Calculation table of cooling energy reduction rate

	Room			Entire house
	Living/Dining room	Master bedroom	Children's room	
(1) Reference energy consumption (GJ)	6.1(VI), 3.4(V)	1.3(VI), 0.5(V)	2.9(VI), 1.8(V)	10.3(VI), 5.7(V)
(2) Air change rate (ACH) ←Table 2				
(3) Energy consumption rate ←Table a				
(4) Cooling energy consumption (GJ) (1) x (3) or Energy consumption during use of an electric fan (GJ) ←Table b				
(5) Reduction rate of entire house (%)(1 - (4) / (1) x 100)				

* For reference energy consumption of (1), use the figures on the left for Zone VI and on the right for Zone V.
The reference energy consumption of (1) and the energy consumption during use of an electric fan (GJ) in Table b are indicated on a primary energy (electricity) basis (Primary energy conversion factor: Electricity 9,760 (kJ/kWh; value based on the revised 2006 building energy conservation standard).
For a room without air conditioner, leave (3) blank and enter the energy consumption during the period of using an electric fan of (4) according to Table b.
The reference value of (1) for Zone VI and the energy consumption during the period of using an electric fan in Table b refer to the value for a children ' s room (shared by two children).
The reference value of (1) for Zone V and the energy consumption during the period of using an electric fan in Table b refer to the total value for two children ' s rooms.

【Calculation example】
Conditions of calculation Zone: Zone VI
Air change rate: Living and dining rooms 10 ACH; master bedroom 5 ACH; children ' s room 10 ACH
Air conditioner is not installed in the children ' s room

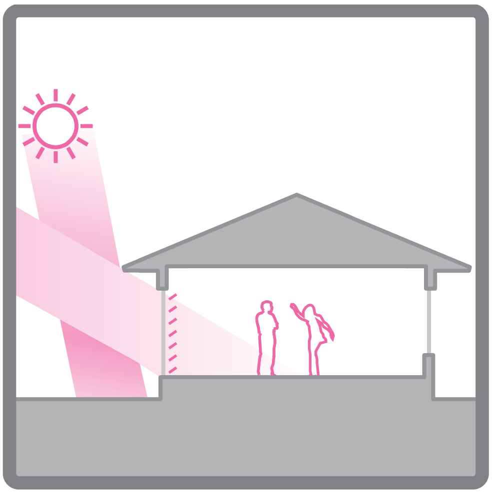
Calculation results Cooling energy reduction rate for entire house: Approximately 31%

	Room			Entire house
	Living/Dining room	Master bedroom	Children's room	
(1) Reference energy consumption (GJ)	$\boxed{6.1(VI)}$, 3.4(V)	$\boxed{1.3(VI)}$, 0.5(V)	$\boxed{2.9(VI)}$, 1.8(V)	$\boxed{10.3(VI)}$, 5.7(V)
(2) Air change rate (ACH) ←Table 2	10	5	10	
(3) Energy consumption rate ←Table a	0.91	0.93	— (No air conditioner)	
(4) Cooling energy consumption (GJ) (1) x (3) or Energy consumption during use of an electric fan (GJ) ←Table b	5.6	1.2	0.26	7.1
(5) Reduction rate of entire house (%)(1 - (4) / (1) x 100)				31%

3

Chapter 3
Natural Energy
Application Technology
(Elemental Technology
Application Method 1)

3.2 Daylight Utilization (Sunlight Utilization 1)



Daylight utilization planning is a technology that aims to secure light during the day and achieve a reduction in lighting energy consumption as well as increased comfort by skillfully introducing sunlight into a building. It can be largely classified into the daylighting method and the daylight guiding method.

Daylight utilization requires a well-planned scheme to maintain a good balance with solar shading, particularly in the summer. Moreover, since openings for cross ventilation may be an effective in daylighting, comprehensive planning is crucial for daylight utilization planning.

3.2.1 Purpose and Key Points of Daylight Utilization

- In a hot humid region (Zone VI), daylight utilization is hardly taken into consideration, particularly in the summer when solar shading is of the most significance, and lighting energy tends to increase. However, the skillful introduction of daytime brightness into the room reduces unnecessary use of lighting, thereby enabling a reduction in lighting energy consumption.
- As seen in indoor light environments that employ intense daylight in such regions as Zone VI, there is a stark contrast in lighting between an opening and the inside of a room. When the lighting contrast is too strong, the result is daytime lighting, a situation in which unnecessary lighting is used due to dark indoor conditions despite sufficient daylighting.
- Skillful sun control, which regulates the brightness coming from openings, can decrease the stark contrast in lighting inside the room and achieve visual comfort as well as reduced use of lighting, while implementing solar shading.
- The daylight utilization technology consists of the daylighting method, which directly introduces the brightness of openings into the room, and the daylight guiding method, which is an indirect approach involving reflection from the windows into the room. In Zone VI, a critical aspect of the daylighting method is controlling the introduction of daylight into the room (sun control) rather than securing daylight, and for the daylight guiding method, it is very important to effectively use controlled daylight as much as possible.

3.2.2 Energy Conservation Target Levels for Daylight Utilization

1. Definition of target levels

- Energy conservation target levels for daylight utilization are divided into the following levels 1 to 3. These levels indicate the necessity of artificial lighting, i.e. the reduction rate of the energy consumption of a lighting system.

Level 0	:	Cooling energy reduction	None
Level 1	:	Cooling energy reduction rate	Approx. 2-3%
Level 2	:	Cooling energy reduction rate	Approx. 5%
Level 3	:	Cooling energy reduction rate	Approx. 10%

- The typical lighting energy consumption in 2000 was 13.6 GJ (approximately 20% of total energy consumption) for Zone VI, and 11.3 GJ (approximately 17% of total energy consumption) for Zone V (See Section 6.1 on p.339).

- Energy conservation target levels for daylight utilization can be achieved by combining the site conditions and indoor daylighting conditions of a house.

2. Requirements for achieving target levels

1) Site conditions

- The possibility of sunlight utilization varies depending on conditions around the building site, such as whether there is a building that prevents sunlight from entering the house that is being built. This also determines which method is effective for energy conservation. It is effective to review the site conditions using the following three categories (See Section 2.3.1 Understanding Design Requirements of Low Energy Housing with Validated Effectiveness on p.026).

Location 1	:	High-density, high-rise location in which sunlight is hard to utilize
Location 2	:	High-density location in which sunlight can be utilized with ingenuity
Location 3	:	Suburban location in which sunlight can be easily utilized

- At sites such as those in Location 1 which is surrounded by high-rise buildings and sunlight hours are extremely short (dense, high-rise location), as well as Location 2 which is a narrow urban site with short distances between the adjacent buildings (dense location), daylight utilization can sometimes be difficult. Nevertheless, selecting a method that suits the site conditions achieves energy saving effects to some extent.

2) Daylighting conditions

- Table 1 shows the indoor daylighting conditions of a house using Condition 0 (equivalent to the Building Standard Law of Japan) to Condition 3 as a guideline by considering the necessity of daylight in habitable rooms (used for extended periods of time) and non-habitable rooms (not used for extended periods of time).

Table 1 Guideline for daylighting conditions

	Living/dining rooms	Senior's/children's rooms	Other habitable rooms	Non-habitable rooms (Kitchen, hallway, entrance, washing room, bathroom, toilet)
Daylighting condition 0 (equivalent to the Building Standard Law)	Mono-directional daylighting	Mono-directional daylighting	Mono-directional daylighting	–
Daylighting condition 1	Bi-directional daylighting	Mono-directional daylighting	Mono-directional daylighting	–
Daylighting condition 2	Bi-directional daylighting	Bi-directional daylighting	Mono-directional daylighting	–
Daylighting condition 3	Bi-directional daylighting	Bi-directional daylighting	Mono-directional daylighting	Mono-directional daylighting for all

- Mono- or bi-directional daylighting shown in Table 1 refers to the number of daylight utilization methods adopted. Daylight utilization methods discussed in this document (see Table 3 on p.068) are classified into methods that can be regarded and methods that cannot be regarded as daylighting surface.

Methods that can be regarded as daylighting surface	Cases in which daylighting is implemented according to (1) Planning positions and shapes of openings shown in Method 1: Direct daylight utilization methods (daylighting methods)*
	Cases in which daylight guiding is implemented according to (1) Design ingenuity with spatial structures such as transom windows and light wells shown in Method 2: Indirect daylight utilization methods (daylight guiding methods)
Methods that cannot be regarded as daylighting surface	Other methods

* Although skylights are not evaluated as the daylighting surface for Zone VI due to solar shading considerations, they can be included in the daylighting surface evaluation if either they are installed on the north side of the house or if a sun control device is installed.

- Details of each method are explained in 3.2.4 Daylight Utilization Methods.

Glossary: Senior's/children's rooms
This refers to a room in which occupants spend long hours during the day.

3. How to achieve target levels

1) How to achieve target levels

- The relationship between the energy conservation target levels for daylight utilization and the daylighting conditions by location is shown in Table 2.
- Level 0, the reference level, refers to a house located in a dense area surrounded by high-rise buildings (Location 1) with the level of daylight utilization that barely meets the Building Standard Law of Japan.

Table 2 Target levels for daylight utilization and how to achieve them

Target level	Energy saving effect (Lighting energy reduction rate)	Daylighting conditions (application of methods)		
		Location 1	Location 2	Location 3
Level 0	0	Daylighting condition 0 (equivalent to the Building Standard Law) Mono-directional daylighting Floor area x 1/7	–	–
Level 1	Approx. 2 - 3%	Daylighting condition 3	Daylighting condition 2	Daylighting condition 1
Level 2	Approx. 5%	–	Daylighting condition 3	Daylighting condition 2
Level 3	Approx. 10%	–	–	Daylighting condition 3

- The lighting energy estimated here includes energy during the night. Therefore, if we consider the lighting energy during the day only, we can expect more significant reduction effects.
- At a suburban site in Location 3, daylight utilization equivalent to Level 1 can be achieved without special design ingenuity. However, if sunlight utilization is difficult on a dense site in Location 1 or 2 it is necessary to actively consider methods for introducing daylight.

2) Types of daylight utilization method and light environment characteristics

- Daylight utilization methods discussed in this document are aimed at not only introducing more light into the room but also increasing the uniformity of the indoor light, i.e. illuminance of the areas where light is hard to reach, in addition to reducing the contrast in lighting. Table 3 shows the degree of effectiveness in terms of an increased amount of guided light, enhanced light uniformity, and reduced contrast in lighting when each method is used.

Table 3 Light environment characteristics of daylight utilization methods

Details of methods					Increased amount of light	Enhanced uniformity	Reduced contrast in lighting
Method 1	Direct daylight utilization methods (daylighting methods)	(1) Positions and shapes of openings	Side window	Direction	○	○	○
				Shape	△	○	–
				Height	△	◎	○
			Top side window		○	◎	○
			(Skylight: Zone V only)		(○)	(◎)	(◎)
		(2) Sun control devices	Bamboo blind, screen, paper sliding door, curtain		△	△	◎
			Louver, blind*		○	○	◎
			Overhang, awning*		△	△	○
Method 2	Indirect daylight utilization methods (daylight guiding methods)	(1) Spatial structures	Transom window, etc.		○	△	–
			Light well		○	◎	○
		(2) Reflection on finished surfaces			△	○	○
		(3) Devices	Horizontal reflector, etc.		○	○	–
			(Light duct, etc.: Zone V only)		(◎)	(◎)	(○)

◎: Effective, ○: Effective depending on plan, △: Not very effective
* Sun control devices including louvers and overhangs can be also used as daylight guiding method.

3.2.3 Steps for Examining Daylight Utilization Technology and Prerequisites

1. Steps for examining daylight utilization technology

- Confirmation of the site conditions and sunlight conditions is an important prerequisite for examining daylight utilization methods.
- Next, direct daylight utilization methods (daylighting methods) can be examined. During this step, it is important to also consider factors such as future changes in the surrounding environment and the possibility of partial sale of the site.
- At the same time, indirect daylight utilization methods (daylight guiding methods) that suit the daylighting methods should also be examined.

Step 1 Confirming site and sunlight conditions

1) Study the seasonal site and sunlight conditions from a floor planning perspective and consider a location that will continue to ensure sunlight in the future.
2) Study the seasonal site and sunlight conditions from a sectional planning perspective and consider a framework of the three-dimensional building shape, including the number of stories, that will continue to ensure sunlight in the future.

▼

Step 2 Examining direct daylight utilization methods (daylighting methods) – Method 1

1) Examine the positions and shapes of openings that enable daylighting. Thoroughly consider the relationship between the daylight utilization and the wind utilization.
2) Examine the sun control systems around the openings. Thoroughly consider the relationship between the daylight utilization and the solar shading.

▼

Step 3 Examining indirect daylight utilization methods (daylight guiding methods) – Method 2

1) Examine daylight guiding methods according to the spatial structures and daylighting methods.
2) Make the daylight guiding plan feasible for the entire space as much as possible by fully examining the spatial connection, use of partition walls and their types.

▼

Step 4 Identifying areas lacking daylight and incorporating this into lighting systems

1) Identify the areas lacking light during the day and incorporating Section 5.5 Lighting System Planning.

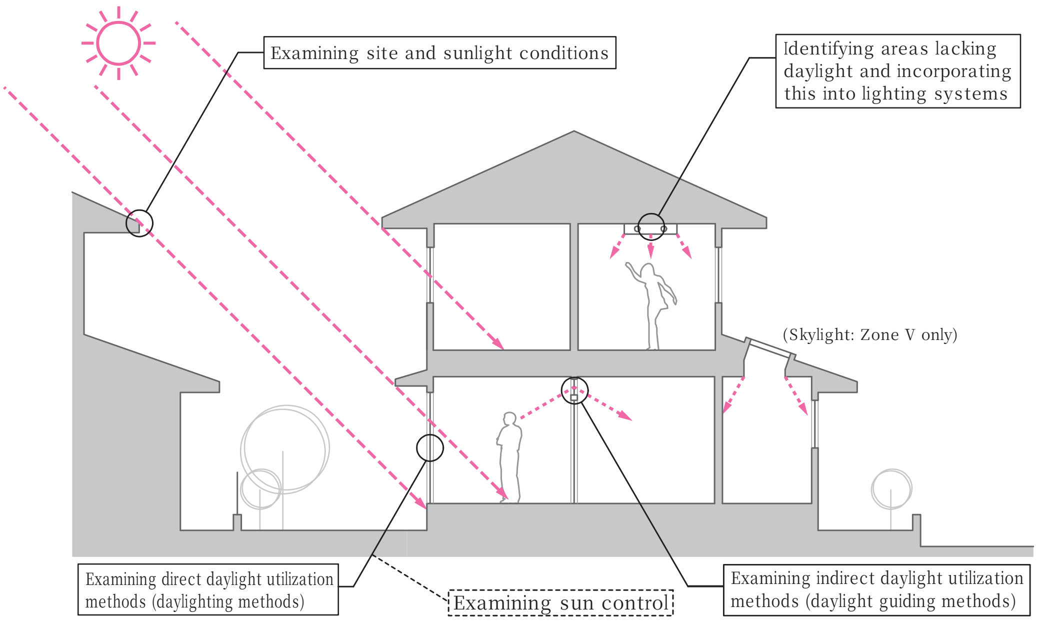


Fig. 1 Overview of daylight utilization technology

2. Prerequisites (site and sunlight conditions) and points to note for planning

1) Points to note for floor planning based on site conditions

First, perform a floor plan check for outline planning.

How surrounding buildings and other objects cast a shadow over the site can be studied using a sun shadow diagram. For season, closely examine when the shortest sunshine hours (winter solstice) are in winter when sunlight needs to be secured, in addition to when the longest sunshine hours (summer solstice) are in summer (Fig. 2 and Fig. 3). Since the position of the sun and shadows caused by it varies in the morning, noon and afternoon, checking it carefully by the hour leads to a pleasant and bright indoor environment. If there is a possibility of buildings being developed around the site in the future, it is important to predict the situation.

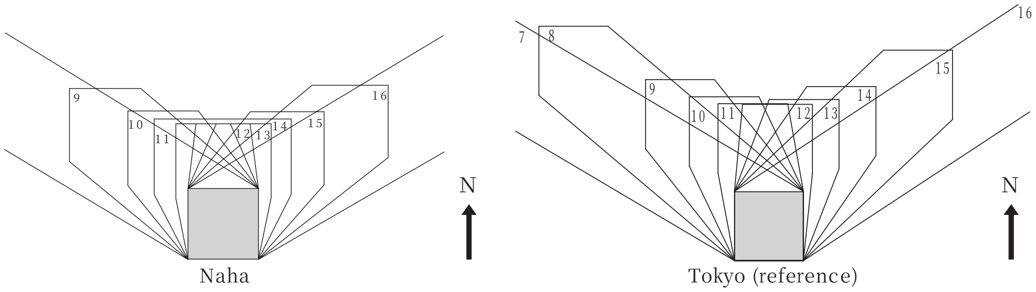


Fig. 2 Sun shadow diagram (bungalow) at winter solstice (December 21)

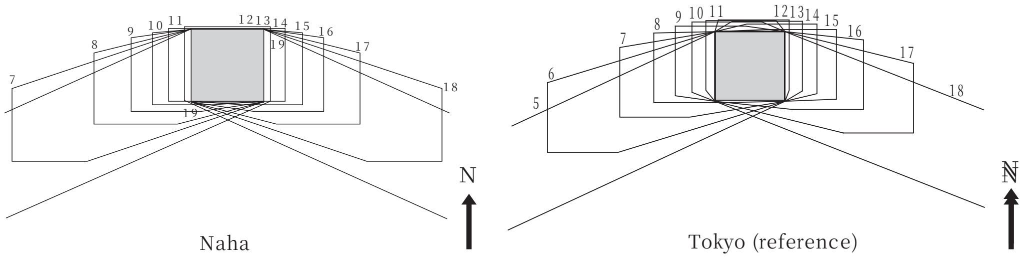


Fig. 3 Sun shadow diagram (bungalow) at summer solstice (June 21)

Once the position and time of day at which sunlight is secured are identified, use ingenuity in floor plan layouts from long-term perspectives, such as which time of the day sunlight is required and the lifestyle of occupants.

2) Points to note for sectional planning based on site conditions

Next, perform a three-dimensional shade check for specific planning.

For example, the solar altitude in the due south position for Naha should be treated as 40.4° at the winter solstice, 87.3° at the summer solstice, and 64° at the spring and fall equinox. The seasonal solar altitude and state of shadows caused by it can indicate the extent of floor area covered in shadow by the buildings on the south of the house through the south-facing windows on the first floor. It also enables consideration for the window positions and opening shapes (described later in this section), thereby allowing a more specific, three-dimensional spatial image (Fig. 4).

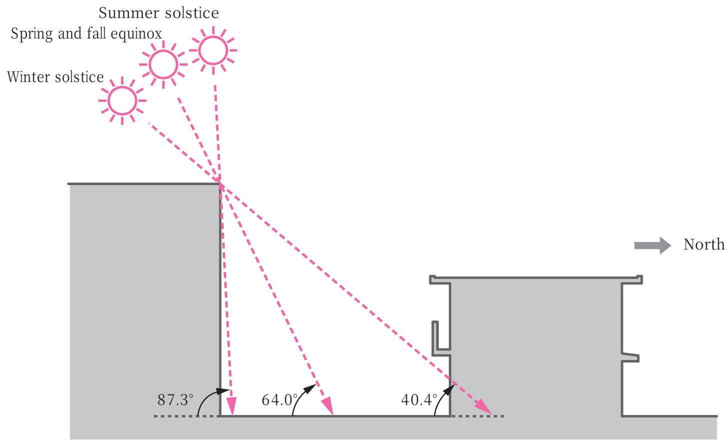


Fig. 4
Three-dimensional shade check
(Solar altitude in Naha)

Key Point

Differences in indoor illuminance due to site conditions

A floor illuminance distribution simulation was conducted on the first floor assuming the existence of a two-storey building on the south, a building site in which the space between adjacent buildings is narrow in one case and wide in another (Fig. a and Fig. b), as well as the existence of two-storey buildings surrounding the site (Fig. c). Results show the possibility of receiving direct daylighting from the opening is high when the space between buildings is wide.

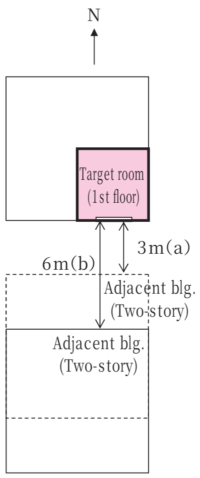
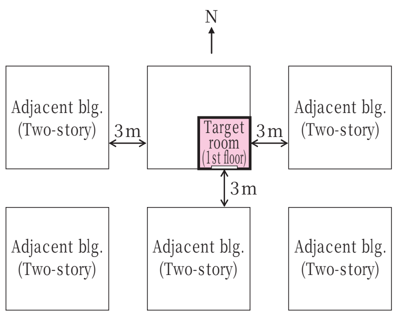


Fig. a
Floor illuminance distribution with narrow space between buildings (3 m)

Fig. b
Floor illuminance distribution with wide space between buildings (6 m)

Conditions a, b of space between buildings on south



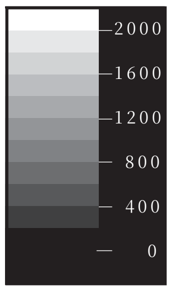
Conditions c of surrounding buildings (c)

Fig. c
Floor illuminance distribution with surrounding buildings (3 m)

■ Conditions (Naha)

Adjacent building: Two-storey
8 m x 8 m x 6 m (height)
Target room: South-facing first floor
4 m x 4 m x 2.5 m (ceiling height)
Window dimensions: 200 cm x 200 cm
(patio door)
Season and time: Spring and fall equinox; noon

Illuminance (lx) level



Comment ● Is lighting energy consumption in hot humid region highest in Japan?

As the hot humid region is located in the south of Japan, people tend to think the lighting energy consumption is low because of its long sunshine hours. However, sunshine hours are actually short because of the high precipitation level, and the lighting energy consumption is very high compared to other regions in Japan. For example, in Naha, the number of sunshine hours was 1,621 in 2006, ranking 12th in terms of the short sunshine hours among the capital cities of all 47 prefectures. Despite the short sunshine hours, the solar radiation level is high and people tend to close curtains or blinds and use lighting in an effort to ensure solar shading and reduce cooling load in the summer. Furthermore, it is considered that the lighting energy consumption is very high because shutters and other coverings are used for openings to protect them from typhoons.

3.2.4 Daylight Utilization Methods

Method 1: Direct daylight utilization methods (daylighting methods)

- Although daylighting from openings is the first stage of the daylight utilization methods, effects of daylighting vary depending on the location of the openings. Appropriate daylighting methods need to be selected for planning according to the site conditions and living space characteristics.
- At the same time, wind utilization should be considered.
- Even when the positions and shapes of openings have been determined, daylighting through openings alone leads to problems such as solar radiation heat directly entering the room and direct sunlight being too bright, which significantly impair the comfort of occupants. To avoid these problems, solar shading and sun control should be planned together so that an appropriate level of daylight is achieved.

1. Planning positions and shapes of openings

1) Planning side windows

Average side windows installed in the exterior walls have a simple window structure and it is also easy to install flashing to these windows. Although often overlooked, another great advantage of side windows is their ease of opening and closing as well as cleaning.

From the perspective of daylight utilization, it is important to be aware of the following characteristics of openings.

(1) The higher the position of the window, the further the light reaches in the room and the greater the uniformity of the indoor illuminance.

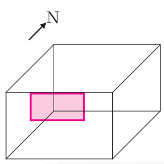
(2) The higher the position of the window, the easier the protection of privacy and the greater the tendency of opening curtains, etc.

(3) The higher the position of the window, the further it is from the center of the visual field and the easier the glare reduction.

Key Point

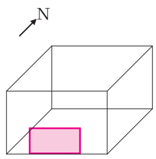
Differences in indoor brightness due to window height

- This section shows, as a reference, the indoor floor illuminance of a room with windows that are the same shape but are installed at a different height.
- In general, the higher the window position, the greater the illuminance uniformity. As shown in Fig. a, the light reaches further into the room. This increases the illuminance at the back of the room as well as the illuminance uniformity of the entire room. Other advantages of high windows are that they are less prone to be influenced by the surroundings and that they can reduce glare. However, these windows receive direct solar radiation and require the use of sun control devices as described later in this section.



a: Height to window sill 150 cm

Fig. a Floor illuminance distribution with high window

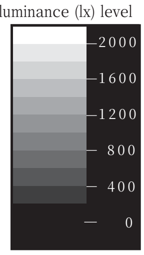


b: Height to window sill 0 cm

Fig. b Floor illuminance distribution with low window

■Conditions (Naha)
Target room: South-facing first floor
4 m x 4 m x 2.5 m (ceiling height)
Window dimensions: 200 cm x 100 cm
Season and time: Spring and fall equinox; noon

Illuminance (lx) level



* This chapter shows the verification results of brightness characteristics using a simulation software called "Inspirer".

2) Planning top side windows

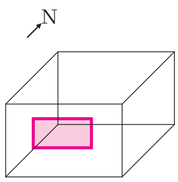
If the space between buildings is narrow and the possibility of daylighting from side windows is extremely low, or if there is a north-facing room that requires more light, it is effective to plan efficient daylighting using top side windows. As mentioned previously, windows that are located high enable efficient daylighting for the back of the room to increase illuminance and uniformity, and provide other advantages such as improved ventilation performance. The way in which maintenance is to be performed should be taken in to account when using top side windows. Careful consideration is required not only in cleaning and inspecting these windows but also in using the sun control devices mentioned hereafter, especially because solar shading is essential for south-facing top side windows in the summer.

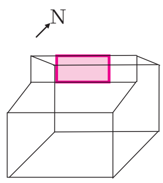
Key Point

Differences in indoor brightness between side windows and top side windows

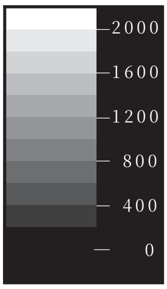
- The differences in the indoor floor illuminance distribution and the luminance distribution, which represent the condition of light in the entire room (perception of light), are shown below as a reference.
- Top side windows brighten the ceiling and walls at the back of the room that were darker with side windows.

■Conditions (Naha)
Target room:
South-facing first floor
4 m x 4 m x 2.5 – 3.5 m
(ceiling height)
Window dimensions:
200 cm x 100 cm
Season and time:
Spring and fall equinox; noon





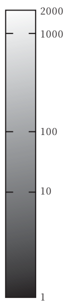
Illuminance (lx) level



Floor illuminance distribution

Floor illuminance distribution

Luminance (cd/m²) level



Condition of indoor light
(Luminance distribution)

Fig. a Indoor brightness with side window

Condition of indoor light
(Luminance distribution)

Fig. b Indoor brightness with top side window

Illuminance (lx) level
An amount of light that reaches a particular point (incident light). The unit of illuminance is lux (lx).

Luminance
An amount of light that represents the brightness on a surface seen from a particular direction.
The unit of luminance is the candela per square meter (cd/m2).

3

Chapter 3
Natural Energy Application Technology (Elemental Technology Application Method 1)

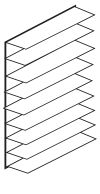
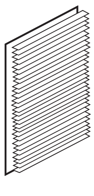
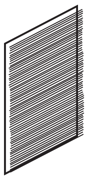
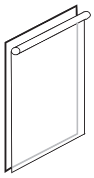
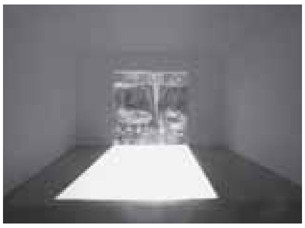
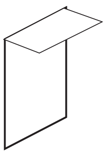
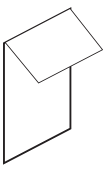
2. Planning sun control devices

Introducing daylight into the room leads to a tremendous reduction in lighting energy consumption in Zone VI. However, since solar shading is important in order to reduce cooling load, particularly in the summer (see Section 4.2 Solar Shading Methods for Zone VI), there is a need for ensuring both indoor brightness and solar shading.

A device that blocks direct sunlight is generally known as “solar shading device”. Considering the light in addition to the heat, it is required to install a device not only for shading to block the heat but also for adjusting the brightness, that is, a “sun control device”.

This section discusses the characteristics of sun control devices that are installed outside (Table 4) and inside (Table 5) including how they relate to solar shading effects. Furthermore, using overhangs and blocks

Table 4 Characteristics of sun control devices 1 (installed outside)

High ▲ Solar shading effect ▼ Low			**Horizontal louver** Direction/season/time: Appropriate for southeast to south to south west and high solar altitude. View: Varies depending on the blade spacing and angle. Direct light diffusion: Hardly any Remark: Blade setting according to the purpose is important. Direct sunlight reflected on the top of blades enters the ceiling, brightening the room.
			**Horizontal blind** Direction/season/time: Works for all directions. View: Varies depending on the blade spacing and angle. Direct light diffusion: Slight, depending on the blade angle. Remark: Appropriate adjustment according to the outside conditions and purpose is important. Possible to guide the light reflected on the blades to the ceiling.
			**Bamboo blind** Direction/season/time: Appropriate for east and west and low solar altitude. View: Not very good Direct light diffusion: Yes Remark: Inexpensive and easy to install. Visual effects of natural material.
			**Roller blind** Direction/season/time: Appropriate for east and west and low solar altitude. View: Not very good, although depends on the material. Direct light diffusion: Very high, although depends on the material. Remark: Effective for blocking the view from outside. Appropriate for creating a soft light environment.
			**Overhang** Direction/season/time: Appropriate for south and high solar altitude. View: Good Direct light diffusion: None Remark: Inappropriate for blocking the afternoon sun as direct sunlight easily enters when the solar altitude is low.
			**Awning** Direction/season/time: Appropriate for any directions except north. View: Good Direct light diffusion: Hardly any, although depends on the material. Remark: Works even when the solar altitude is low unlike the fixed overhang. Some materials allow diffuse transmission of direct sunlight.

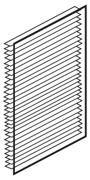
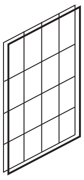
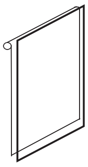
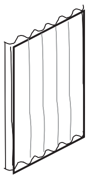
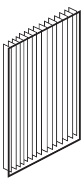
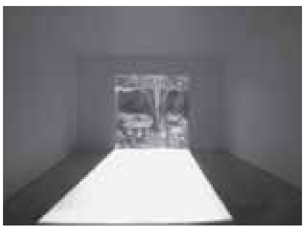
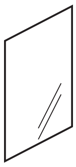
with decorative openings as examples, it explains the methods for reducing the contrast in lighting between openings and surroundings using sun control devices to prevent the room from looking dark.

Regarding the ease of adjusting the light environment, auxiliary devices installed inside such as indoor horizontal blinds have superior performance. On the other hand, outside devices provide a higher solar shading effect and overhangs and blocks with decorative openings are more effective, considering their ability to protect against heavy wind and rain.

It is necessary to understand the characteristics of each sun control device and select the one that suits the period of use, direction to be installed and purpose.

Table 5 Characteristics of sun control devices 2 (installed inside)

High ▲ Solar shading effect ▼ Low

		**Horizontal blind** Direction/season/time: Works for all directions. View: Varies depending on the blade spacing and angle. Direct light diffusion: Slight, depending on the blade angle. Remark: Appropriate adjustment according to the outside conditions and purpose is important. Easy to adjust the blade angle, roll up, etc.
		**Paper sliding door** Direction/season/time: Appropriate for low solar altitude. View: Not good Direct light diffusion: Very high, although slightly varies depending on the material. Remark: Effective for blocking the view into the building, but hard to see the outside environment. Can create a soft light environment.
		**Roller blind** Direction/season/time: Appropriate for east and west and low solar altitude. View: Not very good, although depends on the material. Direct light diffusion: Very high, although depends on the material. Remark: Effective for blocking the view from outside. Appropriate for creating a soft light environment. Easy to roll up and down for adjustment.
		**Sheer curtain** Direction/season/time: Appropriate for low solar altitude. View: Depends on the material. Direct light diffusion: Depends on the material. Remark: Material selection is important according to the purpose, such as whether the priority is on the view or glare control.
		**Vertical blind** Direction/season/time: Works for all directions. View: Varies depending on the blade spacing and angle. Direct light diffusion: Slight, depending on the blade angle. Remark: Appropriate when direct sunlight enters the room with an angle against the window.
		**None** Direction/season/time: View: Good Direct light diffusion: None Remark:

■Some photos in Tables 4 and 5 are available in color in Appendix 2 on p.390.

3

Chapter 3
Natural Energy Application Technology (Elemental Technology Application Method 1)

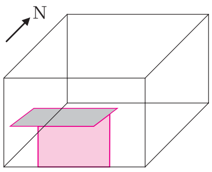
1) Sun control effect of overhangs

Overhangs often used in hot humid regions have a different solar shading effect depending on the depth. The sun control effect also depends on the overhang depth. However, unlike solar shading, this effect varies depending on the perception of light.

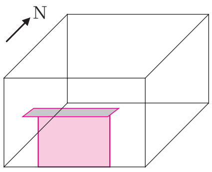
Key Point

Differences in indoor light condition due to depth of overhangs

- The luminance distribution diagrams representing the condition of indoor light indicate the differences in effects of overhangs.
- Fig. a and Fig. b show the differences in perception of light from the south-facing opening at noon according to the depth of the overhang. Since the solar altitude is high, the deep overhang of Fig. b creates a large shady area and the glare (contrast) of the opening is small.
- Fig. c and Fig. d show the differences in perception of light from the east-facing opening at 9:00 a.m. according to the depth of the overhang. Since the solar altitude is lower than that of noon, the sun shines on the floor, but the deep overhang of Fig. d can reduce the glare (contrast) by decreasing the glare area.



Deep overhang



Shallow overhang

■Conditions (Naha)
Target room:
South-facing first floor (a, b); east-facing first floor (c, d)
4 m x 4 m x 2.5 m (ceiling height)
Window dimensions:
200 cm x 200 cm
Overhang depth:
80 cm (a, c); 150 cm (b, d)
Season and time:
Spring and fall equinox at noon (a, b); 9:00 a.m. (c, d)

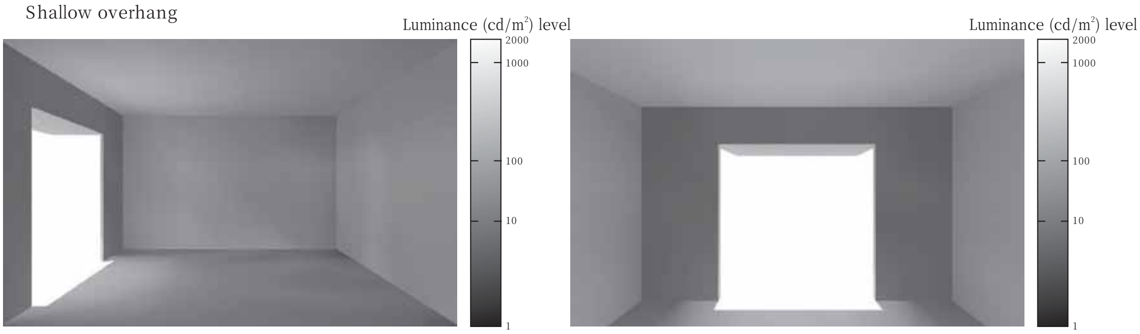


Fig. a Shallow overhang (South-facing opening, noon)
Light on side and opening directions (luminance distribution)

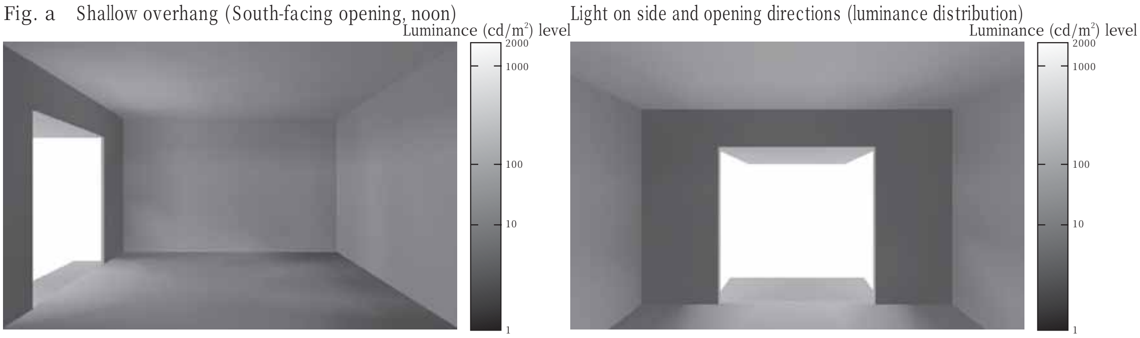


Fig. b Deep overhang (South-facing opening, noon)
Light on side and opening directions (luminance distribution)

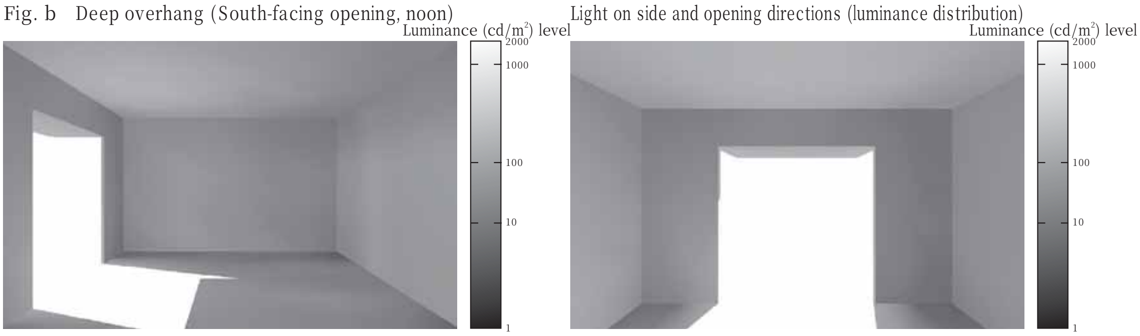


Fig. c Shallow overhang (East-facing opening, 9:00 a.m.)
Light on side and opening directions (luminance distribution)

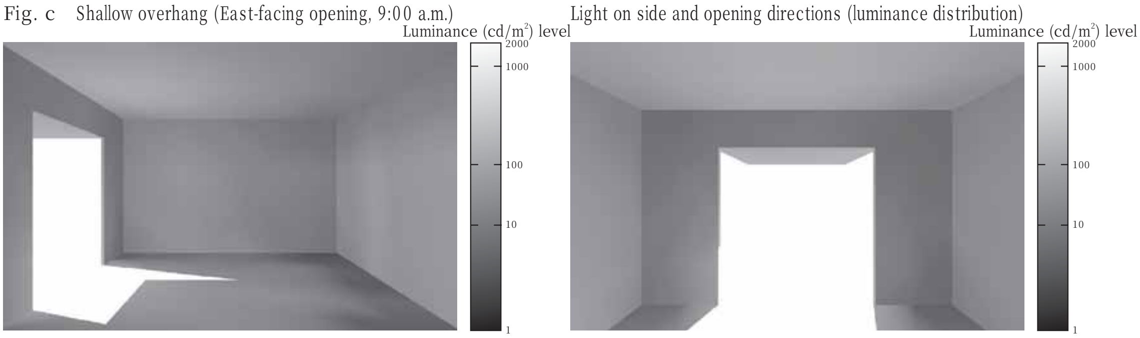


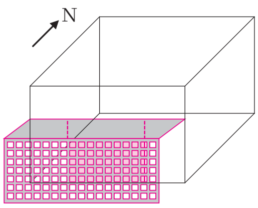
Fig. d Deep overhang (East-facing opening, 9:00 a.m.)
Light on side and opening directions (luminance distribution)

2) Sun control effect of blocks with decorative openings

Blocks with decorative openings are frequently used in Zone VI in order to help protect against heavy wind and provide aesthetic landscaping. Although these blocks also work as an effective solar shading device against the afternoon sun, a combined use with overhangs can achieve a significant effect in terms of sun control.

Key Point

Indoor light condition provided by blocks with decorative openings



- The luminance distribution diagrams expressing the condition of indoor light below shows the effect of blocks with decorative openings.
- Fig. a and Fig. b show the differences in perception of light from the west-facing opening at 3:00 p.m. with or without blocks with decorative openings.
- In Fig. a, which has an overhang but none of these blocks, the afternoon sun directly shines into the room and the opening and wide area of the floor seem too bright. Even though a sufficient amount of daylight is actually secured, the room seems relatively dark.
- In Fig. b, which has both an overhang and blocks with decorative openings, the afternoon sun is softened by the sun control effect of the blocks and the amount of daylight is limited. However, as the contrast in lighting is reduced the back of the room does not seem very dark.
- In short, blocks with decorative openings effectively prevent the back of the room from looking dark by securely blocking solar radiation including the afternoon sun.

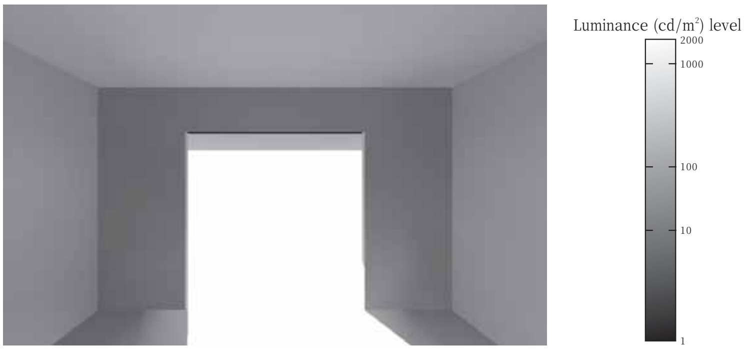


Fig. a
Indoor light condition without blocks with decorative openings (luminance distribution)
Luminance (cd/m2) level

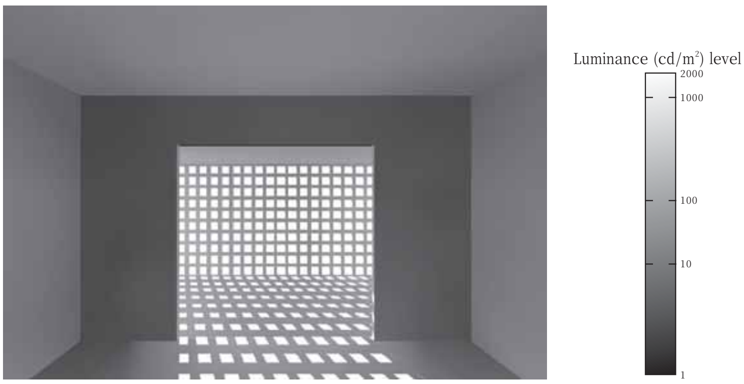


Fig. b
Indoor light condition with blocks with decorative openings (luminance distribution)
Luminance (cd/m2) level

■Conditions (Naha)
Target room: West-facing first floor 4 m x 4 m x 2.5 m (ceiling height)
Window dimensions: 200 cm x 200 cm
Size of decorative openings of blocks: 16 cm x 16 cm x 15 cm (thickness)
Overhang depth: 150 cm
Blocks with decorative openings/overhang width: 4 m
Reflectance: Ground 0.2; back of overhang/blocks with decorative openings 0.3; ceiling 0.7; wall 0.5; floor 0.3
Season and time: Spring and fall equinox; 3:00 p.m.

* Hiding one of the figures (Fig. a or Fig. b) makes the effect of contrast in lighting between the opening and the room easier to see

Comment ● The principle of *hiruandon* which means unnecessary lighting during the day

There is a term ***hiruandon*** (literally, a paper shade lamp in daylight) in Japanese. This is a famous reference to the outer guise of Oishi Kuranosuke, who was the leader of forty-seven masterless samurai whose story is the national epic of Japan . It is used to ridicule someone who is dull or useless, such as "You are like a paper shade lamp in broad daylight". Why is ***hiruandon*** (daytime lighting) useless? That is because the daylight is bright and a paper shade lamp is completely ineffective and wasteful. But think about this: the same amount of light is coming from the paper shade lamp regardless of day or night. Why is the same amount of light effective at night but not in the daytime?

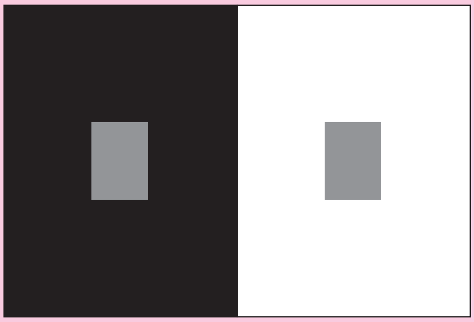


Fig. Simultaneous contrast of brightness

The reason for this is that the effectiveness of light depends on its relationship with the surroundings as well as the amount of light. There is hardly any light around the paper shade lamp at night, but a large amount of light exists during the day. The above figure represents the condition of a paper shade lamp at night and in the daytime. The light emitted from the paper shade lamp is shown in gray, the surrounding light at night is in black and the surrounding light in the daytime is in white. Please look closely at this figure. Don't the small gray squares look different?

This figure expresses the "simultaneous contrast of brightness" phenomenon which is determined by the contrast between the "brightness" of a particular color and its surroundings. In the case of light surrounding the paper shade lamp, the difference between the night and day is far greater than that of the black and white area in the figure. Moreover, since the area around the lamp is much larger this effect is further heightened.

Taking this concept a step further, you can see that this figure is the same as when looking at the window from inside the room in terms of perception of light (Photo 1). If there is no light in the room, the window looks very bright and dazzling. On the contrary, since the window is very bright the area around the window looks dark even though there is light in the room.

Because of this, we tend to turn on a paper shade lamp, i.e. lighting, in order to add light to the dark area even in the daytime (Photo 2). This results in daytime lighting in which we attempt to make the dark area look brighter but it is actually waste of lighting considering the presence of large amount of light.

The sun control and other daylight utilization methods explained in this document reduce the contrast in lighting. These methods are very effective in preventing daytime lighting by keeping the room from looking dark as well as in reducing lighting energy in hot humid regions where the sunlight is so intense that windows look too bright.

Photo 1 Stark contrast in lighting between window and inside of room

Photo 2 Example of how impression of darkness created by contrast with windows can result in use of daytime lighting

Method 2: Indirect daylight utilization methods (daylight guiding methods)

- By guiding the light received from an opening into the back of the room (daylight guiding), brightness and other visual comforts can be increased. Even if there is a house that cannot achieve sufficient daylighting, daylight guiding makes the optimum use of the light obtained by daylighting.
- Daylight guiding methods consist of three methods: daylight guiding using spatial structures, reflection on finished surfaces, and devices. The desirable priorities are that architectural daylight guiding using spatial structures and interior finish are fully examined before adopting daylight guiding using devices to supplement insufficient lighting.
- A combination of daylight guiding methods may further increase the effects.

1. Daylight guiding using spatial structures

Daylight guiding using spatial structures refers to the creation of a passage of light through ingenuity in the floor and elevation planning.

1) Daylight guiding using transom windows and other means

A transom windows that is installed in the upper partition wall as a cross ventilation opening can also guide light into the next room with poor daylighting conditions. As the lower area of the transom windows is covered by the wall, which blocks a view, it can introduce light into the room while maintaining an independent space. Moreover, in hot humid regions where the solar altitude is high, a daylight guiding effect tends to be low and it is important to efficiently use the light reflected in the room which is discussed later in this section.

Daylight guiding using transom windows is also effective in designing exterior openings for non-habitable rooms that tend to be one step behind. Even when it is difficult to plan windows in all the non-habitable rooms such as washing rooms, toilets and bathrooms, sufficient daylighting in one of these rooms and daylight guiding using transom windows in the surrounding spaces creates pleasant spaces with natural lighting.

Similar to transom windows, an efficient use of glass blocks and glass screens in the partition wall guides daylight into the entire space, achieving the same effects.

■Conditions (Naha)
Target room:
North-south consecutive rooms on the first floor
South room:
4 m x 4 m x 2.5 m (ceiling height)
South room window dimensions:
200 cm x 200 cm (patio door)
North room:
4 m x 4 m x 2.5 m (ceiling height)
North room window dimensions:
200 cm x 100 cm (waist-level window)
Dimensions of transom window between north and south rooms:
200 cm x 50 cm
Season and time:
Winter solstice; noon

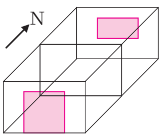
Key Point

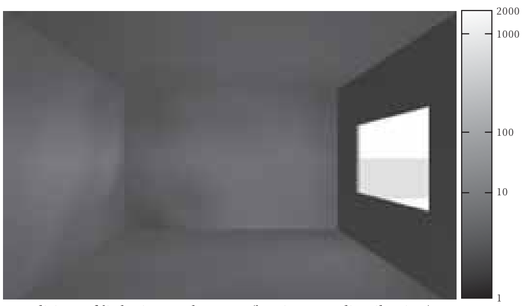
Daylight guiding effects of transom windows

- The difference in the condition of light in the north room and the floor illuminance (including the south-facing room) with or without a transom window is shown below for reference purposes.
- Although the indoor floor brightness is hardly different between the two rooms, areas in the ceiling and walls that are related to the perception of light look brighter when there is a transom window.

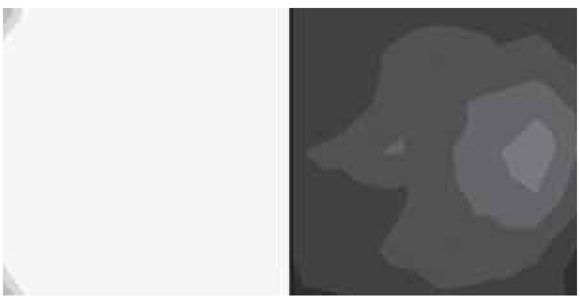
Luminance (cd/m²) level

Fig. a
Without transom window
(Winter solstice, noon)





Condition of light in north room (luminance distribution)



Floor illuminance distribution (left: south room; right: north room)

Illuminance (lx) level

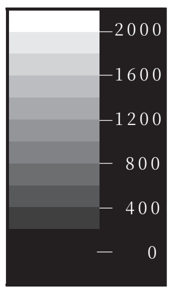
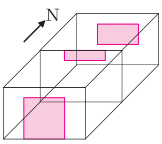
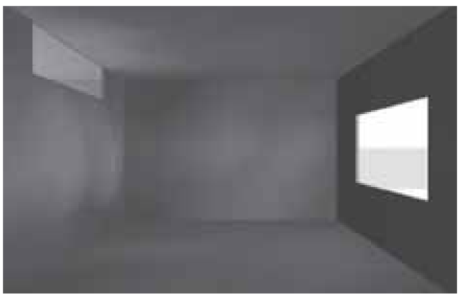


Fig. b
With transom window
(Winter solstice, noon)





Condition of light in north room (luminance distribution)

Floor illuminance distribution (left: south room; right: north room)

2) Daylight guiding using light wells

Planning a light well to create a passage of light through from the upper to the lower floor of the house can guide the light into the lower floor (Fig. 5). The effect of the light well can be obtained even in the staircase by taking into account the light transmittance and reflectance of components. A light well is used in combination with top side windows and other means (skylights are also possible in Zone V). Since it is not direct daylighting through top side windows and other means, a solar shading effect can be expected to some extent.

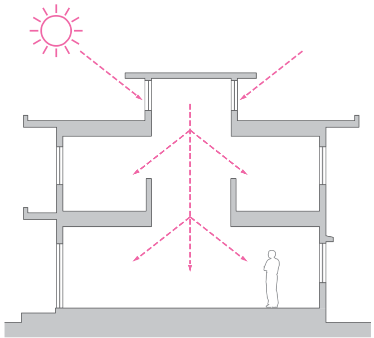


Fig. 5 Example of light well planning

2. Daylight guiding using reflection on finished surfaces: Reflection on outside surfaces, back of eaves and indoor surfaces

Daylight guiding using reflection on finished surfaces is a method used often in traditional Japanese buildings and can be effectively applied to modern houses. The fundamentals of this method are that light reflected on the ground is reflected further on the back of eaves and ceiling around the openings in order to guide the light into the back of the room. However, as the reflection of the light is strong and windows become too bright in hot humid regions, thorough solar shading and sun control are prerequisites.

Fig. 6 is an actual example of effective light guiding which prevents solar radiation and glaring of the openings by skillfully using the reflection on the outside surfaces as well as on the finished surfaces such as the back of the overhang and ceiling. Amahaji (semi-outdoor space with a deep overhang) works to efficiently guide the indirect daylight into the room.

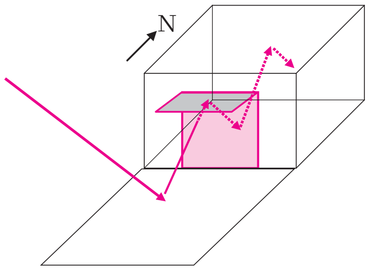
Fig. 6 Daylight guiding using reflection on ground, back of eaves and ceiling by means of amahaji

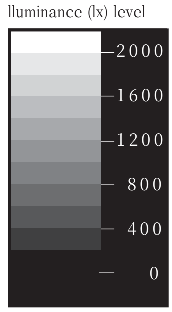
If it is desired to open windows for cross ventilation and view, a combination of the outside surfaces with low reflectance and indoor finished surfaces with high reflectance is an extremely effective method for daylight guiding which makes the most of the reflection on finished surfaces.

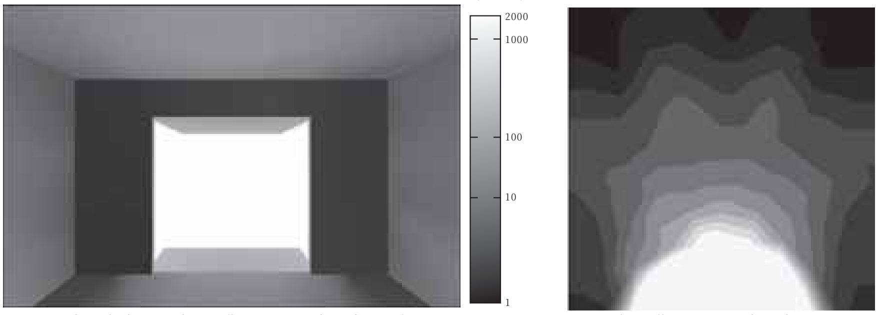
Key Point

Daylight guiding effect using outside surfaces with low reflectance and indoor finished surfaces with high reflectance

- The indoor light condition (luminance distribution) and floor illuminance distribution of the outside surfaces and indoor finished surfaces with different reflectances are shown as a reference.
- When both the ground and indoor reflectance are low (Fig. a), the entire room looks dark (low luminance distribution) and indoor light itself decreases (low illuminance distribution). On the other hand, when the ground reflectance is low but the indoor reflectance is high (Fig. b), the room seems bright (high luminance distribution) while somewhat controlling the contrast with the opening in terms of perception of light and the light reaches the back of the room (high illuminance distribution).
- When the ground reflectance is high but the indoor reflectance is low (Fig. c), the contrast is the greatest and the window seems too bright (high luminance distribution), but the light does not reach as further into the room as Fig. b (low illuminance distribution).
- When both the ground and indoor reflectance are high (Fig. d), the entire room looks bright and the light fully reaches the back of the room (high illuminance distribution), but the entire room seems extremely bright and solar radiation is intense.
- From the above, a combination of the outside surfaces with low reflectance and indoor finished surfaces with high reflectance (Fig. b) is most effective.

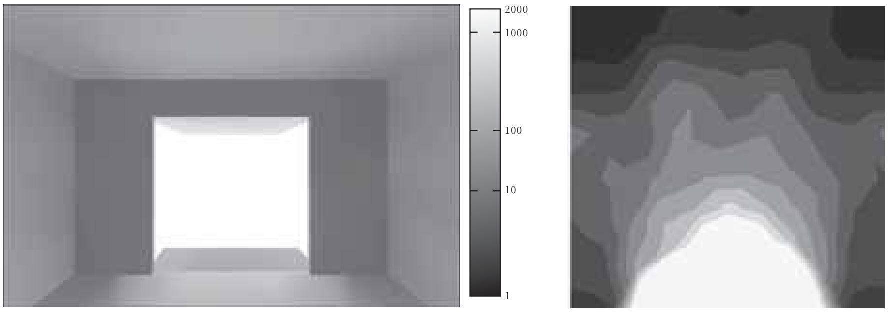






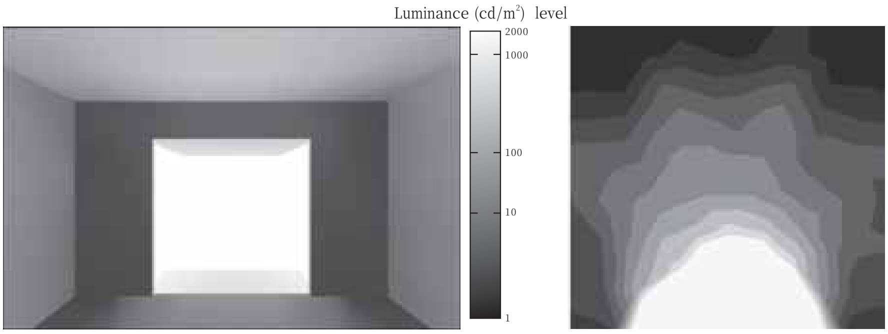
Indoor light condition (luminance distribution)   Floor illuminance distribution

Fig. a When both ground and indoor reflectance are low



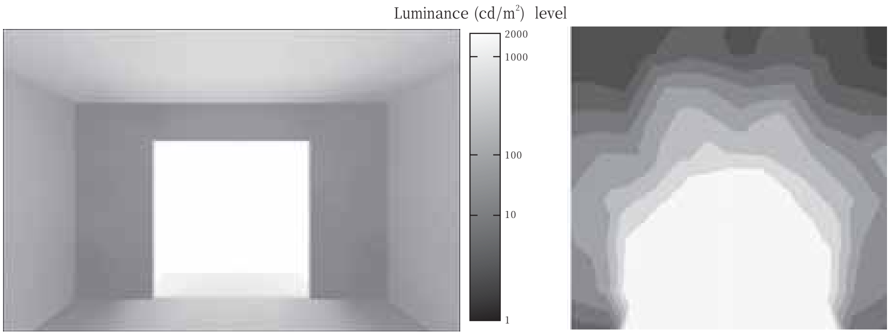
Indoor light condition (luminance distribution)   Floor illuminance distribution

Fig. b When ground reflectance is low but indoor reflectance is high



Indoor light condition (luminance distribution)   Floor illuminance distribution

Fig. c When ground reflectance is high but indoor reflectance is low



Indoor light condition (luminance distribution)   Floor illuminance distribution

Fig. d When both ground and indoor reflectance are high

■Conditions (Naha)
Target room: South-facing first floor
4 m x 4 m x 2.5 m (ceiling height)
Window dimensions: 200 cm x 200 cm
Overhang depth: 150 cm
Season and time: Spring and fall equinox; noon

a. Reflectance (low - low)
Outside surface: 0.2; back of overhang: 0.2; ceiling: 0.5; wall: 0.3; floor: 0.1

b. Reflectance (low - high)
Outside surface: 0.2; back of overhang: 0.8; ceiling: 0.9; wall: 0.7; floor: 0.5

c. Reflectance (high - low)
Outside surface: 0.8; back of overhang: 0.2; ceiling: 0.5; wall: 0.3; floor: 0.1

d. Reflectance (high - high)
Outside surface: 0.8; back of overhang: 0.8; ceiling: 0.9; wall: 0.7; floor: 0.5

The table below shows the reflectance of major finishing materials (including outside surfaces) for reference purposes.

Reference
Table: Reflectance of major finishing materials

Component	Finishing materials	Reflectance (%)	Component	Finishing materials	Reflectance (%)
Ceiling and wall	Japanese cypress (new)	55～65	Floor	*Tatami* mat (new)	50～60
	Cedar (new)	30～50		Light-colored vinyl tile, Astile	40～70
	Colored lacquer, varnish	20～40		Dark-colored vinyl tile, Astile	10～20
	Light-colored wallpaper, typical *fusuma* paper.	40～70		Light-colored flooring	20～30
	Dark-colored wallpaper, typical *fusuma* paper	20～40		Dark-colored flooring	10～20
	White plaster wall (new)	75～85	Outside surface	White gravel	20～40
	Typical white wall	55～75		Gravel, concrete, pavement stone	15～30
	Earth wall top coat , typical light-colored wall	40～60		Asphalt pavement	15～20
	Typical dark-colored wall	15～25		Lawn (grass)	5～15
	Japanese sand wall (green and other dark colors)	5～15		Earth (wet earth)	3～7

3. Daylight guiding using devices

The daylight guiding using devices consists of two methods. The first method reflects the light at the upper surface of a light shelf installed above the window and guides the light into the back of the room using the reflection from the ceiling. The second method also utilizes the reflection from the ceiling in the same manner by using sun control devices installed on windows (p.074) that have blades with a high reflecting effect (e.g. louvers).(In Zone V, the use of mechanical devices, e.g. light ducts, is also effective as it guides the light into the areas where the light normally does not reach (See p.083).)

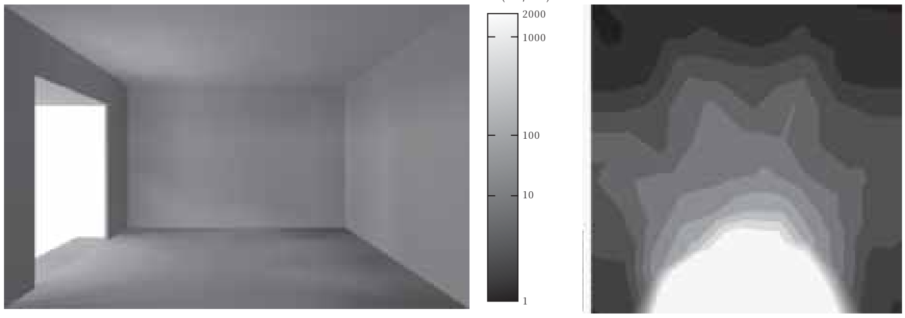
It is desirable that the light shelf is installed at a higher position than the eye level in order to secure a view. When designing a house with a low ceiling, it is necessary to incline the ceiling so that it is higher toward the openings. Employing such techniques for an opening in a living room with a relatively high ceiling is efficient as it enables a large opening above the light shelf.

Key Point

Daylight guiding effects of light shelves

- The differences in the indoor light condition (luminance distribution) and floor illuminance distribution with or without a light shelf are shown as a reference.
- When there is a light shelf, the upper surface of the light shelf and the ceiling have a high reflectance and the entire room is very bright.
- A light shelf is a type of overhang designed to guide direct sunlight to the ceiling. By installing a window above the light shelf, the direct sunlight is reflected on the upper surface of this overhang, entering the ceiling and expanding into the back of the room. If there is no overhang, the direct sunlight enters only the floor near the window, causing a stark contrast in brightness with the back of the room. However, an ordinary overhang blocks direct sunlight only and does not solve the contrast in brightness between the near the window and the back of the room. Light shelves can guide direct sunlight to the ceiling and brighten the back of the room, reducing the contrast between the near the window and the back of the room and creating a pleasant light environment.
- Since light shelves increase the entry of solar radiation heat, it is required to adopt proper solar shading in the summer, such as installing an overhang or blind to the window above the light shelf.

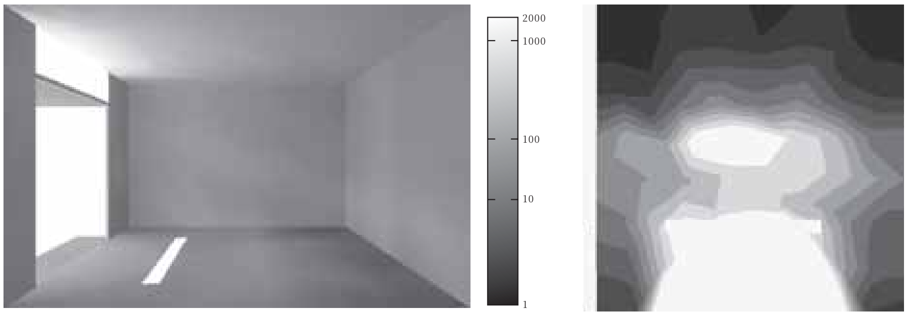
Luminance (cd/m²) level



Indoor light condition (luminance distribution)

Floor illuminance distribution

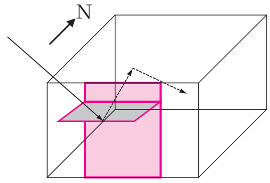
Fig. a　Without light shelf



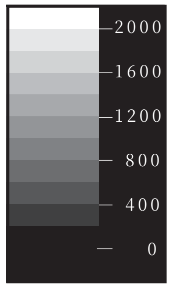
Indoor light condition (luminance distribution)

Floor illuminance distribution

Fig. b　With light shelf



Illuminance (lx) level



■Conditions (Naha)
Target room: South-facing first floor
4 m x 4 m x 2.5 m (ceiling height)
Window dimensions:
200 cm x 200 cm (patio door);
200 cm x 50 cm (high window)
Light shelf depth: 150 cm
Reflectance: top of light shelf 0.8;
ceiling 0.9
Season and time:
Spring and fall equinox; noon

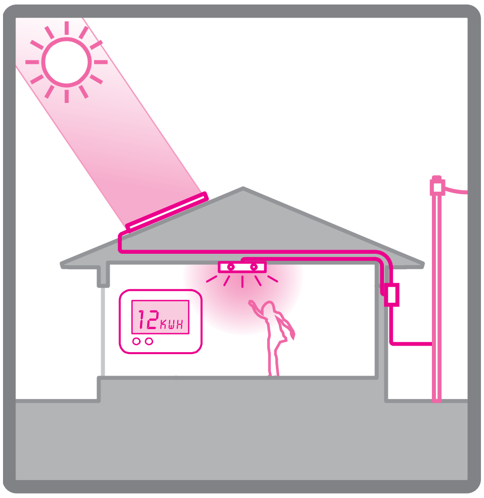
Comment ● Possibility of new daylight guiding methods including light ducts in hot humid region (Zone VI)

There are new daylight utilization methods for the areas where a daylighting path cannot be secured, such as a light duct system which guides light into the building by combining a light collector with ducts made of high reflectance materials, and a method which guides light into the building by combining a sun-tracking light collector and optical fibers. These methods are very effective when a light path can be relatively flexibly designed and daylight cannot be utilized by other means. Photos below are an example of daylight guiding for a hallway, where daylight is unavailable, and an example of introducing daylight by vertically guiding it into a room with a side window.

However, a very high daylight guiding effect also means a high solar heat gain. In Zone VI, one of the hot humid regions, it is necessary to decrease the area for collecting light, such as skylights, in order to reduce solar radiation. Moreover, due to some cost related issues for small houses, daylight guiding is not adopted except in some large-scale spaces, such as the light duct system seen in Citizen's Square within the Okinawa prefectural government building.

Therefore, technologies which can secure a wide radiating area and achieve sufficient indoor light conditions using a small light collecting area are required for Zone VI. If such technologies are developed in the future, the light duct system and other technologies will also be useful in Zone VI.

3.3 Photovoltaic Power Generation (Sunlight Utilization 2)



Photovoltaic power generation is a system that supplies the electricity consumed in a house by generating electricity using sunlight during the day. Although this requires electricity to be purchased during the night, any surplus electricity produced during the day can be sold. This improves the total power balance thereby enabling an extremely low running cost.

3.3.1 Purpose and Key Points of Photovoltaic Power Generation

- A type of photovoltaic power generation system used in houses is called a grid-connected power system (which buys and sells electricity in connection with commercial electric power systems). The amount of photovoltaic power generation largely varies depending on the weather and time of day, but it is possible to purchase electricity during the night and sell it during the day so that running costs can be reduced.
- Photovoltaic power generation provides the largest amount of power generation during the daytime in the summer when the load at power stations is the highest and sells the surplus electricity. This leads to a reduction of the load at power stations and contributes to the reduction of environmental impact from a macro perspective.
- Since solar cells used in the photovoltaic power generation system do not have a driving part it does not require any consumable supplies. The typical service life of solar cells is over 20 years for a power module that has a surface protected by tempered glass, which is extremely long compared to other equipment and devices.
- The amount of power generation depends on the site conditions, such as the duration of shady hours, and careful consideration is required for planning.
- Various verification studies are currently being conducted regarding the age deterioration of the power generation performance and efficiency of photovoltaic power generation systems (e.g. power conditioners and power modules); however such a tendency has not been identified.
- Photovoltaic power generation system distributors generally set a design life of approximately 15 years for power modules and approximately 10 years for power conditioners and provide approximately 10 years of warranty for the entire system.

* Even though the definition of design life varies among manufacturers, 90% of the nominal value is guaranteed in many cases.

3.3.2 Energy Conservation Target Levels for Photovoltaic Power Generation

The energy conservation target levels for photovoltaic power generation refer to the following levels 1 and 2 and indicate the reduction in annual primary energy consumption per household.

Level 0	:	No photovoltaic power generation
Level 1	:	Reduction in annual primary energy consumption; 33.7 GJ (approx. 3 kW of solar cell capacity)
Level 2	:	Reduction in annual primary energy consumption; 45.0 GJ (approx. 4 kW of solar cell capacity)

- The reduction here refers to the amount of photovoltaic power generation, i.e. the amount of power generation which corresponds to the capacities of solar cells (approximately 3 kW and 4 kW) that are assumed for levels 1 and 2. However, with regular residential photovoltaic power generation systems, any surplus electricity generated during the day is sold and electricity is bought during the night.

- The reduction (amount of power generation) varies from region to region and the previously-mentioned data are the values for Naha (photovoltaic panels with a tilt angle of 20°). See Table 1.

3.3.3 Photovoltaic Power Generation

1. Regional solar radiation level

The amount of sunlight (amount of solar radiation) influences the annual photovoltaic power generation. In other words, compared to the Seto Inland Sea and Pacific side of Japan, which has a large number of sunny days, the Sea of Japan side provides slightly lower power generation. It is said that, in areas such as Sapporo in Hokkaido, where there is no rainy season, the power generation is higher than Tokyo.

However, the regional difference in the power generation is approximately 10%, which means photovoltaic power generation can be adopted in any region in Japan. This is related to the fact that photovoltaic power generation is not influenced by outside air temperature unlike solar heat utilization.

Fig. 1 shows normal values of the annual mean global solar radiation and Table 1 lists examples of annual power generation in major cities (when a system with 3 kW and 4 kW of solar cell capacity is installed).

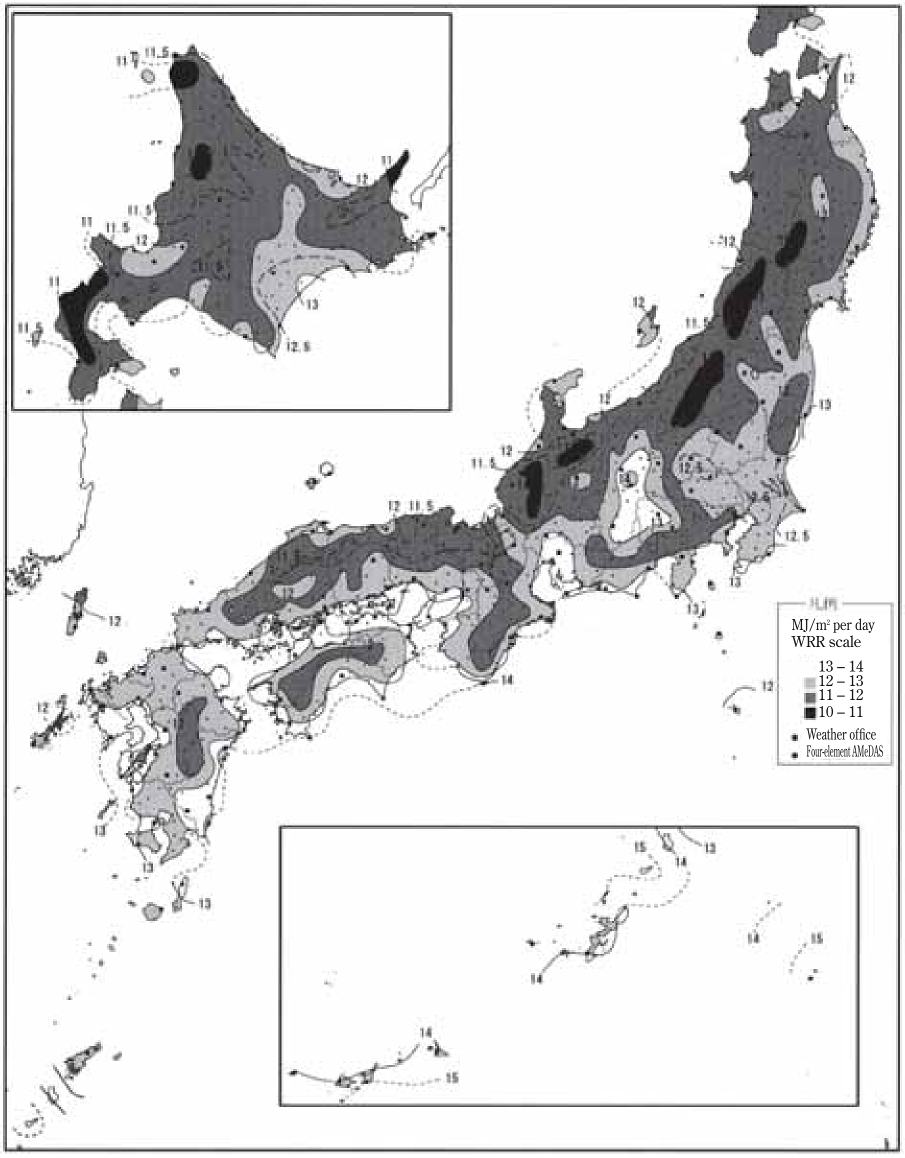


Fig. 1 Normal values of annual mean global solar radiation (1961 - 1990) (Unit: MJ/m² per day)
Source: The National Solar Radiation Data Map (of Japan), New Energy and Industrial Technology Development Organization (NEDO), 1998

Table 1 Examples of annual power generation in major cities
(Unit: GJ; primary energy conversion value)

City	Tilt angle	Solar cell capacity 3 kW	4 kW
Kochi	30 °	35.3	47.1
Miyazaki	30 °	34.9	46.5
Kagoshima	30 °	32.7	43.6
Naha	30 °	33.3	44.3
Naha	20 °	33.7	45.0
Miyakojima	30 °	34.0	45.3
Miyakojima	20 °	34.7	46.3
Ishigakijima	30 °	33.6	44.8
Ishigakijima	20 °	34.2	45.6
Tokyo (reference)	30 °	30.6	40.8
Sapporo (reference)	30 °	31.9	42.6

Note 1: Using the Residential Solar Power Generation Simulation (June 2008) available on the Kyocera's website, the calculation was performed for a system with a capacity of 3.15 kW under the conditions of the direction (due south) and the tilt angle (30° or 20°), which was translated into 3 kW and 4 kW based on a simple ratio conversion.

Note 2: Figures in Table 1 are primary energy conversion values, and this can be converted to power generation (secondary energy conversion values; unit: kWh) by using the following formula:

$$1GJ = \frac{1}{9.76}\ MWh = \frac{1}{9.76} \times 1000kWh = 102.4kWh$$

For example, 33.7 GJ for Naha (20°) using a 3 kW solar cell can be converted as shown below

$33.7 \times 102.4 = 3450kWh$

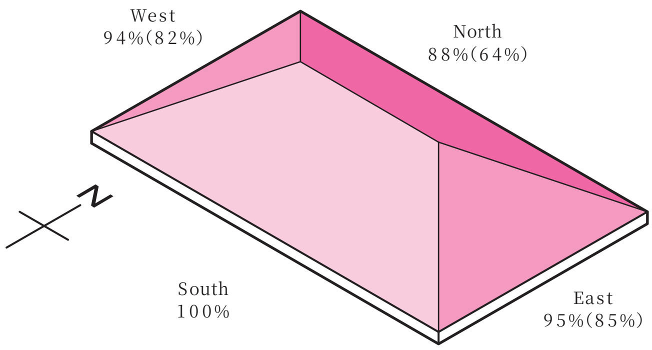
2. Direction of installation and tilt angle

The sunlight utilization efficiency depends on the installation direction and tilt angle of photovoltaic panels but it is also largely influenced by the latitude of the building site (Fig. 2, Table 2).

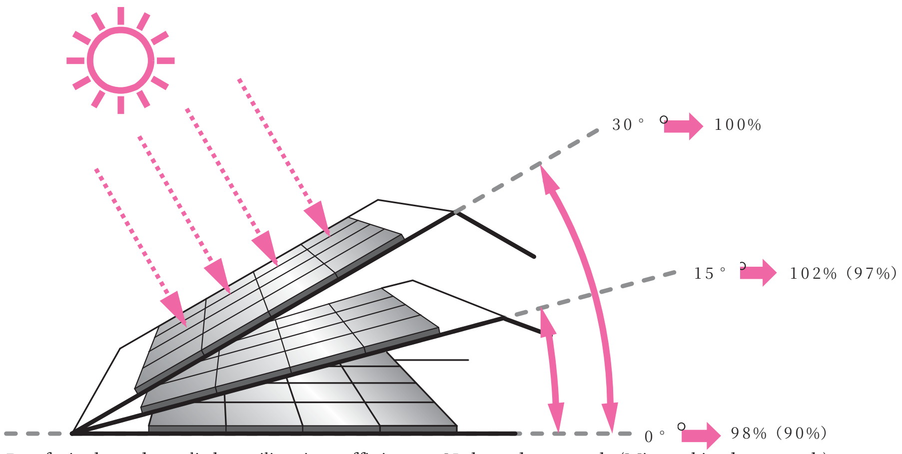
In Zone VI, the difference in utilization efficiency due to the direction of installation is not very significant. For example, in Naha, where the utilization efficiency is 100% for the system installed in due south, the sunlight utilization efficiency is 94 – 95% for east and west and approximately 88% for north installation (when the tilt angle is 20° on a roof). Additionally, with regard to the difference in utilization efficiency due to the tilt angle, the total annual power generation is predicted to become high with a tilt angle of approximately 20° when the system is installed on the south side of the roof. Even when the system is installed on a leveled surface (tilt angle of 0°), the decrease of power generation is estimated to be small.

On the contrary, in Zone V, there is a certain difference in power generation due to the direction of installation. For example, in Miyazaki, while the utilization efficiency is 100% for due south installation, it is approximately 82 – 85% for east and west and approximately 64% for north installation (when the tilt angle is 30° on a roof). This difference in power generation due to the direction is more significant when the tilt angle is larger. Moreover, regarding the difference in utilization efficiency due to the tilt angle, the efficiency becomes the highest with a tilt angle of approximately 30° when the system is installed on the south side of the roof. When this value is regarded as 100%, it is approximately 98% at a tilt angle of 20° and approximately 90% on a leveled surface. This difference is not as significant as that of the direction.

As described above, attentions should be paid to the direction and tilt angle of the panels when installing photovoltaic panels in high latitude regions. On the other hand, in low attitude regions, the roof pitch and direction can be relatively flexibly designed, as long as a sharp tilt angle is avoided, and it may be possible to install photovoltaic panels on the roof of preferred design.



Direction of installation and sunlight utilization efficiency: Naha 20° (Miyazaki 30°)



Roof pitch and sunlight utilization efficiency: Naha - due south (Miyazaki - due south)

Fig. 2 Direction of installation and tilt angle of photovoltaic panels

Table 2 Comparison of power generation by direction and tilt angle (Unit: %)

City	Upper: Latitude Lower: Longitude	Sunlight utilization efficiency by direction				Sunlight utilization efficiency by tilt angle (due south)					
		Due south	Due east	Due west	Due north	0 °	15 °	30 °	45 °	60 °	90 °
Kochi	33.6 133.6	100	83	80	60	88	97	100	98	91	63
Miyazaki	31.9 131.4	100	85	82	64	90	97	100	97	88	60
Kagoshima	31.6 130.6	100	84	83	66	91	97	100	97	88	59
Naha	26.2 127.7	100	95	94	88	98	102	100	93	83	52
Miyakojima	24.8 125.3	100	95	95	90	98	102	100	94	81	49
Ishigakijima	24.3 124.2	100	94	97	90	98	102	100	92	81	48
Tokyo (reference)	35.7 139.8	100	79	79	57	88	97	100	98	91	64

* The table above shows the calculation results based on the expanded AMeDAS weather data (1981 - 2000) issued by the Architectural Institute of Japan. The sunlight utilization efficiency by direction column shows the values calculated when the tilt angle is 20° for Naha, 15° for Miyakojima and Ishigakijima, and 30° for other cities. The utilization efficiency by tilt angle column shows the values calculated when the direction of installation is due south.

3. Local conditions

The outside brightness of the direct solar radiation on a sunny day is at least 15,000 lux, with 7,000 – 8,000 lux on a cloudy day and approximately 3,000 lux in the shade. Photovoltaic power generation is possible on a cloudy day but is impossible in the shade. Therefore, power generation may be lower than the estimated annual power generation shown in Table 1 on p.085 at sites with short sunshine hours, such as north-facing slopes and mountainous areas. It is necessary to check the seasons and time of day when the site is covered in shade and subtract the hours in which power generation is impossible.

Some sites such as mountainous areas are covered in shade in the morning and evening when the power generation efficiency is not high, so the effect may not be significant. However, in the dense urban areas, it is possible that high-rise buildings will be built in the adjacent area causing shade during hours when the power generation efficiency is high. Therefore, future development plans for the surrounding area should be also taken into consideration.

4. Cautionary advice on installing photovoltaic panels

When installing a photovoltaic panel on the roof in regions with heavy wind such as Okinawa, caution is required to prevent damage caused by storms. Consider the use of photovoltaic panels integrated into the roof or use ingenuity such as installing the panels flat on the deck roof. When using a frame, it is necessary to securely attach it to the roof (building envelope) with anchors or other means as well as to tightly fasten the main unit to the frame with bolts or other means. In regions where salt damage is a concern, rustproofing of metal parts such as frames and bolts is essential.

3.3.4 Test Calculation of Photovoltaic Power Generation Costs

Under the following conditions, power generation simulation was performed and calculation was conducted for Naha (Zone VI) and Miyazaki (Zone V) in order to determine the number of years it will take to recover the initial costs of installation (Table 3, Fig. 3 and 4).

Table 3 Conditions of simulation

Prerequisites	Solar cell capacity*: 3 kW (test calculation results f or an installation area of 21.9 – 23.6 m2 at 3.15 kW converted to 3 kW) Rated capacity of power conditioner: 4 kW Solar radiation data: Naha in Okinawa Prefecture, Miyazaki in Miyazaki Prefecture Data Creation and Research on Solar Radiation, NEDO and Japan Weather Association, March 1998 Module installation conditions: tilt angle; Naha 20°, Miyazaki 30°, angle of direction 0° (due south)
Conditions of test calculation	1) Loss due to increased element temperature (seasonal temperature loss): 10% (Dec. – Feb.); 15% (Mar. – May, Sep. – Nov.); 20% (Jun. – Aug.) 2) Loss rate due to wiring, soiled receiving surface, backflow preventing diode, etc.: 5.35% 3) Temperature correction factor of installation method: 1.00 (pitched roof) 4) Power conversion efficiency of power conditioner: 94.5% (replacement cost of the power conditioner is not included in this cost test calculation)

* The solar cell capacity of a system refers to a total output of the solar cell module calculated according to the Japanese Industrial Standards (JIS). The output during actual use (generated output) varies depending on the solar radiation intensity, installation conditions (direction, installation angle, surrounding environment), regional differences, and temperature conditions. The maximum generated output is 70 – 80% of the solar cell capacity due to loss caused by increased temperature and other factors.

1) Test calculation results for Naha

The calculation for Naha indicates the estimated annual power generation to be 3,430 kWh (33.7 GJ).

The following shows the conversion of this amount into electricity costs (based on the unit price as of April 2009).

(1) 31.48 yen/kWh (hourly rate lighting service provided by the Okinawa Electric Power Company)
3,430 kWh x 31.48 yen/kWh = 107,976 yen

(2) 27.15 yen/kWh (meter rate lighting service provided by the Okinawa Electric Power Company)
3,430 kWh x 27.15 yen/kWh = 93,124 yen

Although not all the generated electricity is sold in reality, the calculation was performed to determine the number of years it will take to pay back the installation costs assuming that all the generated electricity is sold for simplification purposes.

If the installation cost is 2,753,000 yen (labor and material prices estimated under certain conditions; See p.356), the following number of years is required to pay back the initial costs:

(1) 2,753,000 yen / 107,976 yen = approximately 25.5 years (hourly rate lighting service provided by the Okinawa Electric Power Company)

(2) 2,753,000 yen / 93,124 yen = approximately 29.6 years (meter rate lighting service provided by the Okinawa Electric Power Company)

2) Test calculation results for Miyazaki

The calculation for Miyazaki indicates the estimated annual power generation to be 3,546 kWh (34.9 GJ).

The following shows the conversion of this amount into electricity costs (based on the unit price as of April 2009).

(1) 25.0 yen/kWh (Yoka Night 10 lighting service provided by the Okinawa Electric Power Company: rate for 80 kWh to 200 kWh)
3,546 kWh x 25.0 yen/kWh = 88,650 yen

(2) 25.0 yen/kWh (meter rate lighting service provided by the Kyushu Electric Power Company: rate for 120 kWh to 300 kWh)
3,546 kWh x 25.0 yen/kWh = 88,650 yen

Although not all the generated electricity is sold in reality, the calculation was performed to determine the number of years it will take to pay back the installation costs assuming that all the generated electricity is sold for simplification purposes.

If the installation cost is 2,546,000 yen (labor and material prices estimated under certain conditions; See

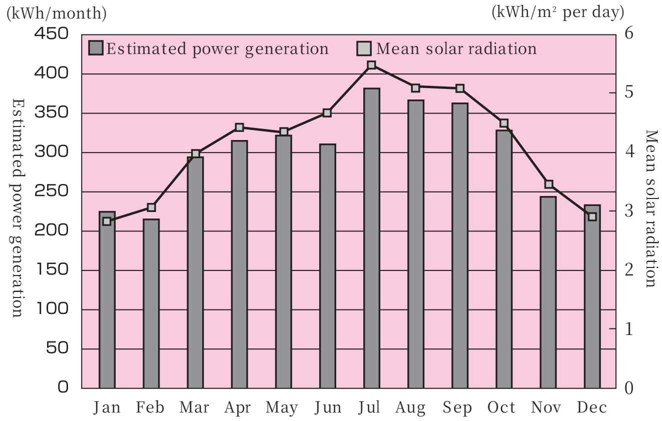


Fig. 3 Monthly mean solar radiation and simulation results of estimated photovoltaic power generation (Naha)

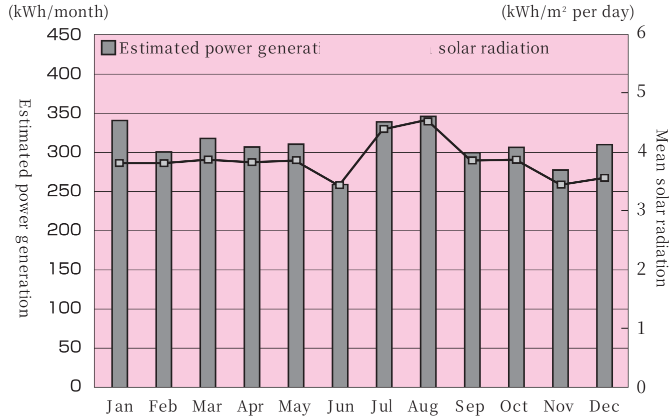


Fig. 4 Monthly mean solar radiation and simulation results of estimated photovoltaic power generation (Miyazaki)

p.362), the following number of years is required to pay back the initial costs:

(1) 2,546,000 yen / 88,650 yen = approximately 28.7 years (Yoka Night 10 lighting service provided by the Okinawa Electric Power Company: rate for 80 kWh to 200 kWh)

(2) 2,546,000 yen / 88,650 yen = approximately 28.7 years (meter rate lighting service provided by the Kyushu Electric Power Company: rate for 120 kWh to 300 kWh)

The above simulation results suggest that initial costs can be paid back in 25 to 30 years depending on the rate scheme; however electricity costs vary according to the year and electric power company, thus careful attention is required.

Subsidies are available that help reduce the initial costs. For example, the Ministry of Economy, Trade and Industry of Japan offers residential solar generation installation subsidies for fiscal year 2009 in accordance with the Implementation Guidelines for Subsidy for Assisting Residential Solar Generation Installation. This subsidy provides 70,000 yen per nominal output of a 1 kW solar cell module constituting an eligible photovoltaic power generation system that meets the requirements. There are also prefectural and municipal subsidies programs that vary locally, and by combining these programs a further reduction in initial costs can be achieved.

On February 24, 2009, the Ministry of Economy, Trade and Industry announced that it would introduce a new program that imposes a mandatory obligation on electric power companies to purchase the surplus electricity generated by photovoltaic power systems at prices nearly double that of the current level. The details including the electricity purchase price, commencing time and application period are to be determined, but if this program were implemented in 2010 for 10 years, it is expected that the number of years required for paying back the initial costs mentioned above would significantly be reduced and the number of installations would increase.

For example, if these subsidies and the electricity purchase program are applied in Naha and the annual estimated power generation is converted into electricity cost, the payback time is approximately 20.6 years as shown below, which is five to nine years less than the current level.

Current

3,430 kWh x 31.48 yen/kWh = 107,976 yen

When the electricity purchase price has doubled

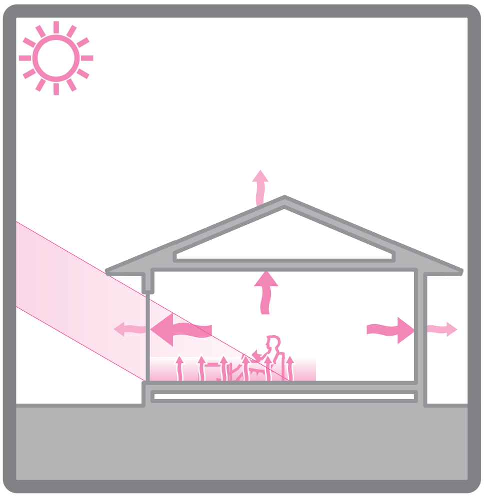
3,430 kWh x 0.5 x 31.48 yen + 3,430 kWh x 0.5 x 50.00 yen = 139,738 yen

Payback time of initial costs

(2,753,000 yen − 210,000 yen − 1,397,000 yen) / 107,976 yen + 10 years = approximately 20.6 years

* The hourly rate lighting service provided by the Okinawa Electric Power Company is applied to the electricity consumed at the house. The electricity selling price is set based on an assumption that half of the electricity produced by photovoltaic power generation is sold at double the electricity purchase price of the hourly rate lighting service for 10 years.

3.4 Solar Radiation Heat Utilization for Zone V (Solar Heat Utilization 1)



The basics of reducing heating energy are to decrease heat loss from buildings. Additionally, we can also reduce heating load by increasing the heat gained by buildings.

Solar radiation is the most significant cause of heat gain, and solar houses are designed to actively positively proactively utilize solar heat in heating. Of these solar heating plans, a method for obtaining natural heating effects using solar heat in buildings is called passive solar heating. Among those houses, a method for obtaining natural heating effects mainly by envelope design is called passive solar heating. It is important to design a house by maintaining the balance of the three architectural techniques—heat collection, thermal insulation of openings and heat storage—while taking into account the regional climate characteristics and site conditions. Solar heat utilization technology is not applicable to Zone IV, which is warm in winter.

3.4.1 Purpose and Key Points of Solar Radiation Heat Utilization

- Utilization technology of solar radiation heat is effective in reducing heating energy consumption in winter. Here, we will discuss architectural technology that obtains solar heat from openings and effectively utilizes it.
- Solar heat radiation gain and utilization can be achieved using the three methods: increasing the amount of heat gain (heat collection), controlling heat gain loss (insulation), and effectively utilizing heat gain while preventing a decrease in room temperature (heat storage). It is vital to efficiently combine these methods according to the regional climate characteristics and site conditions and minimize the room temperature variation in an effort to maintain the heat balance of buildings.
- Major components that obtain solar radiation heat are glass window openings. In order to increase solar heat gain, it is necessary to make floor and opening planning based on the directions and sizes, such as placing major openings on the south.
- Glass windows are heat collection areas as well as significant heat loss areas in general. Expanding the heat collection window area to increase solar heat gain results in the dilemma of increasing heat loss. Therefore, the specification for the openings needs to consider the heat balance. Glazing has a high solar transmittance and the greater the insulation performance of glazing and frames, the better heat balance.
- In winter, most heat gain occurs during the day when solar radiation is available, and heat loss continues all day. Generally, heat loss is lower during the day than at night when the outside air temperature decreases. Therefore, in order to maintain stable room temperature, it is effective not only to retain the heat balance all day but also to supplement the heat loss at night by receiving the heat gain that exceeds the heat loss during the day. This requires heat storage technology that carries heat over from the day to the night.
- Although solar radiation gain and utilization technology provides heating effects in winter, it is important to plan opening areas that allow for both solar radiation gain and shading as we also need to consider the cooling energy reduction effects using solar shading schemes in summer (See Section 4.3 Solar Shading Methods for Zone V on p.188 for solar shading).

3.4.2 Energy Conservation Target Levels for Solar Radiation Heat Utilization

1. Definition of target levels

・Energy conservation target levels for solar radiation heat utilization are divided into the following levels 1 to 4 and indicate the reduction rate of energy consumed by heating systems.

Level 0	:	Heating energy reduction rate	None
Level 1	:	Heating energy reduction rate	Approx. 5%
Level 2	:	Heating energy reduction rate	Approx. 10%
Level 3	:	Heating energy reduction rate	Approx. 20%
Level 4	:	Heating energy reduction rate	Approx. 40%

・The typical heating energy consumption in 2000 was 5.0 GJ (approximately 7% of total energy consumption) (See Section 6.1 on p.339).

・Any target level can be achieved by combining the regional climate characteristics, site conditions (influence of obstruction of sunlight), building direction (direction of opening serving as heat collection area), and methods for utilizing solar radiation heat to be adopted.

2. Requirements for achieving target levels

1) Regional climate characteristics (Passive solar zone classification)

・Effectiveness of solar radiation heat gain and utilization is largely related to regional climate characteristics. Here, we focus on solar radiation characteristics and coldness in winter among regional climate characteristics. The passive solar zone classification (PSP) refers to the classification of regional solar radiation characteristics based on solar radiation level and temperature in winter. This categorizes Japan into five zones from Zone A to Zone E. Zones C to E, which have high solar radiation levels, belong to Zone V. Zone V includes Zones C to E, which have high solar radiation levels.

Zone A	:	Very cold region with low solar radiation level
Zone B	:	Cold region with low solar radiation level
Zone C	:	Cold region with high solar radiation level
Zone D	:	Region with high solar radiation level
Zone E	:	Warm region with high solar radiation level

・Passive solar zone classification map (PSP classification map) showing distribution of the PSP classification and corresponding prefecture and municipality list are provided in Appendix 1 Zone Classification Data on p.384.

Key Point

Passive Solar Potential (PSP)

・PSP refers to the ratio of the mean solar radiation levelheating degree days in January (sum of the difference between 18°C room temperature and mean outside air temperature of days in which daily mean outside air temperature falls below 18°C) to the heating degree daysmean solar radiation level in January (sum of the difference between 18°C room temperature and mean outside air temperature of days in which daily mean outside air temperature falls below 18°C), and indicates the possibility of solar radiation utilization in the region.

・PSP is the highest in warm regions with less heating degree days and high solar radiation and the lowest in cold regions with more heating degree days and low solar radiation.

・Compared to the regional classification created based on heating degree days, PSP classification is clearly influenced by solar radiation level. Zone V and pacific side of Zone IV, which are classified in the 1999 energy conservation standard, are areas with some of the highest solar radiation levels in the world and solar radiation can be easily utilized for heating. In Zone A of the PSP classification, we cannot expect much solar heat to be used for heating while solar heat utilization is highly effective in Zone E.

* The PSP classification was changed with the original five zones consolidated into three based on the amendment of the energy conservation standard in April 2009. However, in this document we use the five zones which conform to the original standard that was issued in 1999.

2) Site conditions (influence of obstruction of sunlight)

- Effectiveness of solar radiation heat gain and utilization is greatly linked to the influence of obstruction of sunlight received by the building, i.e. sunshine hours of the planned building.
- If solar radiation is obstructed in winter because of tall buildings around the building site, it is difficult to gain and utilize solar radiation. It is necessary to investigate prior to the design process any factors causing obstruction of sunlight to the planned building, such as objects blocking the sun, topography and influences of trees.
- Here, we have divided the building site into the following three categories according to the influence of obstruction of sunlight (Table 1).

Table 1 Site classification by influence of obstruction of sunlight

Classification	Degree of obstruction of sunlight	Guideline for sunshine hours (winter solstice)
Site 1	Site with large influence of obstruction of sunlight (approx. 50%) where solar radiation heat utilization is difficult	At least 3 hours (e.g. only 3 hours of sunlight between 10:30 and 13:30)
Site 2	Site with small influence of obstruction of sunlight (approx. 25%) where solar radiation heat utilization is possible	At least 5 hours (e.g. 5 hours of sunlight between 9:30 and 14:30)
Site 3	Site with no influence of obstruction of sunlight (0%) where solar radiation heat utilization is easy	Sunlight can be received all day

* Degree of obstruction of sunlight (%) refers to a ratio of the solar radiation level that is blocked by buildings and other objects and cannot be used to the solar radiation level that is not blocked by surrounding buildings and other objects and can be used (total solar radiation) during a winter day (8:00 – 17:00).

- If the building site is applicable to Site 1 classification, hardly any heating effects can be expected even when methods for utilizing solar radiation heat are adopted.

Key Point

How to check sunshine hours

- Sunshine hours can be checked by taking the following steps after surveying the position and height of surrounding buildings.
  ①Create a sun shadow diagram (or sky diagram) using a sun-shadow simulation tool.
  ②Read sunshine hours at the point that is estimated as the major opening surface position of the planned building using a sun shadow chart (sunshine curve measurement scale).
- The central area of the height of the first floor opening (approximately 1.5 m from the ground level) is considered appropriate for the height of the measuring point of sunshine hours here.
- The diagram below is a sun shadow diagram of ground level plus 1.5 m in height at winter solstice using a two-storey house as an example. It was confirmed that at least 5 hours of sunlight (equivalent to Site 2 classification) can be received at point (C) which is set approximately 5.5 m in recess of the north lean-to roof of the house.

■Measurement conditions
Measurement date: Winter solstice
Measurement place: Kagoshima (Zone E)
Measurement time: 8:00 – 17:00
Measurement height: Ground level + 1.5 m

■Building conditions
Maximum height: Approx. 7.4 m (eaves)
Eave height: Approx. 6.0 m (upper roof)
Approx. 3.3 m (lean-to roof)
Width x depth:
10.32 m x 7.735 m (5.46 m for second floor)

Table: Sunshine hours at specific points

Point	Recess distance	Sunshine hours	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h
A	4.5 m	Approx. 2.5 hrs.										
B	5.0 m	Approx. 4.5 hrs.										
C1	5.5 m	Approx. 6.5 hrs.										
C2	5.5 m (4 m to west)	Approx. 6.5 hrs.										
C3	5.5 m (4 m to east)	Approx. 5.5 hrs.										

* Lines indicate shady hours.

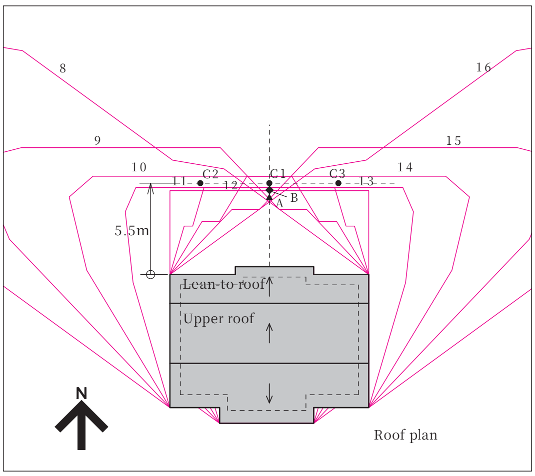


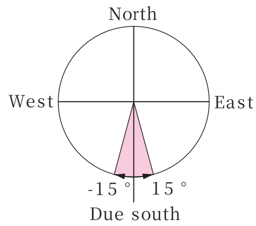
Fig. Example of sun shadow diagram of two-storey house

3) Building direction (direction of opening serving as heat collection area)

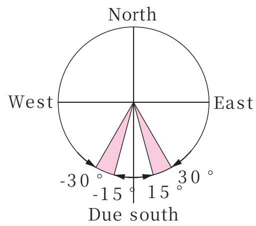
- Effectiveness of solar radiation heat gain and utilization is largely related to the direction of opening which serves as the heat collection area.
- Direction of opening* is effective in terms of heat collection, if it is within 30° east or west of due south, regardless of the regional classification. If it exceeds 30° from due south the heat collected from the opening drastically decreases.
- Therefore, the direction of opening aimed for heat collection must be within 30° of due south and the following two categories within this range are used with due south as the baseline:

Direction 1	:	Due south ±15 °
Direction 2	:	Due south ±30 ° (excluding range of Direction 1)

* "Direction of opening" refers to the orientation of the normal line from the opening toward the outside (i.e. from the interior to the exterior in a direction perpendicular to the straight line connecting both ends of the opening).



Direction 1



Direction 2

4) Methods for utilizing solar radiation heat

- This document covers the following methods for utilizing solar radiation heat that are effective in reducing heating energy.

Method 1	:	Insulation method for openings (enhanced insulation performance of openings)
Method 2	:	Method for collecting heat from openings (enlarged opening area for heat collection)
Method 3	:	Heat storage method (use of heat storage material)

- Of the three methods, Method 2 is not very effective if used alone. On the other hand, Method 1 and Method 3 are somewhat effective even when used alone, however a combination of these methods achieve higher energy saving effects. In order to obtain energy saving effects, it is necessary to adopt one of the following methods (or combinations).
  - Method 1
  - Method 3
  - Method 1 + Method 2
  - Method 1 + Method 3
  - Method 1 + Method 2 + Method 3
- Details of each method will be explained in Section 3.4.4 Solar Radiation Heat Utilization Methods.

3. How to achieve target levels

- Energy conservation target levels for solar radiation heat utilization are determined by site conditions (influence of obstruction of sunlight), building direction, and the use of methods for utilizing solar radiation heat.
- Tables 2 - 4 on p.094 show the correspondence between target levels and methods for each passive solar zone classification. Methods that have energy saving effects and energy reduction rate vary depending on the region.
- The heating energy reduction rate of each level is based on heating energy consumption in respective region. Even when the target level is the same, heating load is higher in Zone D of Table 3 and Zone C of Table 4 than Zone E of Table 2.

- In order to achieve the target level for low energy housing with validated effectiveness (LEHVE), the following conditions a and b need to be satisfied in terms of housing insulation level and opening area for heat collection:
  a. Housing insulation level: at least Level 3 (equivalent to the 1999 energy conservation standard (See Section 4.1 Insulated Building Envelope Planning for Zone V for details of insulation levels.)
  b. Opening area for heat collection: at least 10% ratio of opening area for heat collection to total floor area (The direction of openings for heat collection must be within 30° east or west of due south.)

Table 2 Target levels for solar radiation heat utilization and how to achieve them (Zone E: Kagoshima)

Target level	Energy saving effect (heating energy reduction rate)	Method to be adopted			
		Site 3: 0% obstruction of sunlight		Site 2: 25% obstruction of sunlight	
		Direction 1 Due south ±15 °	Direction 2 Due south ±30 ° (excluding Direction 1)	Direction 1 Due south ±15 °	Direction 2 Due south ±30 ° (excluding Direction 1)
Level 1	Approx. 5%		Method 3	Methods 1 + 3	
Level 2	Approx. 10%	Method 3	Method 1	Methods 1 + 2	Methods 1 + 2 + 3
Level 3	Approx. 20%	Method 1 Methods 1 + 2 Methods 1 + 3	Methods 1 + 2 Methods 1 + 3	Methods 1 + 2 + 3	
Level 4	Approx. 40%	Methods 1 + 2 + 3	Methods 1 + 2 + 3		

Table 3 Target levels for solar radiation heat utilization and how to achieve them (Zone D)

Target level	Energy saving effect (heating energy reduction rate)	Method to be adopted			
		Site 3: 0% obstruction of sunlight		Site 2: 25% obstruction of sunlight	
		Direction 1 Due south ±15 °	Direction 2 Due south ±30 ° (excluding Direction 1)	Direction 1 Due south ±15 °	Direction 2 Due south ±30 ° (excluding Direction 1)
Level 1	Approx. 5%*			Method 1 Methods 1 + 3	Methods 1 + 2
Level 2	Approx. 10%*	Method 1	Method 1	Methods 1 + 2 + 3	Methods 1 + 2 + 3
Level 3	Approx. 20%*	Methods 1 + 2 Methods 1 + 3	Methods 1 + 2 Methods 1 + 3 Methods 1 + 2 + 3		
Level 4	Approx. 40%*	Methods 1 + 2 + 3			

* Indicated values are based on Nagasaki and heating load is estimated to be 1.5 times higher than Kagoshima.

Table 4 Target levels for solar radiation heat utilization and how to achieve them (Zone C)

Target level	Energy saving effect (heating energy reduction rate)	Method to be adopted			
		Site 3: 0% obstruction of sunlight		Site 2: 25% obstruction of sunlight	
		Direction 1 Due south ±15 °	Direction 2 Due south ±30 ° (excluding Direction 1)	Direction 1 Due south ±15 °	Direction 2 Due south ±30 ° (excluding Direction 1)
Level 1	Approx. 5%*			Method 1 Methods 1 + 3	Methods 1 + 2
Level 2	Approx. 10%*	Method 1	Method 1 Methods 1 + 3	Methods 1 + 2 Methods 1 + 2 + 3	Methods 1 + 2 + 3
Level 3	Approx. 20%*	Methods 1 + 2 Methods 1 + 3 Methods 1 + 2 + 3	Methods 1 + 2 Methods 1 + 2 + 3		

* Indicated values are based on Fukuoka (Hakata-ku) and heating load is estimated to be 1.6 times higher than Kagoshima.

3.4.3 Steps for Examining Solar Radiation Heat Utilization Technology

Step 1 Checking and examining possibility of solar radiation heat gain and utilization

1) Check regional climate characteristics (passive solar zone classification)
2) Check site conditions (influence of obstruction of sunlight)
3) Check building direction (direction of opening serving as heat collection area)

▼

Step 2 Checking and examining possibility of solar radiation heat gain and utilization

1) Ensuring housing insulation level (at least Level 3)
2) Ensuring opening area for heat collection (at least 10% of total floor area)

▼

Step 3 Considering insulation method for openings (Method 1)

- Enhanced insulation performance of openings (e.g. adoption of low heat transmission coefficient)

▼

Step 4 Method for collecting heat from openings (Method 2)

- Enlarged opening area for heat collection (at least 20% of total floor area)

▼

Step 5 Heat storage method (Method 3)

- Use of heat storage material (adoption of materials and construction methods that can provide heat capacity increase)

3.4.4 Solar Radiation Heat Utilization Methods

Method 1: Insulation method for openings (Enhanced insulation performance of openings)

- The lower the heat loss from buildings, the lower the solar radiation heat that needs to be collected. Therefore, if we can secure sufficient insulation performance the possibility of solar radiation utilization increases.
- In order to reduce the heat loss from buildings, it is necessary to increase the level of insulated building envelope planning for the entire building. In particular, insulation methods for openings that are at high risk of being areas of significant heat loss are important.

1) Points to note when choosing materials for openings

① Glazing specification

- Glazing is required not only to minimize heat loss but also to increase heat gain. Because of this, it is generally believed that it is effective to choose glazing that is high in insulation performance (low heat transmission coefficient) as well as in solar transmittance.

② Frame specification

- In order to enhance insulation performance of window frames, it is also effective to make fittings and fixtures using wood, resinvinyl or other less heat conductive materials that are high in insulation performance.
- As air tightness of sashes affect heat loss from openings, it is desirable to use airtight sashes.

2) Insulation performance requirements for openings (heat transmission coefficient of openings)

- Table 5 shows heat transmission coefficients of openings and examples of opening specifications that are required for adopting Method 1. All openings are considered here, in principle.

Table 5 Requirements for insulation performance of openings (Method 1)

Heat transmission coefficient of openings*	Example of frames and glazing
2.91 (W/m^2・K) or below	・Wood or plastic sash + double glazing (A12) ・Metal frame with thermal break + low-E double glazing (A12)

* For insulation performance (heat transmission coefficient) of openings, see Section 4.1 Insulated Building Envelope Planning for Zone V on p.153.

Key Point

Relationship between regional climate characteristics and glazing specification

- In terms of the relationship between glazing specification and regional climate characteristics, it is generally desirable in many cases to choose double glazing that has medium insulation performance and high solar transmittance in Zones D and E where solar radiation level is high, and low-E double glazing that has high insulation performance in Zones A and B where solar radiation level and outside air temperature are low.
- It is necessary to examine the specifications for glazing while considering solar shading schemes in summer. Solar radiation should be controlled in both winter and summer using solar shading schemes including overhangs, eaves, and curtains and other window coverings, for example (See Section 4.3 Solar Shading Methods for Zone V). However, if the curtain and other window coverings are open, energy saving effects through solar radiation heat utilization will further increase.

Comment ● Space structuring method in consideration of heat balance

By separating the heat collection space and heat collection components from the living space, it is easy to control the indoor heat balance. A buffer space such as a roofed veranda or sunroom is an example of separating the heat collection space from the living space.

It is also very effective to locate auxiliary rooms, such as bathrooms, washing rooms or storage rooms, where thermal environmental performance is not as critical as that of the living space, in the north as areas for preventing cold air.

Method 2: Method for collecting heat from openings (enlarged opening area for heat collection)

- Although openings lead to significant heat loss, south-facing openings often have a positive daily heat balance and it is effective to enlarge opening area that serves as a heat collection area. However, as this is related to the regional climate characteristics and glass window specifications, it is desirable to consider these factors.
- Table 6 shows the required opening area for adopting Method 2. Here, we will discuss openings facing due south ±30° that can serve as heat collection area.

Table 6 Requirements for opening area for heat collection (Method 2)

Opening area for heat collection	Remarks
At least 20% of total floor area	• Applicable to openings facing due south ±30° that can serve as heat collection area

- The opening area referred to here is based on “sash inside width x sash inside height” similar to when calculating the effective daylighting area according to the Building Standard Law of Japan.

Key Point

Relationship between regional climate characteristics and opening area

- In terms of the relationship between regional climate characteristics and opening area, it is generally more effective to enlarge the opening area in Zones D and E where solar radiation level is high. On the other hand, as the opening area becomes larger, the heat balance tends to be unfavorable in Zone A where solar radiation level is low.

Key Point

Relationship between direction and size of opening

- Consideration for the direction of opening also influences the size of opening. If the opening area is enlarged but the amount of solar radiation gain is low, heating load will increase due to heat loss from the openings. Therefore, the larger the opening, the more necessary it is to design the direction of the opening to be as close as possible to due south and adopt schemes to effectively obtain solar radiation. On the other hand, the smaller the opening, the less influence the direction of the opening has.

3

Chapter 3
Natural Energy Application Technology
(Elemental Technology Application Method 1)

Glossary: Heat capacity
This refers to the amount of heat that is required to raise the temperature of the material by the unit temperature. Generally, heat capacity of a uniform material can be obtained from the multiplication of specific heat and volume or weight.

Method 3: Heat storage method (Use of heat storage material)

- Heat storage is technology which effectively maintains a stable room temperature. It prevents the overheating of the room by absorbing heat during the day and the decrease of room temperature by releasing the absorbed and stored heat at night. Conversely, it stores cool air (cold storage) at night in summer and provides cooling effects during the day.
- Building components that are effective in heat storage include floors, exterior walls, partition walls and ceilings.
- Furniture, equipment and other living necessities are used in the house and the heat capacity of these objects also brings about heat storage effects.

1) Materials for heat storage components

- It is appropriate to use the materials for heat storage components which have the following characteristics:
  ① Having large heat capacity (volumetric specific heat);
  ② Being heat conductive; and
  ③ Quick heat absorption and emission from the surface.
- The most important characteristic of the above is the heat capacity. The larger the heat capacity of the heat storage component, the more stable and less variable the room temperature. Although this is the same as when heating is used, the room is less likely to be heated if materials with large heat capacity are used. However, once the room is heated these materials keep the room from losing heat.
- The heat capacity can be obtained using the following formula:
  Heat capacity (kJ/°C) = volume of heat storage component (m^3)
  x volumetric specific heat of heat storage material (kJ/m^3・°C)
- The volumetric specific heat of major materials is shown in Table 7 for reference purposes.

Table 7 Volumetric specific heat and effective thickness of major materials

Material	Effective thickness (m)*		Volumetric specific heat (kJ/m^3・°C)
Concrete	Regular concrete	0.20	2013
	Lightweight concrete	0.07	1871
Plastering material	Mortar	0.12	2306
	Lime plaster	0.13	1381
	Plaster	0.07	2030
	Wall clay	0.17	1327
Lumber	Pine	0.03	1624
	Cedar	0.03	783
	Japanese cypress	0.03	933
	Lauan	0.04	1034
	Plywood	0.03	1113
Gypsum, etc.	Plasterboard	0.06	854
	Perlite board	0.06	820
	Flexible board	0.12	1302
	Wood wool cement board	0.06	615
Other	Tile	0.12	2612
	Rubber tile	0.11	1390
	Linoleum	0.15	1959

* Materials have an "effective thickness" which can be considered as part of heat storage component. When calculating the volume of a material, if the actual thickness of the material is greater than the effective thickness, the maximum level we can include in the calculation is the effective thickness. This indicates that heat storage effects of a material having a thickness greater than the effective thickness are low. The more heat conductive the material, the greater the effective thickness.

2)　Requirements for heat storage components (heat capacity)

- Table 8 shows the heat capacity of heat storage components which is required for adopting Method 3.

Table 8　Requirements for heat storage components (Method 3)

Heat capacity of heat storage components
Use materials that are expected to have heat capacity increase of at least 170 (kJ/°C・m^2) for heat storage components per unit floor area

- In the case of wooden houses, in order to satisfy the requirements shown in Table 8, for example, mud-plastered walls are used for exterior and partition walls and slab on grade floors can be designed using materials with large heat capacity. The calculation examples of using mud-plastered walls and slab on grade floors as heat storage components are shown below for reference purposes:

Heat capacity = heat storage component area volume x volumetric specific heat of heat storage material

$= 210\ (m^2) \times 0.07\ (m) \times 1327\ (KJ/m^3 \cdot {}^\circ C)$

$+ 20\ (m^2) \times 0.15\ (m) \times 1327\ (KJ/m^3 \cdot {}^\circ C)$

$= 25{,}546\ (KJ/{}^\circ C)$

$> 25{,}500 = 150\ (m^2) \times 170\ (KJ/m^2 \cdot {}^\circ C)$

■ Calculation conditions

Total floor area	150 m^2
Heat storage component	Exterior/partition walls: mud-plastered wall (area: 210 m^2, thickness: 70 mm) Slab on grade floor: concrete floor (area: 20 m^2, thickness: 150 mm)

3)　Points to note when designing heat storage components

- In order to ensure heat storage effects, it is important to pay attention to the following points when designing a house:

①Position of heat storage components

- Heat storage effects become more apparent if the heat storage component receives direct solar radiation and the amount of solar radiation heat increases. However, heat storage effects can be expected even if the component does not receive direct solar radiation.

②Area of heat storage components

- The greater the area of heat storage components, the higher the heat storage effects. It is desirable to design a wide and shallow heat storage area.

③Thickness of heat storage components

- When considering the thickness of heat storage components, keep in mind that the heat storage performance of a material will not change if the thickness exceeds the effective thickness. For example, it is effective to choose 15 – 20 cm of thickness when using stone or concrete.
- Even if the thickness of the heat storage component is small, a certain level of heat storage effects can be achieved. If cork is used for floors as a finish, heat storage effects although slightly lower are observed.

Comment ● Systems for heat storage

There are two heat storage systems: direct and indirect heat storage systems.

①Direct heat storage system

This system directly gives and receives heat via radiation and convection using floors, walls, ceilings and other heat storage components within the living space. It consists of a direct gain system which uses the same surface for heat absorption and emission and a trompe wall system in which the heat absorbed from a surface penetrates through the heat storage component and emitted from the opposite surface.

②Indirect heat storage system

In this system, the heat collection section is separated from the heat storage section and heat is transferred in-between these sections. This system is available in different varieties, such as a stationary greenhouse type in which the heat collection section belongs to the living space, and an outdoor air-collecting type that is installed independently on the roof. Other varieties include a method in which a water bag is installed between wood joists and a method which sends indoor air to the crawl space and stores heat on the slab on grade floor.

3.4.5 Estimating Effects of Adopting Solar Radiation Heat Utilization Methods

1. Trial calculation methods

This section shows the trial calculation results of the heating load reduction effects achieved by the three methods using Solar Designer ver. 5.0. These three methods improve the indoor thermal environment in winter and save heating energy by utilizing solar radiation heat as explained in Section 3.4.4.

Seven cities are selected from Zones C, D and E of different PSP classification, which all belong to Zone V (Table 9), and heating load calculation is performed using the standard building model (Fig. 1, Table 10). Heating hours and other conditions are shown in Table 11. Additionally, in order to examine the influence of obstruction of sunlight and building direction, we performed the calculation by combining two conditions of obstruction of sunlight; 0% and 25% and three conditions of building direction; 0°, 15°, 30° from due south.

Table 9 PSP classification and regions

PSP classification	City
Zone E	Kagoshima
Zone E	Miyazaki
Zone E	Kochi
Zone D	Nagasaki
Zone D	Yatsushiro
Zone C	Fukuoka (Hakata)
Zone C	Shimonoseki
Zones VI, D	Tokyo (reference)

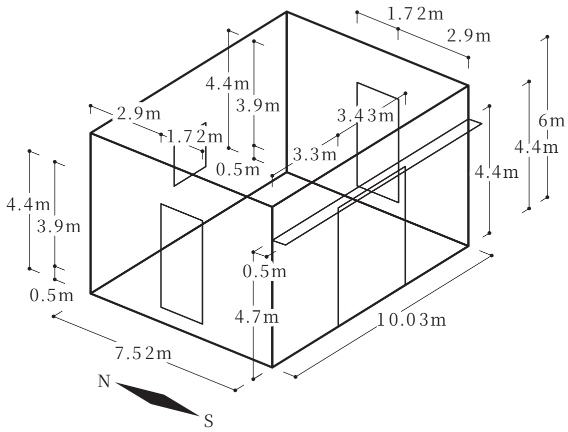


Fig. 1 Outline drawing of standard building

Table 10 Specifications of standard building

Specifications			
Building direction		Due south	
Building shape		Width: 10.03 x Depth: 7.52 x Height 6.0 (m)	Raised floor
Total floor area		151.0 (m²)	
Overhang		Depth: 0.5 (m), Height: 4.7 (m)	
South opening	Size	Depth: 3.43 x Height 4.40 (m)	
	Position	Spanerel wall height: 0 (m)	Distance from west wall: 3.3 (m)
East opening	Size	Depth: 1.72 x Height 3.90 (m)	
	Position	Spanerel wall height: 0.5 (m)	Distance from south wall: 2.9 (m)
West opening	Size	Depth: 1.72 x Height 3.90 (m)	
	Position	Spanerel wall height: 0.5 (m)	Distance from north wall: 2.9 (m)
Opening glazing	Heat transmission coefficient	4.65 (W/m²·K)	
	Solar transmittance	0.83	
	Sash ratio	0.85	
Floor finish	Thickness	Cedar	
	Thermal conductivity	0.12 (W/m²·℃)	0.1032 (kcal/m²·h·℃)
	Volumetric specific heat	783 (kJ/m²·℃)	187.0 (kcal/m²·℃)
Floor	Heat storage thickness	Plywood	
	Insulation thickness	0.1420 (m)	
Wall	Heat storage thickness	Plasterboard	
	Insulation thickness	0.0950 (m)	
Roof*	Heat storage thickness	Concrete	
	Insulation thickness	0.1980 (m)	
Indoor solar absorptance		0.2	
Outdoor solar absorptance		0.9	
Opening area not used for heat collection		2.69 (m²)	
Insulation	Thermal conductivity	0.043 (W/m²·℃)	0.037 (kcal/m·h·℃)
	Volumetric specific heat	33.5 (kJ/m²·℃)	8.0 (kcal/m²·℃)

* Specifications for standard building roof are calculated by adding the heat capacity of furniture, equipment and other living necessities to the heat capacity of roof and converting it into concrete.

Table 11 Heating and other system mode settings

Mode setting			
Heating	Temperature setting 18℃		
	Duration	7:00-10:00 12:00-14:00 16:00-23:00	
Air change rate		0.5 ACH (24h)	
Indoor generated heat	Daily total	57.348 MJ/day (13,700 kcal/day)	
	Breakdown by time period	0.2326kW [200kcal/h]	14:00-16:00
		0.3488kW [300kcal/h]	13:00-14:00 16:00-17:00
		0.4652kW [400kcal/h]	10:00-12:00
		0.5814kW [500kcal/h]	00:00-07:00 09:00-10:00
	0.6977kW [600kcal/h]	08:00-09:00	12:00-13:00
			17:00-18:00
		0.8140kW [700kcal/h]	07:00-08:00
		1.0465kW [900kcal/h]	18:00-00:00

2. Detailed settings of methods

1) Insulation method for openings (Method 1)

Four types of specifications, A to D, have been set for openings (Table 12).

2) Method for collecting heat from openings (Method 2)

There are two types of ratio, 10% and 20%, for the ratio (Ag/Af) of the south-facing opening area for heat collection (Ag) to the total floor area of a house (Af) as shown in Table 13.

3) Heat storage method (Method 3)

Two types of volumetric specific heat, equivalents of plasterboard and mud-plastered wall, have been set for the indoor heat collection storage components (Table 14).

Table 12 Opening specifications for examination

Heat transmission coefficient (W/m^2・K)	Heat transmission coefficient (kcal/ m^2・h・K)	Solar transmittance	Example specifications
A 6.51	5.5986	0.90	Metal frame + single glazing
B 4.65	3.9990	0.83	Metal frame + double glazing
C 2.91	2.5026	0.70	Metal frame with thermal break + low-E double glazing
D 1.80	1.5480	0.66	Wood sash + low-E double glazing + insulating shutter

* Specifications B are for basic building

Table 13 Opening area for heat collection for examination

Ag/Af	Opening area for heat collection (m^2)	Opening width (m)	Distance from west wall (m)
10	15.10	3.43	3.30
20	30.20	6.86	1.58

* Ag/Af = 10 (%) is the specification for basic building.

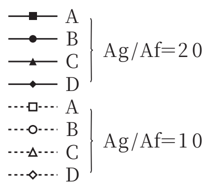
Table 14 Settings for volumetric specific heat of heat collection storage component (wall)

Volumetric specific heat (kcal/ m^3・°C)	Volumetric specificheat (kJ/m^3・°C)	Estimated specifications
204	854	Interior plasterboard wall
316.9	1327	Mud-plastered wall

* Volumetric specific heat = 204 (kcal/ m^3・°C) is the wall specification for basic building, and specifications shown in Table 10 should be used for floors and ceilings.

3. Results of trial calculation

Fig. 2 shows the results of trial calculation of annual heating load (unit: GJ) using solar radiation heat utilization methods for eight cities listed in Table 9. Obstruction of sunlight is set at 0% (Site 3) in all cities.



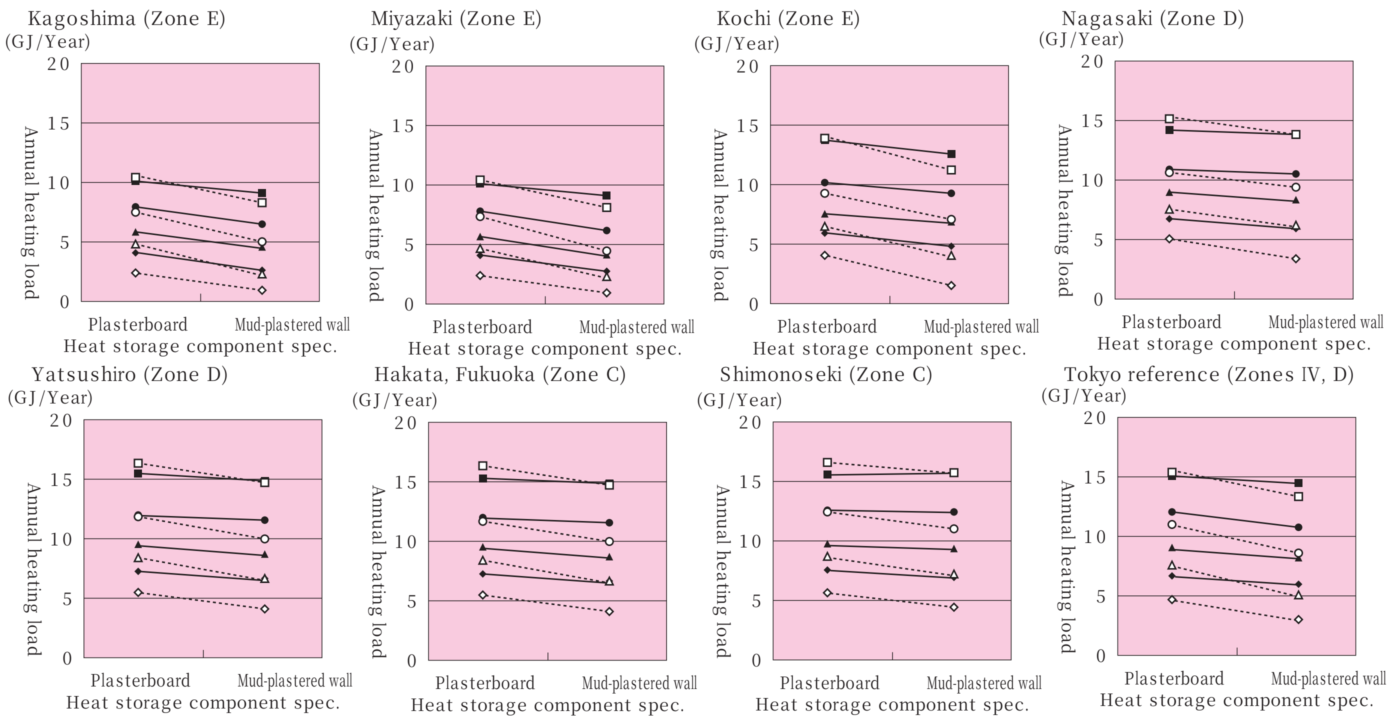
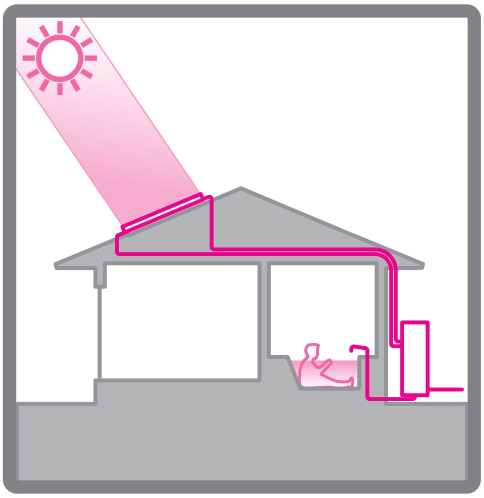


Fig. 2 Annual heating load using solar radiation heat utilization methods in major cities of hot humid regions

3

Chapter 3
Natural Energy Application Technology
(Elemental Technology Application Method 1)

3.5 Solar Water Heating (Solar Heat Utilization 2)



Water heating accounts for a very large portion of the total residential energy consumption, and the adoption of solar water heating systems that utilize natural energy is effective from an energy saving perspective.

3.5.1 Purpose and Key Points of Solar Water Heating

* This section explains solar water heating systems when a heat collection section is installed on the roof of a detached house. There are systems that use solar heat not only for the domestic hot water supply but also for space heating, but this document does not discuss such systems.

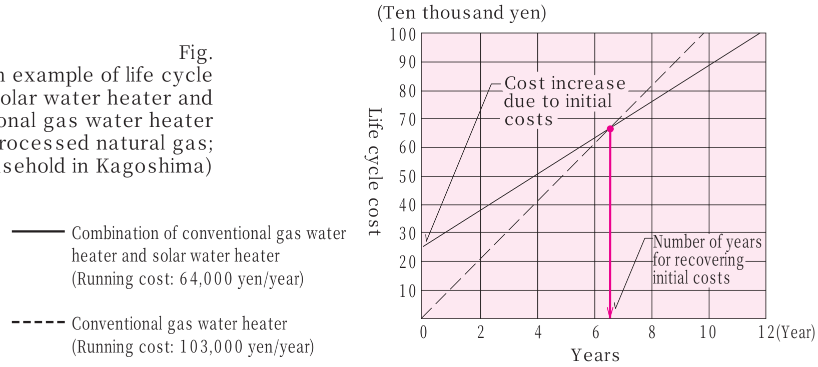
- Heat sources of domestic hot water system used in houses are classified into gas, oil, electricity and natural energy. Among these, solar water heating devices that utilize natural energy have a long history of achievements since the oil shocks of the 1970s, and are still one of the most effective energy saving means of water heating today.
- Compared to other systems, the initial costs of solar water heating are higher for the portion that is required for installing solar water heating devices. Nevertheless, once the installation is completed running costs can be drastically reduced and the appropriate installation enables the recovery of initial costs during the service life of the device.
- There are many different types of solar water heating devices but all of these devices consist of a heat collection section which collects solar heat and a hot water storage section which stores heated water. The area of the heat collection section has the most significant influence on the amount of heat collection. The larger this area the greater the amount of heat obtained, however, if it is too large compared to the usage amount of hot water, the device will be over capacity making it difficult to recover the initial costs.
- Since hot humid regions are warm as well as rich in solar radiation, a typical heat collection area of 3 – 4 m2 can cover more than half of the annual domestic hot water energy and solar water heating is an extremely effective energy saving method.
- Solar water heating devices are generally classified into “solar water heaters” and “solar systems” that are defined in the Japanese Industrial Standards (JIS A 4111). These devices use a different connection style between the heat collection section and the hot water storage section.
- Generally, it is common to plan solar water heating as an auxiliary heat source system by connecting it to gas or oil water heater. Appropriate connection is extremely important here in order to ensure energy performance of solar water heating.
- Solar water heating devices require heavy heat collectors to be installed on the roof and some models need a hot water storage tank. To ensure safety due attention must be given to design and installation.

Key Point

Number of years for recovering initial costs of solar water heating device

• The figure below is a graph showing the life cycle costs of a solar water heating device (solar water heater) and a conventional gas water heater by the number of years used. In this example, the solar water heater requires approximately 250,000 yen in initial costs (including installation cost) in addition to the gas water heater which is an auxiliary heat source. The annual running costs are reduced by nearly 40,000 yen and it takes approximately 6.4 years to recover the increase in the life cycle cost caused by initial costs. Generally speaking, the service life of solar water heating devices is over 10 years and it is possible to recover the initial costs during the life span.

Fig.
Test calculation example of life cycle costs of solar water heater and conventional gas water heater
(For using processed natural gas; four-person household in Kagoshima)



Key Point

Definition of terms

• Some terms used in the previous Design Guidelines for Low Energy Housing with Validated Effectiveness (issued in June 2005) have been reviewed and revised to comply with names and definitions employed by the Japanese Industrial Standards. The following table shows major changes.

Name and definition	Name and definition in previous guidelines	Name and definition in present guidelines
Solar water heater	System that supplies hot water directly from solar water heating device to faucet without auxiliary heat source	Type of solar water heating device with integrated heat collection and hot water storage section that collects heat through natural circulation
Solar system	System that uses both solar water heating device and auxiliary heat source	Type of solar water heating device that collects heat through forced circulation between heat collection and hot water storage sections
Device used for connecting solar water heating device and auxiliary heat source that mixes heated water and tap water and controls auxiliary heat source	Domestic hot water temperature control section	Solar connection unit

3.5.2 Energy Conservation Target Levels for Solar Water Heating

1. Definition of target levels

- The energy conservation target levels for solar water heating refer to the following levels 1 to 4 and indicate the reduction rates of energy consumed by domestic hot water systems.
- Any target level can be achieved by adopting solar water heating methods.

Level 0	:	Domestic hot water energy reduction rate	None
Level 1	:	Domestic hot water energy reduction rate	At least 10%
Level 2	:	Domestic hot water energy reduction rate	At least 30%
Level 3	:	Domestic hot water energy reduction rate	At least 50%
Level 4	:	Domestic hot water energy reduction rate	At least 70%

* The domestic hot water energy reduction rate is based on the typical hot water consumption of a four-person family.

- The typical domestic hot water energy consumption in 2000 was 13.8 GJ (approximately 21% of total energy consumption) for Zone VI and 19.2 GJ (approximately 28% of total energy consumption) for Zone V (See Section 6.1 on p.339).

2. How to achieve target levels

- This document discusses the following solar water heating methods that provide energy saving effects.

Method 1 : Securing heat collection area and other considerations	1a: Small effective heat collection area (below 3.5 m^2) 1b: Medium effective heat collection area (3.5 m^2 – 5.5 m^2) 1c: Large effective heat collection area (over 5.5 m^2)
Method 2 : Appropriate connection with auxiliary heat source	2a: Not connecting with auxiliary heat source 2b: Connecting with auxiliary heat source using a three-way valve 2c: Connecting with auxiliary heat source using solar connection unit
Method 3 : Adopting energy-efficient circulating pump	Solar systems only

- The corresponding relationship between the target levels and methods of energy conservation by solar water heating is as shown in Table 1.

Glossary: Effective heat collection area
The heat collector used to collect solar radiation in solar water heating does not utilize the entire unit for this task. The area that actually collects heat is referred to as an "effective heat collection area" in this document (See p.108 for details).

Table 1 Target levels of solar water heating and how to achieve them

Target level	Energy saving effect (domestic hot water energy reduction rate)	Method applied	
		Solar water heater	Solar system
Level 0	0	Use of conventional domestic hot water systems without energy saving method	
Level 1	At least 10%	Methods 1a + 2a	(Methods 1a + 2a)
Level 2	At least 30%	Methods 1a + 2c Methods 1b + 2b	Methods 1a + 2c Methods 1b + 2b
Level 3	Approx. 50%	Methods 1b + 2c	Methods 1b + 2c + 3
Level 4	Approx. 70%	Methods 1c + 2c	Methods 1c + 2c + 3

- Since weather conditions vary locally in the hot humid regions, Kagoshima is used as a typical example in this section.
- ( ) in Table 1 indicates uncommon method.
- The most important method is the securing of heat collection area and other considerations (Method 1), a prerequisite of which is that the heat collection section is installed in the appropriate direction and tilt angle.
- To increase energy performance, it is important to increase the solar heat utilization rate and an appropriate connection with an auxiliary heat source (Method 2) is required. In Table 1, Method 2a applies to solar water heating used for bathtubs only while Method 2b and Method 2c apply to all uses including the kitchen sink and wash basin. When comparing Method 2b and Method 2c, the use of a solar connection unit (Method 2c) generally has a higher solar heat utilization rate (The three-way valve method or Method 2b can also increase the solar heat utilization rate if operated properly; See p.112 for details).
- There is a loss in the energy saving effect of solar systems if the heat medium circulating pump consumes a large amount of electricity. When a high energy saving effect is desired, it is essential to select a device that uses energy-efficient circulating pump (Method 3).

3.5.3 Steps for Examining Solar Water Heating and Prerequisites

1. Steps for examining solar water heating

・The selection of solar water heating devices should be examined according to the steps shown below:

Step 1 Examining the feasibility of adopting solar water heating

1) Check the local weather conditions
2) Check the surrounding conditions of the building site
3) Check the building structures and other factors
4) Examine the installation location, direction, etc.

▼

Step 2 Examining the type, size and other elements of solar water heating

Select the type that suits the conditions and examine each method
1) Securing heat collection area and other considerations (Method 1)
2) Appropriate connection with auxiliary heat source (Method 2)
3) Adopting energy-efficient circulating pump: solar system/forced circulation type only (Method 3)

▼

Step 3 Making considerations for planning and using solar water heating

1) Considerations for planning
2) Considerations for efficient operation and controlling methods

2. Prerequisites

1) Local weather conditions

Solar water heating devices use natural solar heat energy and local weather conditions need to be fully examined. There is a possibility that solar heat cannot be sufficiently collected in the following regions:

・Regions with insufficient solar radiation
・Regions with severe winters (devices and pipes freeze and cannot be used)
・Regions with high snowfall or snow cover (devices and pipes are covered with snow and cannot be used)

As hot humid regions are warm as well as rich in solar radiation, solar heat collection can be expected. However, since the heat collection section is commonly installed on the roof, wind protection is required especially in the typhoon-prone regions. Specific measures will be discussed in Section 3.5.5 on p.116.

2) Surrounding conditions of the building site

If either of the following statements applies to the surrounding conditions of the building site, there is a possibility that solar heat cannot be sufficiently collected:

・There are many adjacent buildings that obstruct solar radiation on the roof
・There are trees and other elements that obstruct solar radiation on the roof

3) Building structures and other factors

In general, since the heat collection section of the solar water heating device is installed on the roof, the building structure and roof need to be designed by taking into account the weight of the device. Caution is required especially when using a device with an integrated heat collection and hot water storage section, as such devices are heavy (approximately 400 kg with a full tank for a device with a heat collection area of 4 m^2). Additionally, if there is piping through the roof it is important to take proper measures to prevent leakage.

3.5.4 Solar Water Heating Methods

There are a wide range of solar water heating devices and they have different features. It is necessary to select the appropriate type according to the house.

Solar water heating devices can be classified into the following items in general:

(1) Heat collection system (direct or indirect heat collection)
(2) Heat collection medium (water, antifreeze solution, air, or heat pipe)
(3) Heat medium circulating method (forced or natural circulation)
(4) Structure of heat collection and hot water storage sections (integrated or separate)
(5) Heat collection section shape (flat plate, vacuum tube, etc.)

Detailed structures of each solar water heating system will be explained in Section 3.5.6 on p.118.

Actual products consist of a combination of the above mentioned items. However, some combinations may not be available in actual products (**Table 2**).

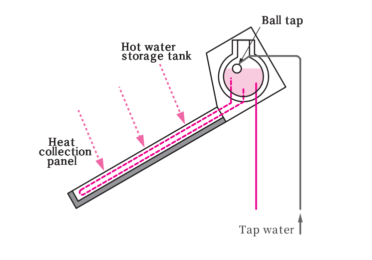
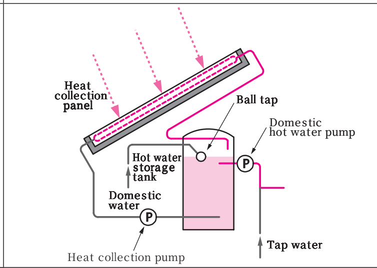
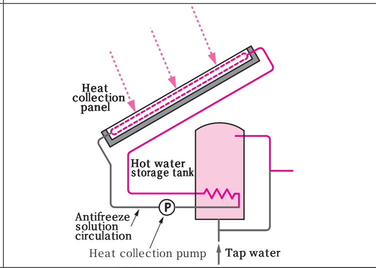
Table 2 Combination of heat collection section shapes, heat collection methods and hot water storage section

Heat collection section		Flat plate type		Vacuum tube type	
Hot water storage section		Integrated type	Separate type	Integrated type	Separate type
Direct heat collection (heat collection medium: water)	Natural circulation type (without pump)	◎	×	△ (vacuum hot water storage type)	×
	Forced circulation type (with pump)	×	△	×	△
Indirect heat collection (heat collection medium: antifreeze solution)	Forced circulation type (with pump)	△	○	×	○

◎: very common; ○: common; △: somewhat uncommon; ×: uncommon

Table 3 shows the structures and features of the typical solar water heater and solar systems in Japan. It is important to fully understand these characteristics and select the appropriate model.

Table 3　Structures and features of typical solar water heating devices

Item	Solar water heater	Solar system	
Heat collection type	Natural circulation type (direct heat collection)	Forced circulation type (direct heat collection)	Forced circulation type (indirect heat collection)
Hot water storage section	Integrated with heat collection section	Separate	Separate
Heat collection section	Flat plate type is mostly used in Japan	Flat plate type is mostly used in Japan	Flat type/Vacuum tube type
System diagram			
Heat collector appearance			
Heat collection area	• Commonly 3 – 4 m^2.	• Commonly 4 m^2.	• Adjustable (4, 6, 8, 10 m^2).
Hot water storage amount	• Commonly 200 L.	• Adjustable, commonly 200 – 300 L (50 L per 1 m^2 of heat collection area as guideline).	• Adjustable, commonly 200 – 300 L (50 L per 1 m^2 of heat collection area as guideline).
Ease of antifreezing	× • Generally difficult to operate in cold regions.	× • Generally difficult to operate in cold regions.	× • Circulates the antifreeze solution.
Solar space utilization	× Impossible	× Impossible	× Possible
Burden on the roof/structure	× • Weight of both main unit and stored water.	○ • Weight of the heat collection unit and small amount of stored water only.	○ • Weight of heat collection unit and small amount of antifreeze solution only.
Direct connection with water supply system	× Impossible • Booster pump is essential for shower.	× Impossible • Booster pump is essential for shower as device ' s open structure does not allow use of water supply pressure.	○ Possible • Can use water supply pressure as it is directly connected with water supply system.
Power consumption	◎ • Not required for main unit. • Booster pump consumes electricity during domestic hot water supply.	△ • Pump consumes electricity both during heat collection and domestic hot water supply.	△ • Pump consumes electricity during heat collection.
Energy saving effect	• Many models have small heat collection area. • Radiation heat loss is significant in cold regions. • High energy efficiency for initial costs.	• Low hot water storage loss. • Power consumption can be issue.	• Heat collection area can be easily adjusted. • Low radiation heat loss. • Power consumption can be issue.
Initial cost	◎ • Has relatively simple structure. • Many manufacturers are available.	○ • Has slightly complex structure. • Many manufacturers are available.	△ • Circulation system for heat collector, hot water storage tank and antifreeze solution is required.
Ease of maintenance	○ • Fewer moving parts limit the replacement to ball taps, gaskets, etc.	× • System is complicated with many moving parts. • Necessary to replace pumps, valves, etc.	× • System is complicated with many moving parts. • Necessary to replace pumps, valves, etc. • Necessary to replace antifreeze solution once every three years.

The superiority descends in the order of ◎, ○, △ and ×.

Method 1 : Securing heat collection area and other considerations

1. Heat collection area

- The most important factor in sufficiently collecting solar heat is to secure a large heat collection area. Some devices have a small heat collection area of 2 m^2, but a heat collection area of 3 m^2 is required in order to achieve energy saving effects in hot humid regions.
- Table 4 shows the required heat collection areas for Method 1 by classifying them into the three categories according to the energy saving effect.

Table 4 Heat collection area requirements for Method 1

Method	Effective heat collection area	Energy saving effect
Method 1a	<3.5 m^2	Low
Method 1b	≥ 3.5 m^2, <5 m^2	Medium
Method 1c	≥ 5 m^2	High

- The "effective heat collection area" refers to the area of the heat collector that can actually collect solar heat. Although the Japanese Industrial Standards define the "effective heat collection area" (JIS A4111) for solar water heaters and "heat collection surface area" (JIS A1425) for photovoltaic system heat collectors, this document uses "effective heat collection area" for all devices.
- The total area of the heat collector is defined as the "total heat collector area" (JIS A1425).
- The effective heat collection area is described as the "maximum area of the transmitting body of the heat section that is projected onto the heat collection surface" (JIS A4111). Vacuum tube types and other devices with a gaps between the transmitting bodies have a smaller "effective heat collection area" in relation to the same "total heat collector area" than flat plate types and other devices that have a continuous heat collection surface.
- The effective heat collection area of an average heat collector is 1.5 – 2.0 m^2 and multiple heat collectors are connected and installed. Please check the information provided by manufacturers for details.

2. Direction of installation and tilt angle of heat collection section

- The prerequisite for successful implementation of Method 1 is that the heat collection section should be installed in the appropriate direction and tilt angle.

1) Direction of installation

- Although the heat collection section should be installed on the south side as much as possible, even if it is slightly off south it can still collect heat. The east side is less effective than the west side as it collects heat in the morning and has a great heat release loss before the night when the hot water usage is high. The north side has hardly any effect. It is also necessary to select a location that will not be in the shade due to adjacent buildings and other elements in the future.
- Use a frame for a north-south roof ridge so that the heat collector faces the south (Fig. 1).

2) Tilt angle

- Generally, the maximum annual heat collection can be reached when the installation angle (tilt angle) of the heat collection section is 30° in relation to a leveled surface. However, since there is no significant difference in heat collection due to the tilt angle in both hot humid and warm regions, please choose a tilt angle of up to approximately 60° by taking into account the roof pitch. A frame is required when installing heat collectors at an angle that is steeper than the roof pitch (Fig. 1).
- If the tilt angle of the heat collectors is steeper, the heat collection increases in the winter when the solar altitude is low and decreases in summer. Since water heating energy consumption is higher in the winter,

the use of a steep tilt angle for heat collectors increases the solar energy utilization rate, in general.

- In Okinawa, reinforced concrete flat roof houses are common. If heat collectors are installed horizontally on the flat roof, the amount of heat collection becomes too large in the summer and too little in the winter. For that reason, a flat surface frame needs to be used (Fig. 1).

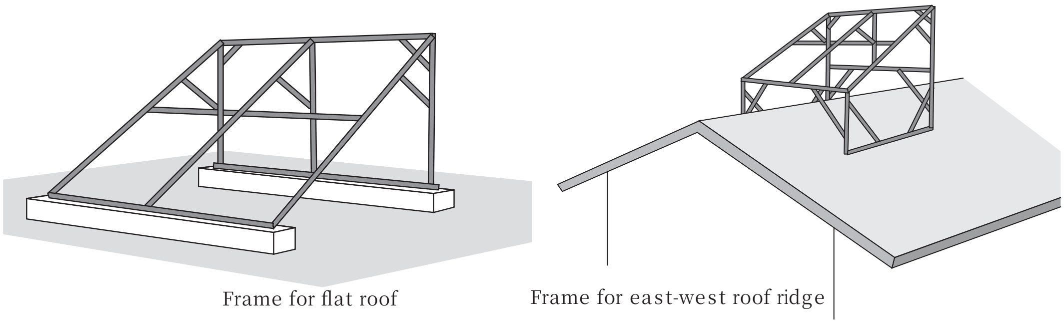


Fig. 1 Example of heat collector frame

Key Point

Energy saving effects of heat collection area

The figure on p.110 shows the results of calculating the ratio of the solar water heating energy to the total water heating energy by heat collection area at six representative locations in hot humid regions.

- The energy saving effect of water heating is high in hot humid regions where solar radiation is abundant and the tap water temperature is naturally high. In most locations the heat load halves with a heat collection area of 3 m^2. The energy saving effect further increases at 4 m^2 and the energy reduction rate is almost 70% in Okinawa. On the other hand, when the heat collection area exceeds 6 m^2, the reduction rate decreases in relation to the proportion of an increase in area. This is because the amount of heat collection becomes too large in relation to the heat load and the proportion of the effective heat collection decreases.
- From the above, it is considered that the appropriate heat collection area in hot humid regions is 3 – 4 m^2.

Key Point

Selecting the hot water storage section

- As solar water heaters have an integrated heat collection and hot water storage section, most models have a fixed capacity. The typical capacity of the hot water storage section is approximately 200 L.
- Some photovoltaic systems allow the capacity of the hot water storage section to be changed according to the heat collection area. Generally, the capacity is approximately 50 L per 1 m2 of a heat collection area. Therefore, if there is a heat collection area of 4 m2, the capacity of the hot water storage section is approximately 200 L.
- If the heat collection area is large, select the larger size of hot water storage section. Although 300 – 400 L is common, if the device also serves as a hot water storage tank for solar space heating it tends to be larger.

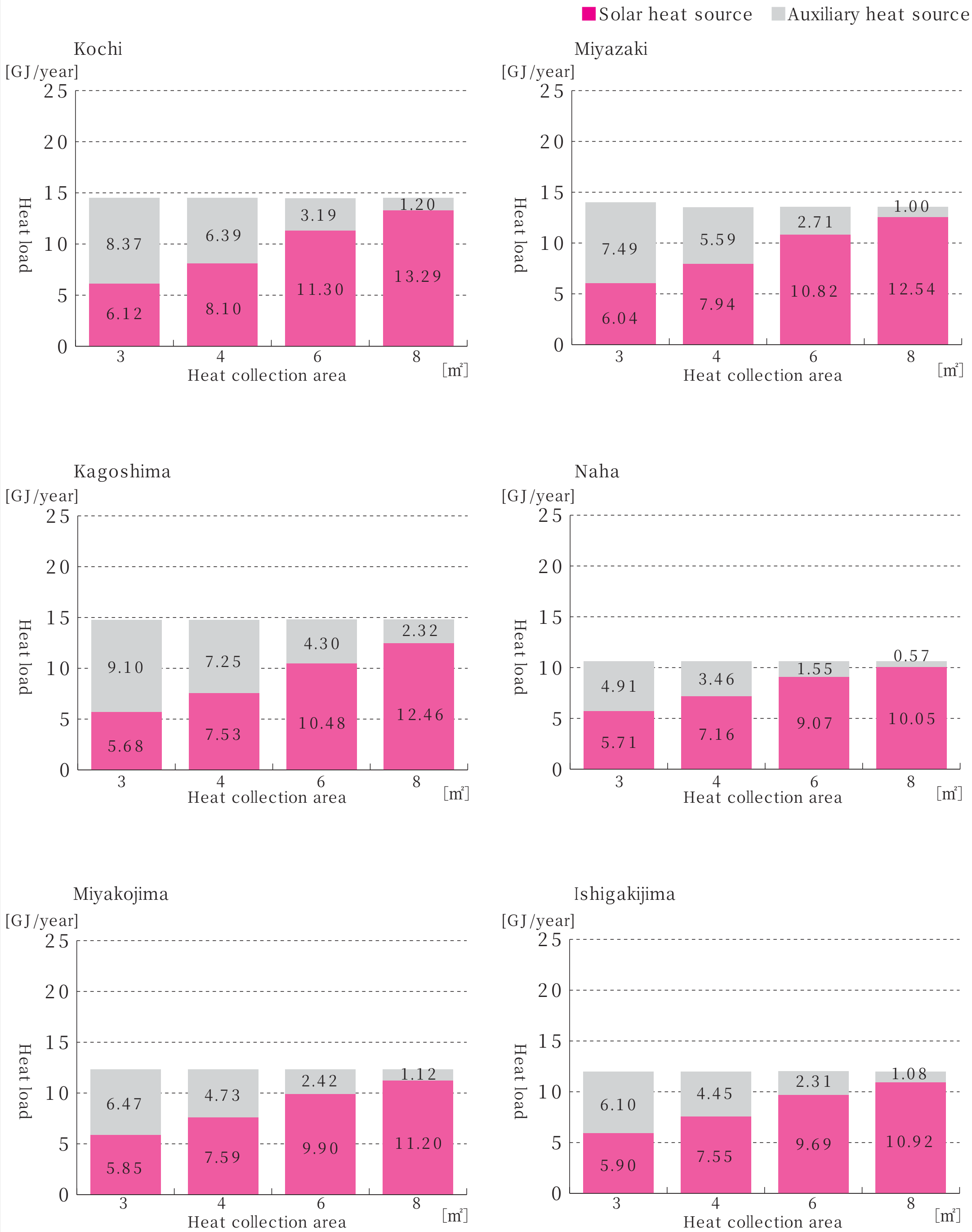


Fig. Domestic hot water energy saving effect of solar water heater (when installed due south with tilt angle of 30°)

■ Calculation conditions

- The calculation estimates the reduction effect of water heating load based on the monthly mean solar radiation by taking into account the efficiency of the heat collection section and system loss.
- The efficiency of the heat collection section is regarded as 40% throughout the year. This value is estimated from the experiment results of solar water heaters and indicates a combined efficiency of the heat collection and hot water storage sections. The results may be different for photovoltaic systems but the trend is predicted to be almost identical.
- The heat loss of the system caused by the piping and other sections is assumed to be 10%. This applies to when combining a solar connection unit with an auxiliary heat source. Compared to when using a three-way valve, it is thought that mixing hot water with cold water decreases the effective utilization rate of solar heat and the loss becomes greater.
- It is assumed that any hot water not used within the day becomes too cold to carry the heat to the next day.

Method 2 : Appropriate connection with auxiliary heat source

- Although solar water heaters achieve a high energy saving effect, they cannot collect heat under poor weather conditions and satisfy all the domestic hot water needs. Therefore, an auxiliary heat source that uses other types of energy is used at the same time. Gas and oil combustion are commonly available auxiliary heat sources.
- In order to help reduce energy consumption of water heaters, it is critical to increase the proportion of solar water heating over the other heat source. The adequate combination of a solar water heater and an auxiliary heat source such as a gas or oil water heater significantly increases the solar energy utilization rate. This document discusses three connection methods for these water heaters.
- In the past, the method of not connecting with an auxiliary heat source (Method 2a) was sometimes used, but this method provides a low solar heat utilization rate as it utilizes solar heat in the bathtub only.
- At present, connecting with an auxiliary heat source using a three-way valve (Method 2b) is most commonly practiced. This method provides an increased solar heat utilization rate if the switching of the three-way valve is properly performed, but if the switching is neglected solar heat cannot be used.
- Connecting with an auxiliary heat source using a solar connection unit (Method 2c) allows the unit to automatically control the solar water heater in order to increase the solar heat utilization rate. This provides both high energy efficiency and convenience as well as the superior safety.
- Table 5 summarizes characteristics of Methods 2a to 2c that are related to the methods for connecting solar water heating devices and auxiliary heat sources. When using a solar connection unit (Method 2c) initial costs are high yet other characteristics are extremely good. This method is expected to become more common in the future.

Table 5 Connection methods of solar water heating device and auxiliary heat source

Item	Method 2a Not connecting with auxiliary heat source	Method 2b Connecting with auxiliary heat source using three-way valve	Method 2c Connecting with auxiliary heat source using solar connection unit
Applications for which solar heat can be utilized	△ • For bathtubs only (solar heated water is sent to tub and reheated). • Solar heat cannot be utilized when automatically filling bathtub.	○ • Solar heat can be utilized for purposes other than bathtubs (reheating of the tub is impossible). • Depends on connection method whether solar heat can be utilized when automatically filling bathtub.	◎ • Solar heat can be utilized for purposes other than bathtubs (reheating of tub is impossible). • Solar heat can be utilized when automatically filling bathtub.
Convenience	× • Solar heated water needs to be sent to bathtub then reheated in bath boiler.	△ • Generally, as three-way valve is manually switched, solar heat utilization rate declines without proper operation. • Convenience increases if three-way valve is automatically switched by temperature sensor.	◎ • Highly convenient as unit automatically switches circuit. Users only need to set domestic hot water temperature of auxiliary heat source.
Solar heat utilization rate	× • Solar heat cannot be utilized for purposes other than use for bathtubs.	△ – ○ • Varies largely depending on whether three-way valve is properly used. Generally, since only one circuit changing switch is available in kitchen, it is difficult to switch at other places.	◎ • Unit automatically increase solar heat utilization rate.
How to increase solar heat utilization rate	• Solar water heating plays significant role for households in which bathwater accounts for large proportion of hot water consumption.	• Always appropriately operate three-way valve. • Use solar water heating circuit as much as possible even when temperature of solar heated water is slightly low.	• Lower domestic hot water temperature setting of auxiliary heat source. • Turn off auxiliary heat source during summer and in-between seasons when domestic hot water at fixed temperature is unnecessary (when using kitchen sink and wash basin).
Initial cost	○ • Least expensive.	△ • Three-way valve and piping costs.	△ • Additional cost of unit.
Safety	△ • Very hot solar heated water may be discharged particularly in summer.	△ • Very hot solar heated water may be discharged particularly in summer. Thermostat combination faucet is desirable for showers, kitchen sinks and wash basins.	◎ • Highly safe as unit automatically mixes solar heated water and tap water and maintains proper inlet water temperature even when operating auxiliary heat source.
Remarks	• This system is rarely used for new installations.	• This system used to be common.	• This system has recently become more common. • Model with built-in booster pump increases heated water pressure and improves discharging performance.

◎: Very advantageous; ○: advantageous; △: not very advantageous; ×: disadvantageous

This document covers three methods for connecting a solar water heating device with an auxiliary heat source. The following section provides a detailed explanation of each method.

1) Method 2a: Not connecting with auxiliary heat source

- In the past, there was a frequent use of the system which simply delivers the solar heated water into the bathtub and reheats it in the bath boiler without connecting the solar water heater with the auxiliary heat source (Fig. 2).
- This system is simple and inexpensive, and used to be effective when bathwater accounted for a majority of the domestic hot water consumption, but is now hardly used for new installations.

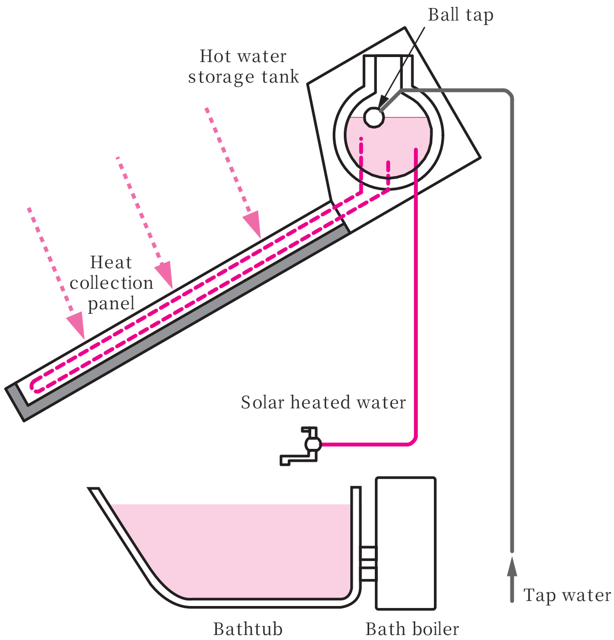
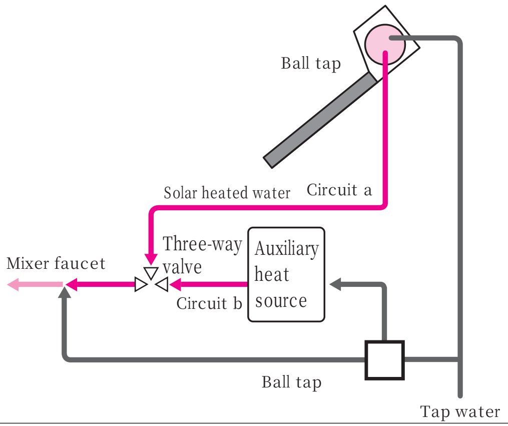
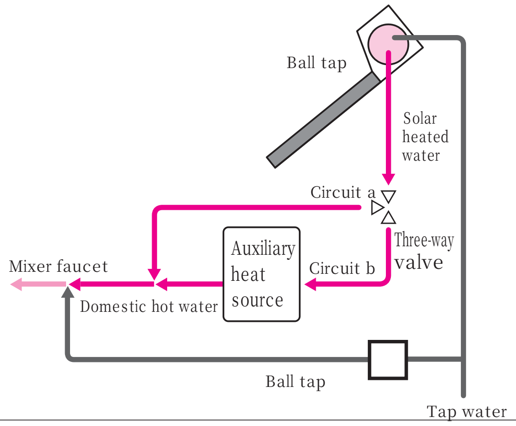
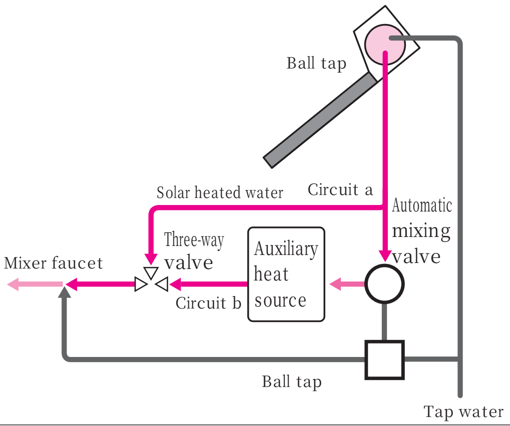


Fig. 2　Example of not connecting with auxiliary heat source (Method 2a)

2) Method 2b: Connecting with auxiliary heat source using three-way valve

- A system which uses a three-way valve for switching the solar water heater with the auxiliary heat source became widespread after Method 1a. There are many combinations of connecting the solar water heater with the auxiliary heat source. See Table 6 for the outline and characteristics of the major combinations.
- Three-way valves are relatively simple and can increase the solar heat utilization rate if operated properly. On the other hand, they are less convenient as they require the circuit to be switched manually according to the solar heated water temperature. If the circuit switching is neglected and the circuit for the auxiliary heat source is always used, the solar heat utilization rate may decrease.

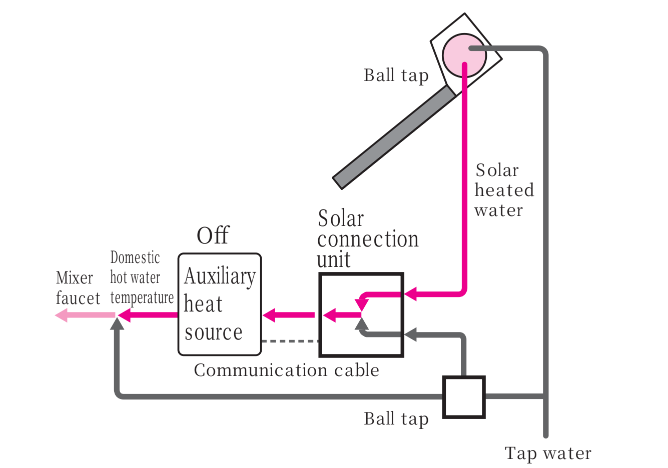
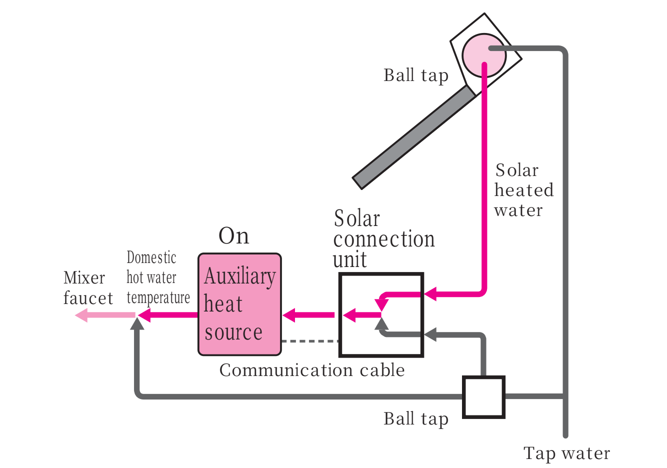
Table 6　Example of connecting with auxiliary heat source using three-way valve (Method 2b)

	System diagram	Characteristics
Connection example 1		• When temperature is sufficiently high, solar heated water is used directly through circuit a. • When solar heated water temperature is low, circuit is switched to circuit b and hot water supplied solely from auxiliary heat source is used. • Any auxiliary heat sources can be used without giving particular consideration to connection with solar water heater. • When circuit is switched to circuit b, solar heat higher than tap water temperature cannot be used at all. • When solar heated water temperature is extremely high particularly in summer, use of facets other than thermostatic type may be dangerous. • Solar heat cannot be used for automatically filling bathtub function of auxiliary heat source.
Connection example 2		• When temperature is sufficiently high, solar heated water is used directly through circuit a. • When solar heated water temperature is low, circuit is switched to circuit b and solar heated water is reheated with auxiliary heat source for domestic hot water supply. • Even when circuit is switched to circuit b, solar heat higher than tap water temperature can be used. • Solar heat can be used for automatically filling bathtub function of auxiliary heat source. • When solar heated water temperature from circuit b is relatively high, auxiliary heat source cannot limit its output and outlet hot water temperature may exceed preset domestic hot water temperature.
Connection example 3		• Although similar to example 1, auxiliary heat source is connected with solar water heater at inlet using automatic mixing valve so that solar heated water and tap water are mixed. • Automatic mixing valve automatically adjusts mixing ratio of two inlet systems so that outlet temperature stays at constant level. Thermowax valve is commonly used for this purpose. • Even when solar heated water temperature from circuit b is relatively high, it is safe as automatic mixing valve maintains low inlet temperature of auxiliary heat source. • Even when circuit is switched to circuit b, solar heat higher than tap water temperature can be used. • Solar heat can be used for automatically filling bathtub function of auxiliary heat source.

3) Method 2c: Connecting with auxiliary heat source using solar connection unit

- With the popularization of the central domestic hot water system, hot water became available in the kitchens and washing rooms. As the automatic filling of the bathtub by the auxiliary heat source became common, consumers began to seek out more convenient connection methods. As a result, solar connection units came on the market that enabled the automatic operation of the three-way valve and provided optimal control by communicating with the auxiliary heat source.
- The solar connection unit is installed on the auxiliary heat source inlet and connects the solar heated water with tap water at the unit inlet where they are mixed in an optimum ratio to increase the solar heat utilization rate. Since the solar connection unit and the auxiliary heat source should be connected with a dedicated communication cable, both the devices need to be compatible.
- Since all the control processes are automatically performed, this method provides great convenience and safety. Users can obtain hot water at a preset temperature by simply setting the domestic hot water temperature of the auxiliary heat source. Moreover, proper automatic control of the auxiliary heat source reduces unnecessary burning of the auxiliary heat source fuel, achieving further energy conservation (Table 7).
- As mentioned above, the use of the solar connection unit increases the solar heat utilization rate without performing special operations. When installing a solar water heating device for the first time, the solar connection unit is strongly recommended. This is why Method 2c is required for achieving the energy conservation target levels 3 and 4.

Table 7　Connection methods of solar connection unit (Method 2c) and general behaviors

Solar heated water temperature ≥ Preset domestic hot water temperature of auxiliary heat source	Solar heated water temperature < Preset domestic hot water temperature of auxiliary heat source
	
• Solar connection unit mixes solar heated water and tap water and sends it to auxiliary heat source. • Solar connection unit sends signal to auxiliary heat source not to ignite burner through the communication cable. • As auxiliary heat source does not perform unnecessary ignition, wasteful gas consumption is reduced. • Lowering domestic hot water temperature setting of auxiliary heat source further increases proportion of solar water heating. • Some models enable solar connection unit to perform mixing function only even when auxiliary heat source is turned off.	• Solar connection unit mixes solar heated water and tap water and sends it to auxiliary heat source so that it does not exceed upper tap water temperature limit of auxiliary heat source. • Auxiliary heat source sets upper limit of tap water temperature (generally 30 to 35 °C) in order to prevent domestic hot water temperature of auxiliary heat source from being too high. • When solar heated water temperature is below upper tap water temperature limit of auxiliary heat source, only solar heated water is supplied to that source. • Even when solar heated water temperature is low, if it is higher than tap water temperature, the surplus heat can be effectively utilized.

Key Point

Selecting auxiliary heat source

It is advisable to consider the following items when selecting the auxiliary heat source:

- A latent heat recovery device is desirable as the auxiliary heat source when the proportion of solar water heating is low in cases such as a small heat collection area and low solar radiation due to the surrounding environment. A wide range of latent heat recovery water heaters are currently available in both gas and oil (See Section 5.4 Domestic Hot Water System Planning on p.271). If the proportion of solar water heating is high because of the warm climate, conventional water heaters can be used.
- Some new models have an auxiliary heat source built into the hot water storage tank unit.

Method 3 : Adopting energy-efficient circulating pump (photovoltaic systems only)

- Whether it is a direct heat collection type which directly warms water or an indirect heat collection type which indirectly warms the water by heating the antifreeze or other solutions, the photovoltaic system requires a circulating pump which circulates the water and antifreeze solution if it is a forced circulation type.
- If the power consumption of the circulating pump is high, energy performance declines. Therefore, in order to fully demonstrate an energy saving effect, it is necessary to choose a model that operates the pump only when needed, uses a low power consumption pump or operates the pump using solar cell power.

Key Point

Power consumption of circulating pump

- Conventionally, pumps with power consumption of nearly 100 W have been commonly used. However, these pumps consume a large amount of electricity when operated during the day and result in significantly poor energy performance.
- In recent years, devices that use DC pumps and other power saving features have became available on the market. Models having pumps with a variable electrical input of 20 – 65 W operate the motor as needed thus achieving energy saving effects.

3.5.5 Solar Water Heating Planning and Considerations for Use

1. Considerations for sectional planning

1) Installing heat collectors (wind protection)

- Since hot humid regions are prone to typhoons, it is essential to protect against strong winds when installing heat collectors. As heat collectors installed on the roof may be blown upwards or slide sideways due to strong winds, it is necessary to firmly affix them.
- To prevent heat collectors from being blown away by strong winds, it is effective to fasten them as closely as possible to the roof and affix them at a gentle angle (Fig. 3). In the meantime, when using a frame in order to adjust the direction, heat collectors should be tightly affixed using wire and other means (Fig. 4).
- For safety reasons, it is important to carefully calculate wind load and examine how to affix heat collectors.

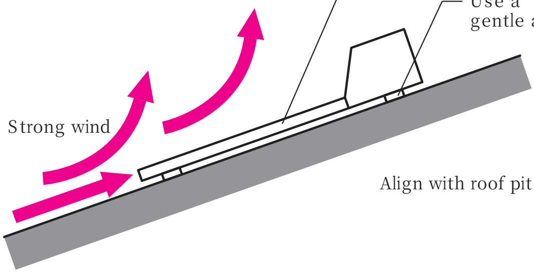


Fig. 3 How to install heat collectors in hot humid regions

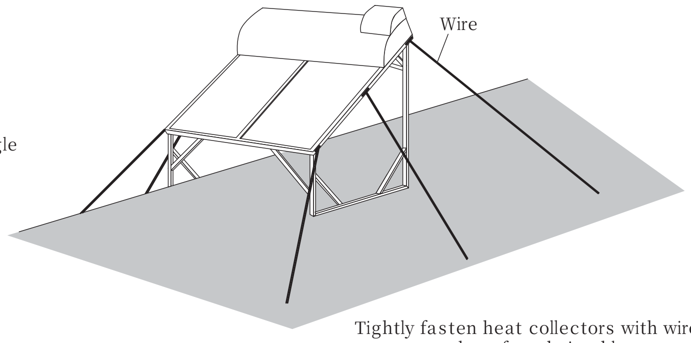


Fig. 4 Example of affixing heat collectors (using frame)

2) Installing hot water storage tank (separate type only)

- For a solar water heating system with separate heat collectors and a hot water storage tank, it is necessary to place the heat collectors, hot water storage tank and water heater as close together as possible.
- Although hot water storage tanks are generally installed outside, it is recommended to select a product that is properly insulated and install it indoors, even in unheated areas such as garages and utility rooms, in order to reduce heat loss.
- Particularly, since circulating pipes for the heat medium are installed outside, they should be as short as possible and must be insulated.

2 Considerations for efficient operation and control methods

Although solar water heating devices have very high energy performance, full advantage cannot be taken of their performance without understanding their characteristics and correct usage. The following section explains cautions to follow when using a system which connects a solar water heating device with an auxiliary heat source using a solar connection unit (Method 2c).

1) Preset temperature of water heater

When using a solar connection unit, the auxiliary heat source communicates with the solar connection unit via a communication cable and hot water is discharged according to the preset domestic hot water temperature of the auxiliary heat source remote control. As the system uses either the solar heat source or the auxiliary heat source according to this preset temperature, it is necessary to properly set this temperature in order to increase the system efficiency (Fig. 5, Table 8).

To increase the solar heat utilization rate, it is important to set the domestic hot water temperature of the auxiliary heat source as low as possible. The domestic hot water temperature should be raised only when very hot water is required and returned to the low setting afterward.

Table 8 Preset water heater inlet temperature and characteristics

Preset water heater inlet temperature	Characteristics
45 – 60 °C	• Mixing with tap water at faucet is prerequisite. Thermal mixing faucets are desirable. • As hot water can be used for shower at relatively high temperature, water pressure can be secured by mixing with water even when using thin hot water pipes. • In winter, solar heated water temperature does not often reach the preset domestic hot water temperature. Because of this, solar heat utilization rate is low and energy saving effects decline.
38 – 43 °C (recommended)	• Mixing with tap water at faucet is not prerequisite (common). • If hot water pipe diameter is thin, water pressure may not be sufficient for shower. • Solar heat utilization rate is high even in winter.

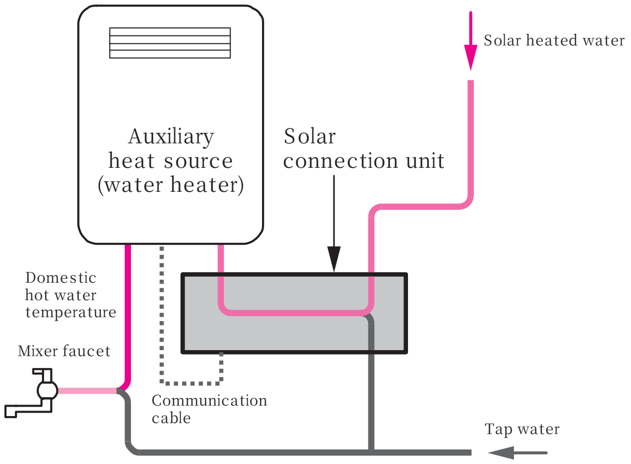


Fig. 5 Overview of solar connection unit

2) Adequate control of auxiliary heat source

• In a system using a solar connection unit (Method 2c), if the solar heated water temperature is lower than the preset domestic hot water temperature, it is reduced to the upper tap water temperature limit (30 – 35 °C) by mixing with the domestic water, and the domestic hot water is sent to the auxiliary heat source. The auxiliary heat source heats this water up to the preset domestic hot water temperature and discharges it. This process is intended to prevent the hot water discharge temperature from becoming too high due to the restriction in the lower capacity limit of the auxiliary heat source. However, this leads to an extremely low load operation of the auxiliary heat source and efficiency declines significantly.

• Additionally, even when sufficiently warm water is stored in the solar water heater, it takes a while before the solar heated hot water reaches the auxiliary heat source after it is discharged. During this period, even though short, the auxiliary heat source burns fuel. Even when solar heated water is supposed to handle all the domestic hot water needs, such as during the summer, the auxiliary heat source actually burns unnecessary fuel, resulting in low efficiency.

• For that reason, for usage in kitchen sinks and wash basins where a constant hot water temperature is not absolutely necessary and hot water discharge is often short and intermittent, turning off the auxiliary heat source stops unnecessary fuel burning and increases energy efficiency.

• Some solar connection units mix the solar heated water with the tap water even when the auxiliary heat source is turned off. As it mixes tap water when the solar heated water temperature is high, it provides enhanced safety.

• When the solar heated water temperate is lower than the preset domestic hot water temperature, the auxiliary heat source does not burn fuel and the domestic hot water temperature stays as is. It is often the case that this is sufficient for usage in kitchen sinks and wash basins. Turning on the auxiliary heat source only when the domestic hot water temperature is too low provides great energy saving benefits.

• In a system in which the hot water storage section and the auxiliary heat source are integrated, some models offer an energy saving mode as stated above (Fig. 6).

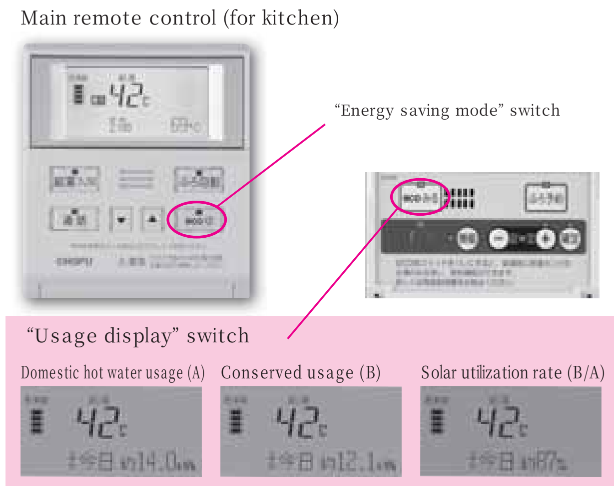


Fig. 6 Auxiliary heat source control panel

3.5.6 Explanation of Solar Water Heating Systems

Characteristics of solar water heating devices were described in 3.5.4 on p.106 and detailed explanation of each system is provided in this section. Please use this as a reference for understanding products.

1. Solar heat collection system + heat medium circulation method

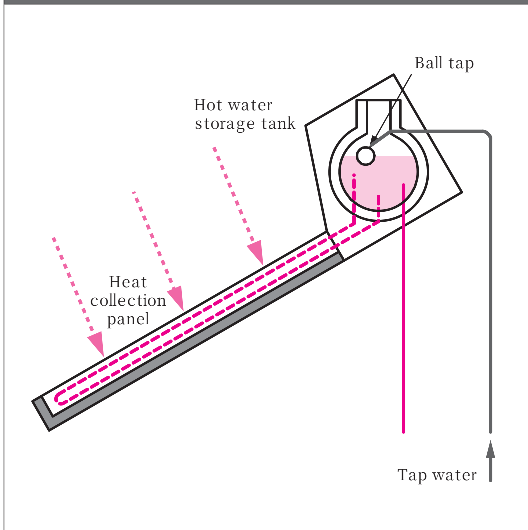
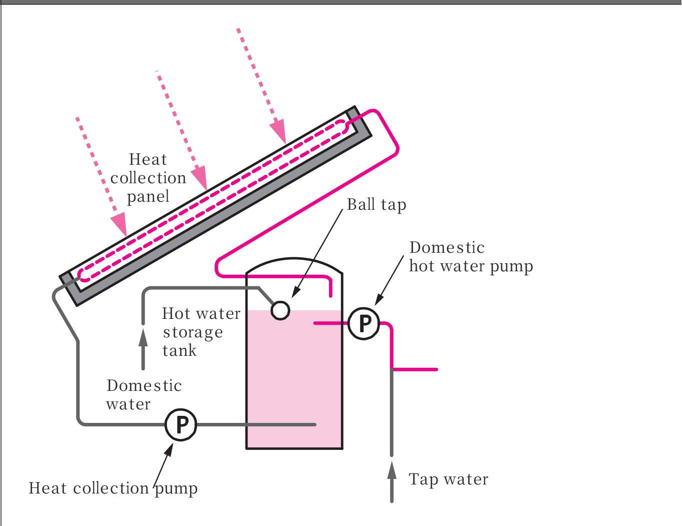
The solar heat collection system is regarded as the most important element that largely dictates the structures and characteristics of solar water heating devices. It determines factors such as weight and antifreezing of the heat collection section and water pressure. The following shows characteristics of each system.

1) Direct heat collection type (natural or forced circulation type)

Many of the direct heat collection devices are solar water heaters but some are photovoltaic systems. The direct heat collection is a system that directly sends water to the heat collection panels where it is heated for domestic hot water. There is a natural circulation type which circulates water by natural convection and a forced circulation type which circulates water with a pump (Table 9 (1) and (2)).

Because of its uncomplicated principles the system is often simple (particularly for the forced circulation type), and provides the benefit of high heat collection efficiency as it collects heat using water, which is used directly as domestic hot water. On the other hand, since the tap water carried to the heat collection section is considered unclean legally, it is necessary to cut off (release) from the water supply system in order to prevent a backflow into the tap water section. Additionally, the water pressure needs to be separately set during domestic hot water supply and antifreezing is difficult as the system circulates water.

Table 9 Principles and characteristics of solar water heating devices

(1) Direct heat collection type (natural circulation type) "Solar water heater" system	(2) Direct heat collection type (forced circulation type) Referred to as "water dripping photovoltaic system", etc.
 	
Operating principle • Water is supplied to hot water storage tank by water supply pressure. • Because of convection effect caused by change in water specific gravity due to temperature increase , low temperature water in tank descends to heat collection panels where it is heated. Once water becomes hot it ascends to hot water storage tank where it is stored. Characteristics • System has simple structure and is very common. • As hot water storage section is installed next to heat collection panels on roof, radiation heat loss is significant at night. • As hot water storage section is exposed to air, water supply pressure cannot be used during domestic hot water supply and hot water supply pressure is low. • As antifreezing is difficult, system needs to be shut down and emptied of water during winter in cold regions.	Operating principle • Water is sent to heat collection section by pump and heated during day when heat is collected. Heated water is drained back to hot water storage tank. • Water is not allowed to flow when heat is not collected at night and other times. Characteristics • Open structure does not allow the use of water supply pressure. Booster pump is essential for shower. • Low heat loss when heat is not collected. • As separate pump is required for heat collection and domestic hot water supply, power consumption tends to be high. • As it directly collects heat with water, the heat collection efficiency is relatively high. However, operation is difficult in winter in cold regions due to risk of freezing.

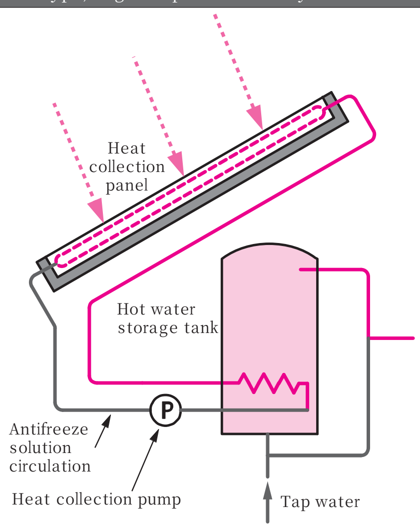
2) Indirect heat collection type (mostly forced circulation type)

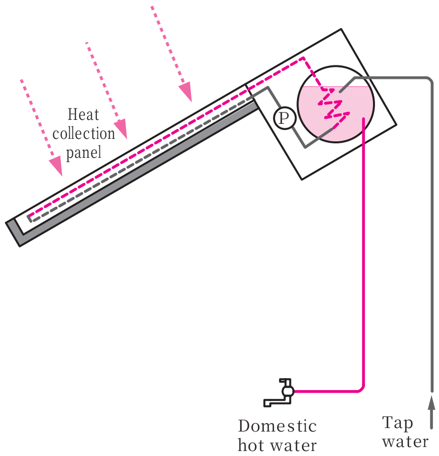
Indirect heat collection is a system that circulates the antifreeze solution instead of water between the heat collection section and the hot water storage section. The heat collection section collects heat while the hot water storage section heats tap water using a heat exchanger located inside the hot water storage tank. Many of the photovoltaic systems are of this type. The circulation of antifreeze solution is mostly performed by forced circulation using a pump. The hot water storage tank is generally separate from the heat collection section, but there are a few models that have these sections integrated (Table 9 (3) and (4)).

Since it neither sends water directly to the heat collectors nor exposes it to the air, the water in the hot water storage tank is considered clean and is allowed to be connected directly to the water supply system. Therefore, the water supply pressure can be used during domestic hot water supply and the shower can be used at a comfortable water pressure even without a booster pump. Since the antifreeze solution is circulated through the heat collection and piping sections, it helps prevent freezing in these sections. However, the antifreeze solution has inferior thermal properties to water and the efficiency is slightly lower than the direct heat collection device because the system indirectly heats water.

Since the indirect heat collection system is complicated, initial costs tend to be high and cost recovery may be difficult in terms of the domestic hot water use alone. In Europe, it is common to use the same hot water storage tank for space heating. Separately, since the high power consumption of the pump circulating the antifreeze solution decreases energy performance, it is required to select a product that has energy-saving features. This includes operating the pump only when needed, using a pump with low power consumption, and pump operation using solar cell power.

Table 9 Principles and characteristics of solar water heating devices





(3) Indirect heat collection type (forced circulation/separate type)Regular "photovoltaic system"	(4) Indirect heat collection type (forced circulation/integrated type)
Characteristics • As antifreeze solution is used in exposed outside pipes, system is resistant to freezing. • As hot water storage section is closed, water supply pressure can be directly used and domestic hot water pressure is high. • Separate space is required for installing hot water storage section. • Circulating pump tends to have large power consumption. • Complicated system makes it expensive.	Characteristics • Appearance is close to that of solar water heater (hot water storage location is different). • As hot water storage section is closed, water supply pressure can be directly used and shower can be comfortably used. • This model is in-between solar water heater and separate photovoltaic system. • As tap water pipes are exposed outside, system is less resistant to freezing. • Model which performs pump circulation using solar cells provides high energy saving effect.

2. Layout of heat collection and hot water storage sections

The layout of the heat collection and hot water storage sections can be either integrated or separate, and is generally determined by the heat collection system mentioned earlier. It is common that solar water heaters have an integrated layout and photovoltaic systems have a separate layout (Table 10 (1) and (2)).

3 Shapes of heat collection section

In order to effectively collect solar heat, it is naturally required that the heat collection section has high performance. The performance of the heat collection section depends on its radiation properties and insulation performance.

With regard to the requirements for radiation properties, it should be not only easy for the solar radiation (short waves from a high temperature heat source) to be absorbed, but also difficult for infrared rays (long waves from a low temperature heat source) to be radiated. Although former models of solar water heaters often had a heat collection unit that was simply painted black, it was easy to heat and cool as it easily absorbed solar radiation while easily radiating infrared rays. In recent years, the mainstream of devices are solar water

Table 10 Layout of heat collection and hot water storage sections

(1) Integrated type (direct heat collection and natural circulation are most common)	(2) Separate type
	Hot water storage tank   Heat collector
Characteristics ・Most of solar water heaters and some photovoltaic systems are of this type. ・Has simple structure and is generally inexpensive. ・As weight of hot water storage section is on roof, it has structural disadvantage. ・As heat collection and hot water storage sections are integrated, it offers little flexibility in system design.	Characteristics ・Many of photovoltaic systems are of this type. ・As only heat collection section is installed on roof, weight load is significantly reduced. ・Layout flexibility of heat collection section and hot water storage tank is high. ・Heat collection section has tidy and functional design. ・As circulation between heat collection and hot water storage sections stops when heat is not collected, radiation heat loss is reduced. ・Provides high system flexibility and can also be used for solar space heating and other systems. ・Has complicated structure and is generally expensive. ・As water, antifreeze or other solution is forcefully circulated by pump between heat collection and hot water storage sections, additional power consumption is required.

heaters boasting high heat collection efficiency using a "selective absorption membrane" that easily absorbs solar radiation but hardly radiates infrared rays. According to the Japanese Industrial Standards (JIS A 4111), at least 40% of heat collection efficiency is required (under outside air temperature conditions of at least 15°C).

Heat collection section shapes are largely classified into the insulation methods of the heat collection unit (black area coated with selective absorption membrane) and the transmission unit (glass). The flat plate type has a flat heat collection unit covered with insulation materials on the back and the transmission unit on the front. The vacuum tube type has a tubular heat collection unit that is protected by a tubular transmission unit and has vacuum gaps for reinforced insulation. The heat collection efficiency is not necessarily indicated in catalogs, but it is generally about 40 – 50% for the flat plate type and 50 – 60% for the vacuum tube type. In Japan, the flat plate type is most commonly used, but the vacuum tube type is often found outside Japan possibly because it is frequently installed in cold regions with poor weather. Both the flat plate and vacuum tube heat collectors are used in combination with various heat collection systems discussed earlier (Table 11 (1) and (2)).

Table 11　Shapes of heat collection section

(1) Flat plate heat collector	(2) Vacuum tube heat collector
	
Characteristics • Has simple structure and is inexpensive. • Very common in Japan. • White glass panels are highly efficient. • Difference between the gross area and effective heat collection area is insignificant. • Has slightly lower insulation performance and heat collection efficiency decreases in cold regions. • Suitable for heat collection of direct solar radiation and is highly efficient on sunny days, but is less efficient under diffused solar radiation on cloudy days.	Characteristics • As space between glass tube and heat collection section is vacuum insulated, it has high heat collection efficiency and freeze resistance even in cold regions. • Especially high efficiency for high temperature heat collection. • As heat collection section is tubular, ratio of effective heat collection area to gross area is limited (except those with external reflector). • As tubular sectional area is effective for heat collection, it is considered to be efficient on cloudy days. • No devices are produced in Japan. • Mainstream outside of Japan, such as in Europe and China. • Generally expensive, but inexpensive imported products have become available in recent years.

Implementing architectural measures against external impact, such as intense solar radiation in summer and cold temperatures in winter, using building envelopes to control and maintain the indoor environment is a vital technology. We must value this technology in order to take advantage of the full potential of natural energy and equipment so that we can create a comfortable living environment.

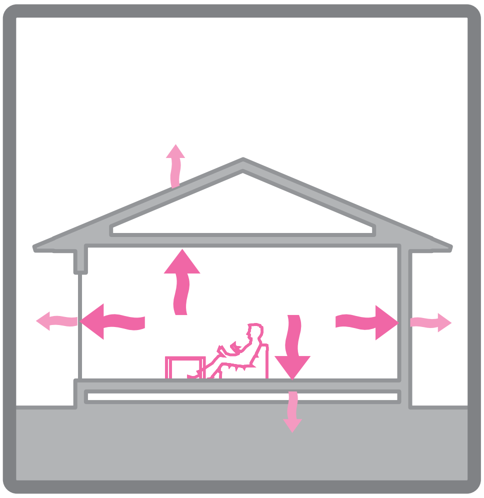
4

Chapter 4 :
Heat Control Technology of Building Envelopes

4

Chapter 4
Heat Control Technology of Building Envelopes
(Elemental Technology Application Method 2)

4.1 Insulated Building Envelope Planning for Zone V



Traditionally, people in warm regions have lived in a house with a thick thatched insulated roof, earth walls with high heat and moisture capacity, open layout, and many windows, whereas people in cold regions have endured harsh winters in a timber frame house filled with sawdust. Even though the purposes are different, these ancient techniques make maximum use of indigenous materials and create a pleasant living environment.

Recently, building insulation has been in the limelight as one of the elemental technologies to achieve energy conservation and an even living environment. As such, this section introduces several insulation techniques that are suitable for diverse housing styles and maintain appropriate temperatures as needed, with focus on the 'accessible technology' aspect of insulation by explaining its original purposes as faithfully as possible.

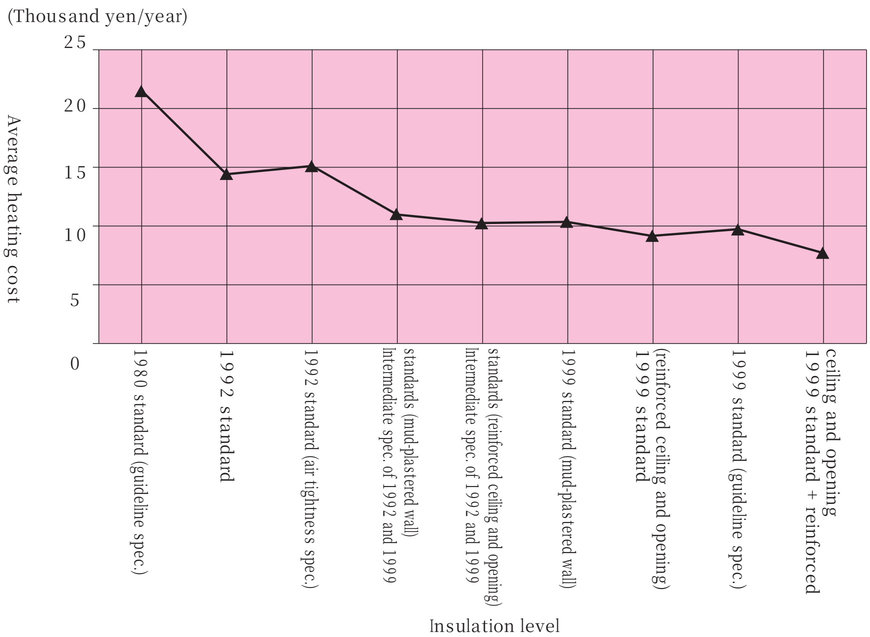
4.1.1 Purpose and Key Points of Insulated Building Envelope Planning

Note
Energy consumption, costs and other data described in this section are based on simulation results of the model house plan (See Chapter 6).

1. Controlling amount of energy used for heating

- The purpose of insulated building envelope planning is to control heat transfer at the boundary between the interior and exterior of the house, i.e. the building envelope. Insulated houses can achieve a comfortable indoor thermal environment using much less energy than uninsulated houses.
- Fig. 1 is a comparison graph of each insulation level of the energy conservation standard (See p.128), i.e. the 1992 standard, the intermediate insulation level of the 1992 standard and the 1999 standard, 1999 standard, and the 1980 standard. The higher the insulation level, the lower the heating cost.

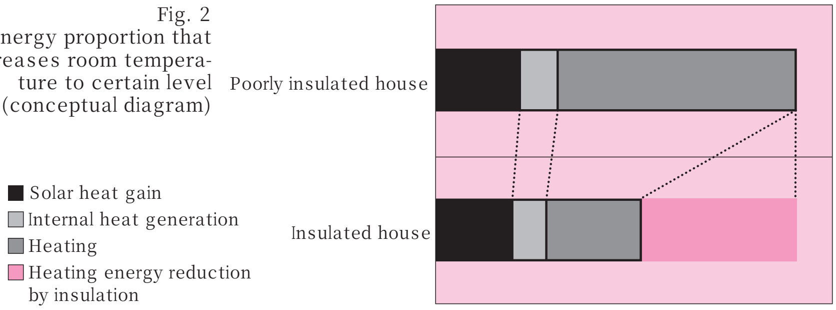
Fig. 1
Comparison of annual heating costs by difference in insulation level (Kagoshima)



■Conditions
Partial intermittent heating: Space heating is set at room temperature of 20 °C and is used only when occupants are in each room.

- In other words, heating of a larger area is possible with less cost and energy.
- Two types of energy are found in houses: energy obtained from solar radiation (solar heat gain) and energy generated from daily activities (internal heat generation). Fig. 2 represents the image of how insulation reduces heating energy and increases the proportion of the solar heat gain and internal heat generation energy contributing to heating.
- If the house is not insulated, solar heat gain and internal heat generation escapes within a short period of time, but with insulation this energy becomes effective in raising the room temperature.

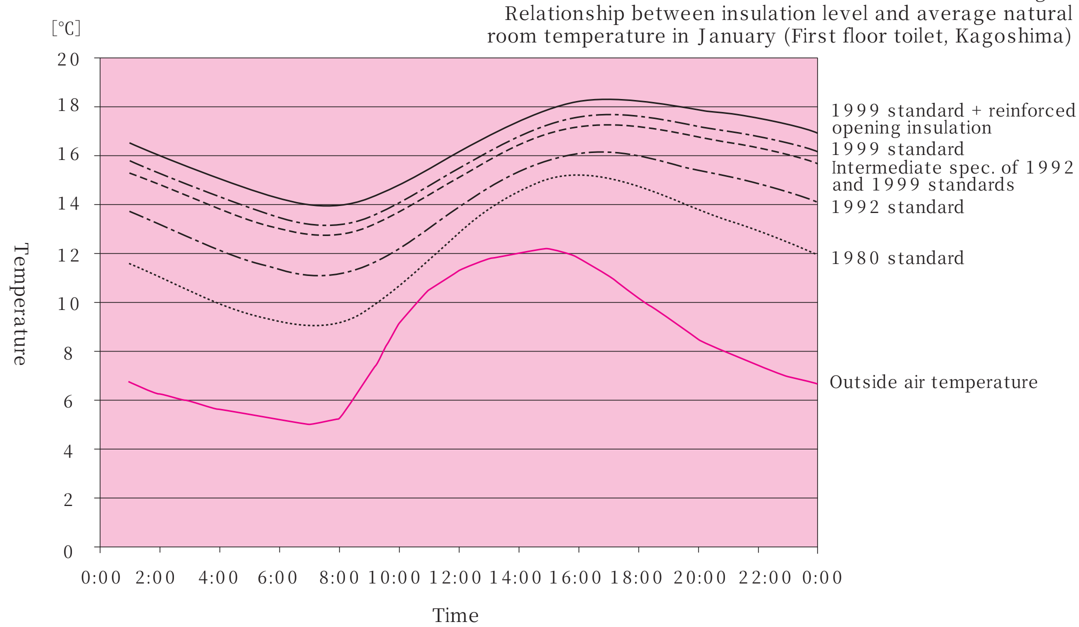
Fig. 2
Energy proportion that increases room temperature to certain level (conceptual diagram)



2. Maintaining natural room temperature

- Fig. 3 is a graph showing changes in the unheated room temperature (natural room temperature*) by insulation specifications. As shown in the graph, the higher the insulation level, the greater the room temperature compared to the outsideoutdoor air temperature.
- Even in an unheated room, the room temperature increases due to the heat coming from heated rooms as well as the solar heat gain and internal heat generation. Insulation can maintain a higher room temperature.

Fig. 3
Relationship between insulation level and average natural room temperature in January (First floor toilet, Kagoshima)



* Natural room temperature: Room temperature obtained from solar heat gain and internal heat generation without heating and cooling system. Here, this refers to natural room temperature of unheated first floor toilet when partial intermittent heating is used only in habitable rooms.

3. Attempts to equalize surface temperature of walls, floors and windows with room temperature

- Many of you must have experienced when the room feels somewhat cold even though the room temperature is not low. This occurs when there is a significant gap between the room temperature (air temperature) and perceived temperature (thermal sensation).
- Generally, thermal sensation perceived in living space is an average of the surface temperature of surrounding windows, walls, floors and other elements (mean radiant temperature) and the room temperature, as shown below.

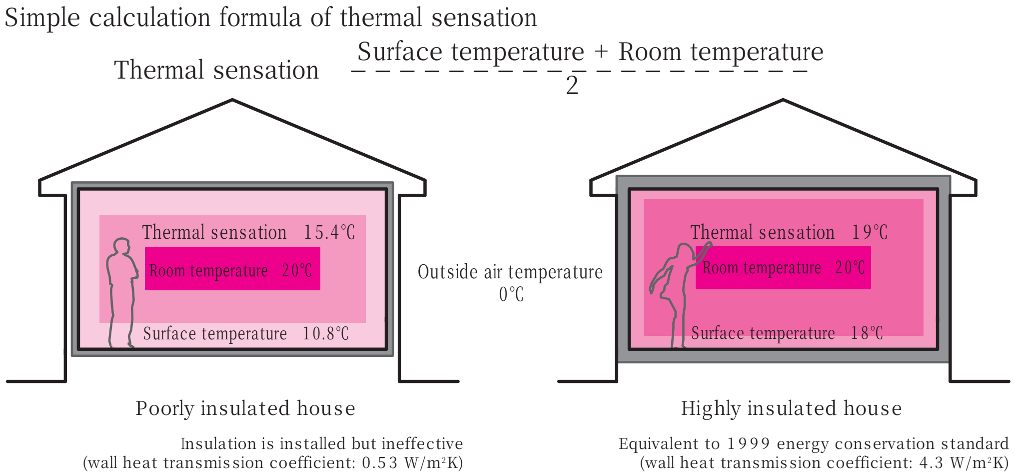


Fig. 4 Room temperature, surface temperature and thermal sensation

- Fig. 4 shows the difference in the room temperature and the thermal sensation between an uninsulated or hardly insulated house and a carefully insulated house. In the left diagram, the wall surface temperature is low and even when the room temperature is set at 20°C using space heating, thermal sensation is only 15.4°C. On the other hand, in the right diagram, since the house is well insulated, the surface temperature of building envelope is closer to room temperature, if the room temperature is set at 20°C in the same way as the left diagram, a thermal sensation of 19°C is felt.
- As described above, simply raising the air temperature does not achieve sufficient warmth within the home. It is necessary to attempt to equalize the surface temperature of walls and other surroundings to the room temperature and reduce the temperature difference between the thermal sensation and the room temperature by insulating the house.

4. Increasing temperature around the feet

- One of the causes of feeling cold is a chilly feeling around the feet. This is due to lack of insulation and air leakage (Fig. 5). Even when the room is heated, it is not comfortable if occupants feel warm around the upper area of the room but their feet are cold.
- Reinforcing the insulation performance of floors (i.e. installing insulation and air leakage prevention) increases the floor surface temperature and reduces the vertical temperature gradient and temperature irregularity within the house.

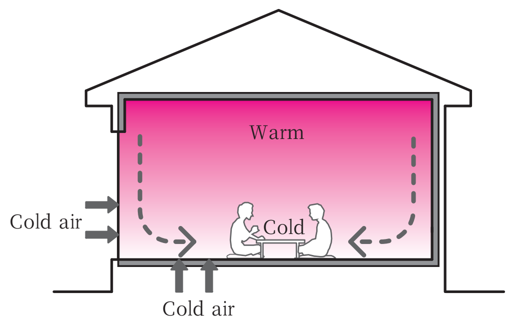
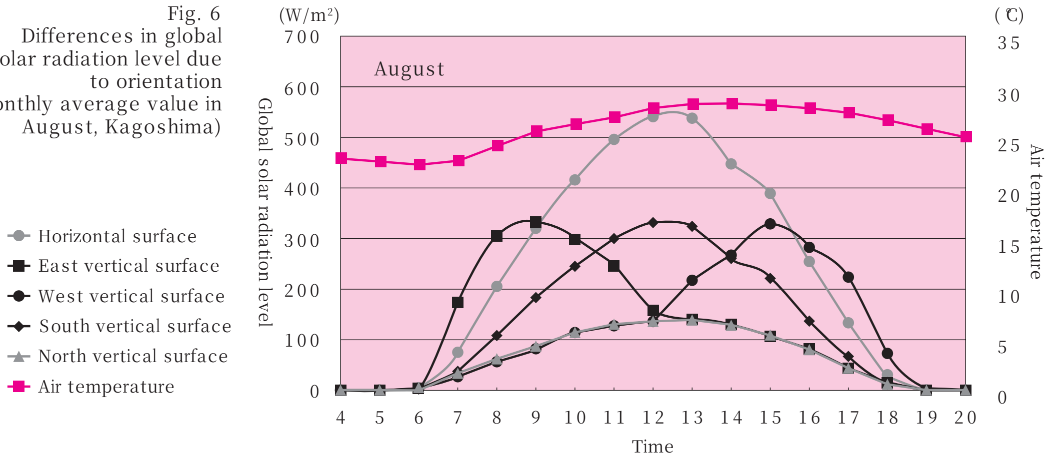


Fig. 5 Indoor vertical temperature gradient

5. Shading solar radiation heat from roof to reduce heat in upper floor rooms

- Horizontal surfaces receive a large amount of solar radiation heat in summer (Fig. 6). Thus, the roof temperature reaches 60 – 70°C in summer.
- Reinforcing roof and ceiling insulation prevents solar radiation heat received on the roof from entering the house and reduces the heat in the upper floor rooms.
- However, a ventilated cavity (at least approx. 30 mm) is required if the roof is insulated and an attic ventilation is required if the ceiling is insulated (See 4.3 Solar Shading Methods for Zone V for details).

Fig. 6
Differences in global solar radiation level due to orientation (monthly average value in August, Kagoshima)



Comment ● Relationship between houses and external environment

Many of you might think houses have less of a relationship with the outside environment (wind, light, warmth and coolness) as their insulation level increases.

However, in fact, by skillfully combining the advanced insulation technology (e.g. openings with high insulation performance) with the cross ventilation and solar shading technology in the summer and in-between seasons, we can maximize the "comfort" brought from nature into the house while ensuring a pleasant indoor environment using a heating and cooling system in winter and during severe summer months.

Insulation is a fundamental housing technology that increases the relationship between the house and the external environment and corresponds to diverse lifestyles.

4

Chapter 4
Heat Control Technology of Building Envelopes
(Elemental Technology Application Method 2)

4.1.2 Energy Conservation Target Levels for Insulated Building Envelope Planning

1. Definition of target levels

・Energy conservation target levels for insulated building envelope planning have been set at levels 1-4 below and indicate the reduction rate of energy consumed by heating systems.

Level 0	:	Heating energy reduction rate	None
Level 1	:	Heating energy reduction rate	Approx. 30% (Approx. 40%)
Level 2	:	Heating energy reduction rate	Approx. 50% (Approx. 50%)
Level 3	:	Heating energy reduction rate	Approx. 55% (Approx. 60%)
Level 4	:	Heating energy reduction rate	Approx. 65% (Approx. 70%)

Energy reduction rates shown above indicate calculated values when partial intermittent heating is set at 20°C in major habitable rooms with occupants (values in parentheses are for when whole-building continuous heating is set at 18°C).

・Target levels are set by the heat loss coefficient[1] according to the current energy conservation standard[2].

・The standard heating energy consumption as of 2000 was 5.0 GJ (approximately 7% of overall energy consumption) for partial intermittent heating and 13.4 GJ (approximately 13%) for whole-building continuous heating (See 6.1 on p.339).

※1 Heat loss coefficient
This refers to a numerical indicator of housing insulation performance and is generally known as Q value. The lower this value the higher the insulation performance. Heat loss coefficient is obtained by calculating the amount of heat (heat loss) that escapes from exterior walls, ceilings, floors and other components of the house as well as the heat loss due to ventilation and air leakage and dividing the result by the total floor area of the house. This is the amount of heat (joules) which escapes outside the house per unit of time (seconds) and $1m^2$ of floor area when the indoor and outdoor temperature difference is 1°C.

※2 Energy conservation standards
Refers to the standard established according to the Law Regarding the Rationalization of Energy Use (Energy Conservation Law) enacted in 1979. Since its establishment in 1980, this standard has been amended and reinforced in 1992 and 1999. The 1980, 1992 and 1999 standards are sometimes referred to as the “Former Energy Conservation Standards”, “New Energy Conservation Standards” and “Next Generation Energy Conservation Standards”, respectively. These standards are almost equivalent to Grades 2, 3 and 4 of the energy saving grading based on the evaluation method standard of the Housing Performance Indication System.

2. How to achieve target levels

・Energy conservation target levels for insulated building envelope planning can be achieved by applying insulation methods that satisfy each value of heat loss coefficient (Table 1).

・Level 0 serves as reference level that is equal to or below the 1980 energy conservation standard. Level 2 refers to insulation performance equivalent to Region III of the 1992 energy conservation standard.

・Please use as reference Table 1 which shows the corresponding relationship between the target levels and the grades based on the energy saving grading (related to thermal environment) of the Housing Performance Indication System.

Table 1 Target Levels for Insulated Building Envelope Planning

Target level	Energy saving effect (heating energy reduction rate)		Heat loss coefficient	Corresponding energy conservation standard	Grade according to energy saving grading of Housing Performance Indication System
	Partial intermittent heating	Whole-building continuous heating			
Level 0	0	0	8.3 W/m²K or below	Insulation level equivalent to 1980 energy conservation standard, etc.	Grade 1 (not satisfying 1980 standard) or Grade 2 (equivalent to 1980 standard)
Level 1	Approx. 30%	Approx. 40%	4.6 W/m²K or below	Insulation level equivalent to 1992 energy conservation standard	Grade 3
Level 2	Approx. 50%	Approx. 50%	3.3 W/m²K or below	Insulation level equivalent to intermediate of 1992 and 1999 energy conservation standards	Grade 3
Level 3	Approx. 55%	Approx. 60%	2.7 W/m²K or below	Insulation level equivalent to 1999 energy conservation standard	Grade 4
Level 4	Approx. 65%	Approx. 70%	2.1 W/m²K or below	Insulation level exceeding 1999 energy conservation standard	Grade 4

3. Target housing construction methods

- This chapter covers the following two housing construction methods and explains the insulation technology that takes into account the characteristics of each construction method. It shows the example methods for achieving the target levels of insulated building envelope planning.
  - a. Average conventional timber frame house
  - b. Traditional conventional timber frame house (typical example: mud plastered wall)
- This chapter is targeted at houses in South Kyushu and other hot humid regions (Zone V of the zone classification of the energy conservation standard). There are various construction methods for conventional timber frame houses reflecting regional characteristics in Zone V.
- This chapter emphasizes the importance of examining insulation methods suitable for each housing construction method, rather than examining housing construction methods that focus on insulation. Therefore, we have chosen a mud plastered wall construction as a typical example of traditional conventional timber frame houses to explain insulation methods as well as a stud wall construction and other average conventional timber frame houses.

4.1.3 Steps for Examining Insulated Building Envelope Planning and Setting Target Levels

1. Steps for examining insulated building envelope planning

Step 1 Confirming lifestyle orientation and other conditions and setting target level

Confirm the lifestyle orientation of occupants, housing structure, construction cost and other conditions and examine and set the target insulation level suitable for those conditions.

1) Confirm lifestyle orientation
2) Confirm insulation construction budget
3) Confirm housing structure and form
   - Average conventional timber frame house
   - Traditional conventional timber frame house (mud plastered wall)

▼

Step 2 Examining insulation plans

Examine the basic plans for insulated building envelope planning for houses.

1) Examine insulation methods (interior insulation, exterior insulation, combined insulation)
2) Examine insulation planning methods for each target level
   (distribution for building components: evenly distributed or partially reinforced insulation type)

▼

Step 3 Examining insulation technology

Examine specific insulation technology and methods.

1) Examine insulation technology for building envelopes
   - Insulation material types and considerations for installation
   - Basic structure of thermal barrier
   - Airflow blocking installation
   - Insulation material installation
   - Examination of insulation methods for each component
2) Examine insulation technology for openings
   - Window selection
   - Sash selection
   - Reinforced insulation with interior and exterior coverings
   - Insulation effects by insulating shutters

4

Chapter 4
Heat Control Technology of Building Envelopes
(Elemental Technology Application Method 2)

2. Confirming lifestyle orientation and other conditions and setting target level

As the first step for examining the insulated building envelope planning, identify and summarize the lifestyle and housing needs of occupants and set the target level.

1) Desired thermal environment

- Typical indicators of the quality of indoor thermal environment in warm regions and hot humid regions including South Kyushu are the temperature irregularity (temperature difference) between the upper and lower areas of the room and between the rooms as well as the decrease in room temperature after stopping heating.
- Table 2 shows these two indicators according to the target level.
- 1) and 2) in Table 2 show the temperature difference between the heated and unheated rooms when heating is used and the difference between the outside air temperature during the dawn hours and the natural room temperature (outcome temperature), respectively. Both change according to the insulation level.
- Although the value difference in Table 2 may not seem very significant, the borderline between comfort and discomfort is markedly influenced by a small difference of 1 – 2°C.
- Based on the above information, confirm with the occupants what their desired thermal environment is before setting the target level.

* Difference between outside air temperature and room temperature (natural room temperature)
In this section, this refers to the difference between outside air temperature and room temperature (natural room temperature) when the outside air is the lowest during the hours of dawn.

Table 2 Insulation level and temperature difference

Insulation level	1) Heated and unheated rooms when heating is used	2) Outside air temperature and room temperature (natural room temperature)*
Level 0	Approx. 7°C	Approx. 4°C
Level 1	Approx. 5.5°C	Approx. 6°C
Level 2	Approx. 4°C	Approx. 7.5°C
Level 3	Approx. 3°C	Approx. 8°C
Level 4	Approx. 2.5°C	Approx. 9°C

■Conditions
House plan: Model house (Type A) (See Chapter 6)
Heated room: Living/dining room
Heating schedule:
7:00 – 10:00
12:00 – 14:00
16:00 – 22:00
(Set temperature: 20°C)

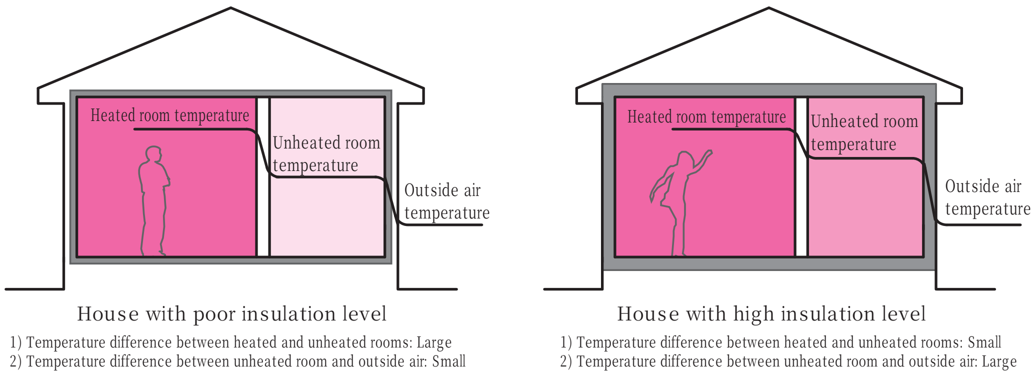


Fig. 7 Temperature difference of heated room, unheated room and outside air (concept diagram)

2) Energy cost efficiency resulting from increased insulation level

- If conditions such as the house plan, way of living, heating and cooling system and its operating hours are exactly the same, even a low level of insulation is definitely effective in energy and cost savings. The effect is higher as the heating duration becomes longer and the heating area becomes larger.
- Fig. 8 shows an example of annual heating and cooling cost by insulation level. The higher the insulation level the greater the energy consumption reduction. In the case of partial intermittent heating and cooling, the heating and cooling energy cost (running cost) of Level 0 decreases 21% at Level 1, 33% at Level 2, 34% at Level 3, and 40% at Level 4.
- Please refer to this information when setting the target level.

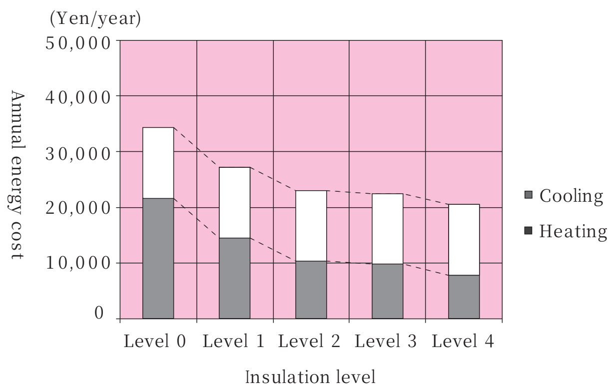


Fig. 8 Insulation level and heating and cooling cost (partial intermittent heating and cooling)

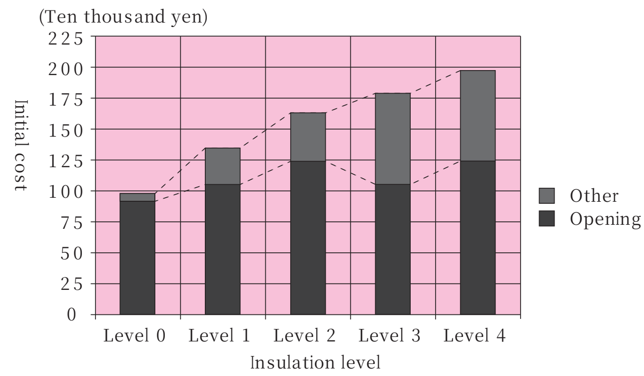


Fig. 9 Insulation level and initial cost

3) Initial cost due to increased insulation level

- The average rise in the initial cost due to increased insulation level is shown in Fig. 9.
- This information is based on the approximate calculation of the specifications covered in this document and should be used as a guideline.

4) Housing structure

- In addition to a stud wall construction and other structures and construction methods for average conventional timber frame houses, this chapter discusses mud plastered wall houses as an example of traditional conventional timber frame houses.
- Compared to stud wall houses, it is difficult to incorporate insulation into mud plastered wall houses as it is structurally challenging to fill thick insulation materials in these houses.
- Nevertheless, a number of variations are found in insulated building envelope technologies. There are insulated building envelope technologies appropriate for the construction characteristics of even mud plastered wall houses. Please refer to some of these technologies introduced in this chapter when setting the target level for insulated building envelope technology suitable for various construction methods.

Comment ● High insulation level does not result in cost savings?

It has been reported that a high level of insulation does not necessary lead to reductions in heating and cooling energy (cost). Major reasons for this are as follows:

①When the house is insulated, occupants leave indoor space open (e.g. leaving doors open) and the heating and cooling area tends to increase compared to before insulation is installed, resulting in increased heating and cooling energy.

②Many architects, builders and occupants believe that whole-building air conditioning is suitable for insulated houses and sometimes air conditioning planning that exceeds the needs of occupants is implemented, resulting in increased heating and cooling energy.

However, this does not mean that a high insulation level does not lead to energy saving. As described earlier, under the same conditions, housing insulation definitely achieves cost savings. Alternatively, with the same energy cost, you can heat and cool a wider area for longer hours.

4.1.4 Examining Insulation Planning

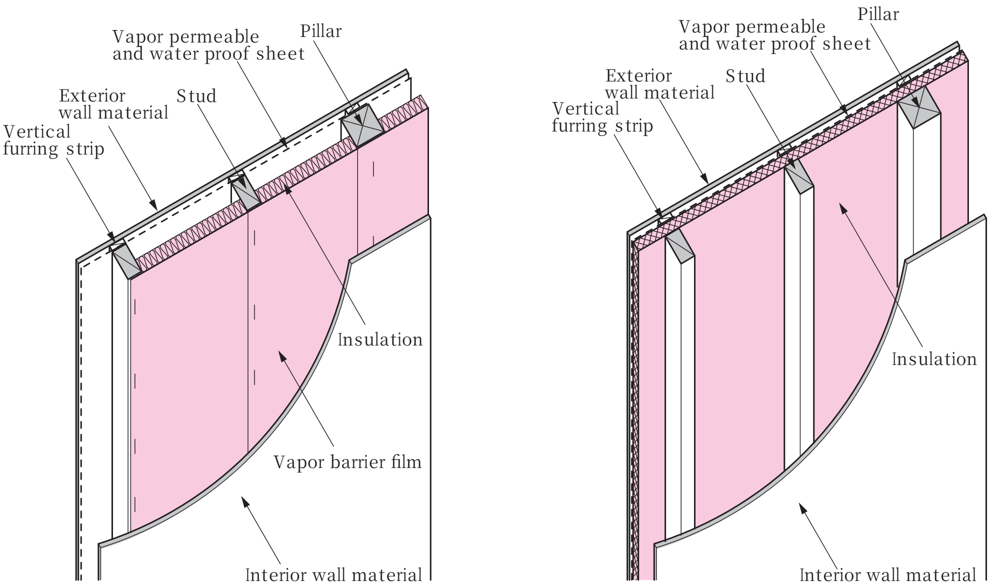
1. Selecting insulation methods

- Insulation methods of wooden houses are largely classified into the following two types: interior insulation and exterior insulation (Fig. 10).
  ①Interior insulation: Refers to an insulation installation method in which insulation is installed between the structural materials such as pillars and studs, rafters and beams.
  ② Exterior insulation: Refers to an insulation installation method in which a thermal barrier is installed on the exterior side of the frame and structure.
- It is not that we have to choose either of these methods and use it for insulating the entire house. As both methods have advantages and disadvantages, it is important to choose the method suitable for each component of the house. In cold regions, sometimes both interior and exterior insulation methods (also referred to as "interior and additional insulation method") are used for the same component in order to ensure thick insulation.
- There are two types of insulation method for the top of the building (roof area): ceiling insulation and roof insulation. Of the ceiling insulation, insulation above beams is not yet commonly practiced, but this method is designed to reduce thermal bridges and it can use various insulation materials.
- The three insulation methods for the bottom of the building (floor area) are floor insulation, foundation insulation and slab on grade insulation.

Table 3 summarizes insulation methods for wooden houses by component (For details, see 5) Examining insulation method for each component in Section 4.1.5 Examining Insulation Technology on p.146).

Table 3 Insulation methods for wooden houses

Building component	Insulated component	Insulation method
Top of building (roof area)	Ceiling insulation	Interior insulation
		Exterior insulation (insulation above beams)
	Roof insulation	Interior insulation
		Exterior insulation
		Combined insulation (interior and additional insulation)
Exterior wall	Exterior wall insulation	Interior insulation
		Exterior insulation
		Combined insulation (interior and additional insulation)
Bottom of building (floor area)	Floor insulation	Interior insulation
	Foundation insulation	Exterior insulation (exterior or interior of foundation)
	Slab on grade insulation (slab on grade entrance, etc.)	



Interior insulation by batt insulation
Exterior insulation by board (plastic foam) insulation

Fig. 10 Interior insulation and exterior insulation

2. Distribution for each building component

1) Evenly distributed insulation type (Fig. 11 ①)

Energy conservation standards stipulate the insulation standard by component (i.e. required heat resistance value and thickness of insulation) as a guideline for design and installation. The insulation standard by component is established by taking into account the balance of the insulation performance of each component (referred to as "evenly distributed insulation type" in this document). Adopting this standard helps you plan how to achieve the target level.

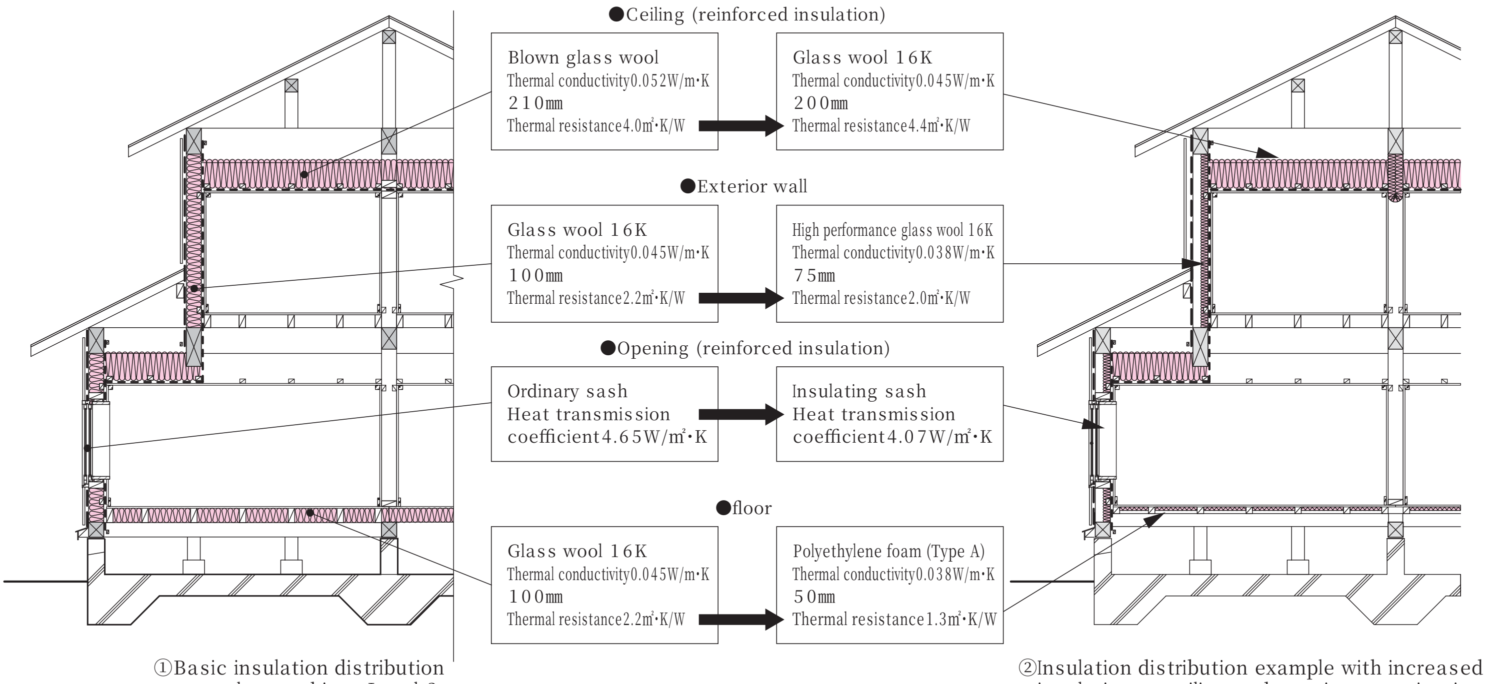
2) Partially reinforced insulation type (Fig. 11 ②)

Depending on the building construction method, for example in the case of a mud-plastered wall or Japanese style wall construction method, it is difficult to install thick insulation materials in the exterior wall. If this is the case, reinforcing the insulation of other components than the exterior wall will reduce the insulation requirement of the exterior wall (referred to as "partially reinforced insulation type" in this document).

4.1.6 Examples of Insulation Planning shows specific insulation examples by target level (See pp.155-163).

For the evenly distributed insulation type, three cases of interior insulation, insulation above beams/foundation insulation and exterior insulation are presented for Level 3.

For the partially reinforced insulation type, five cases of reinforced insulation at the ceiling and openings are shown for Level 1 to 3, in consideration of heat protection and control measures in summer for Zone V, which is a hot humid region according to the zone classification of energy conservation standard.



①Basic insulation distribution example to achieve Level 3 (evenly distributed insulation type)

②Insulation distribution example with increased insulation at ceiling and opening to maintain Level 3 (partially reinforced insulation type)

Fig. 11 Insulation planning methods (distribution to components)

Thermal conductivity : A measure of a material's ability to conduct heat. The amount of heat flow through a material of unit area and unit thickness in unit time when there is a temperature difference of 1°C between its surfaces (Units are W/m·K).

Thermal resistance : A measure of a material's ability to resist heat conduction (Units are m²·K/W).

Heat transmission coefficient : The amount of heat flow per unit area and unit time when there is an air temperature difference between surfaces of windows, walls, etc. (Units are W/m²·K). Heat transmission coefficient is used to express insulation performance of window sashes.

4.1.5 Examining Insulation Technology

This section explains insulation technology for building envelopes and openings. Insulation technology has significantly advanced as the need for energy conservation has become widely recognized. Flaws of building envelopes, such as sagging after installation, have been solved since insulation materials and their installation methods have greatly improved. Insulating sashes that are excellent in both quality and performance are available for openings.

1. Examining insulation technology for building envelopes

The insulation performance we aim for cannot be achieved by simply filling insulation materials into the walls. Moreover, it is necessary to address internal condensation and other obstacles. This section explains insulation technology for building envelopes which are the basics of insulation. Table 4 shows a list of thermal conductivity of insulation materials and minimum thickness to obtain the required thermal resistance.

1) Types and characteristics of insulation materials

Major types and characteristics of insulation materials are as shown below:

①Batt insulation

Batt insulation refers to fiber insulation materials such as glass wool and rock wool. This insulation material can be used in a wide range of components and is most commonly used because of its size adjustability, ease of cutting and installation, low cost and incombustibility. Some disadvantages are that its breathability decreases its insulation performance if there is airflow in the thermal barrier and its flexibility tends to cause variable insulation performance depending on the installation quality. For that reason, it is necessary to ensure ventilation control at the connections between the walls and the floors and ceilings in order to prevent airflow within the walls and insulation materials. It also requires that insulation materials are properly and firmly installed in the required areas inside the building envelope.

②Blown-in insulation

This is a type of loose-fill insulation that is blown into the ceiling, roof, walls and other components. Examples of materials include glass wool, rock wool and cellulose fiber. Even though its insulation performance is slightly lower than that of batt insulation when comparing materials with the same thickness, it is generally easy to install especially for ceiling insulation.

③Board insulation

This insulation material is often used in the exterior insulation method for floor insulation and on the outside of the building frame. Types of materials include plastic foam insulation materials such as extruded polystyrene foam, expanded polystyrene foam, rigid urethane foam, polyethylene foam and phenolic foam, as well as glass wool and rock wool. Generally, it has higher insulation performance than batt insulation when comparing materials with the same thickness.

The finer the foam and the higher the structural independence, the greater the insulation performance of plastic board insulation. Additionally, owing to its low water absorption rate, this material is less susceptible to moisture problems found with batt insulation. The disadvantage is that it needs to be used with a fire-resistant exterior finish when installed on the exterior side of the frame or structure as it is prone to fire and UV damage.

④Foamed-in-place insulation

Foamed-in-place insulation materials such as spray urethane foam insulation are best characterized by their ease of installation. Nevertheless, there are some cases in which insulation is installed with an improper expansion ratio and installation environment. It is important to follow the installation specification.

Note
With regard to urethane foam and extruded polystyrene foam insulation, CFC-free materials should be used from this point forward, from the perspective of preventing global warming and ozone depletion.

Table 4 Quick reference for minimum thickness (d) of insulation materials to obtain required thermal resistance (Unit: mm) d= λ ×Rc×1000

		Thermal conductivity λ Unit:W/m·K																									
		0.052	0.051	0.050	0.049	0.047	0.045	0.044	0.043	0.042	0.040	0.039	0.038	0.037	0.036	0.035	0.034	0.033	0.032	0.030	0.029	0.028	0.027	0.026	0.024	0.023	0.022
Thermal resistance value Rc (m²·K/W)	0.2	11	11	10	10	10	9	9	9	9	8	8	8	8	8	7	7	7	7	6	6	6	6	6	5	5	5
	0.3	16	16	15	15	15	14	14	13	13	12	12	12	12	11	11	11	10	10	9	9	9	9	8	8	7	7
	0.4	21	21	20	20	19	18	18	18	17	16	16	16	15	15	14	14	14	13	12	12	12	11	11	10	10	9
	0.5	26	26	25	25	24	23	22	22	21	20	20	19	19	18	18	17	17	16	15	15	14	14	13	12	12	11
	0.6	32	31	30	30	29	27	27	26	26	24	24	23	23	22	21	21	20	20	18	18	17	17	16	15	14	14
	0.7	37	36	35	35	33	32	31	31	30	28	28	27	26	26	25	24	24	23	21	21	20	19	19	17	17	16
	0.8	42	41	40	40	38	36	36	35	34	32	32	31	30	29	28	28	27	26	24	24	23	22	21	20	19	18
	0.9	47	46	45	45	43	41	40	39	38	36	36	35	34	33	32	31	30	29	27	27	26	25	24	22	21	20
	1.0	52	51	50	49	47	45	44	43	42	40	39	38	37	36	35	34	33	32	30	29	28	27	26	24	23	22
	1.1	58	57	55	54	52	50	49	48	47	44	43	42	41	40	39	38	37	36	33	32	31	30	29	27	26	25
	1.2	63	62	60	59	57	54	53	52	51	48	47	46	45	44	42	41	40	39	36	35	34	33	32	29	28	27
	1.4	73	72	70	69	66	63	62	61	59	56	55	54	52	51	49	48	47	45	42	41	40	38	37	34	33	31
	1.5	78	77	75	74	71	68	66	65	63	60	59	57	56	54	53	51	50	48	45	44	42	41	39	36	35	33
	1.7	89	87	85	84	80	77	75	74	72	68	67	65	63	62	60	58	57	55	51	50	48	46	45	41	40	38
	1.8	94	92	90	89	85	81	80	78	76	72	71	69	67	65	63	62	60	58	54	53	51	49	47	44	42	40
	2.0	104	102	100	98	94	90	88	86	84	80	78	76	74	72	70	68	66	64	60	58	56	54	52	48	46	44
	2.1	110	108	105	103	99	95	93	91	89	84	82	80	78	76	74	72	70	68	63	61	59	57	55	51	49	47
	2.2	115	113	110	108	104	99	97	95	93	88	86	84	82	80	77	75	73	71	66	64	62	60	58	53	51	49
	2.3	120	118	115	113	109	104	102	99	97	92	90	88	86	83	81	79	76	74	69	67	65	63	60	56	53	51
	2.5	130	128	125	123	118	113	110	108	105	100	98	95	93	90	88	85	83	80	75	73	70	68	65	60	58	55
	2.6	136	133	130	128	123	117	115	112	110	104	102	99	97	94	91	89	86	84	78	76	73	71	68	63	60	58
	2.7	141	138	135	133	127	122	119	117	114	108	106	103	100	98	95	92	90	87	81	79	76	73	71	65	63	60
	2.9	151	148	145	143	137	131	128	125	122	116	114	111	108	105	102	99	96	93	87	85	82	79	76	70	67	64
	3.0	156	153	150	147	141	135	132	129	126	120	117	114	111	108	105	102	99	96	90	87	84	81	78	72	69	66
	3.1	162	159	155	152	146	140	137	134	131	124	121	118	115	112	109	106	103	100	93	90	87	84	81	75	72	69
	3.2	167	164	160	157	151	144	141	138	135	128	125	122	119	116	112	109	106	103	96	93	90	87	84	77	74	71
	3.3	172	169	165	162	156	149	146	142	139	132	129	126	123	119	116	113	109	106	99	96	93	90	86	80	76	73
	3.5	182	179	175	172	165	158	154	151	147	140	137	133	130	126	123	119	116	112	105	102	98	95	91	84	81	77
	3.6	188	184	180	177	170	162	159	155	152	144	141	137	134	130	126	123	119	116	108	105	101	98	94	87	83	80
	3.8	198	194	190	187	179	171	168	164	160	152	149	145	141	137	133	130	126	122	114	111	107	103	99	92	88	84
	4.0	208	204	200	196	188	180	176	172	168	160	156	152	148	144	140	136	132	128	120	116	112	108	104	96	92	88
	4.1	214	210	205	201	193	185	181	177	173	164	160	156	152	148	144	140	136	132	123	119	115	111	107	99	95	91
	4.2	219	215	210	206	198	189	185	181	177	168	164	160	156	152	147	143	139	135	126	122	118	114	110	101	97	93
	4.5	234	230	225	221	212	203	198	194	189	180	176	171	167	162	158	153	149	144	135	131	126	122	117	108	104	99
	4.6	240	235	230	226	217	207	203	198	194	184	180	175	171	166	161	157	152	148	138	134	129	125	120	111	106	102
	5.0	260	255	250	245	235	225	220	215	210	200	195	190	185	180	175	170	165	160	150	145	140	135	130	120	115	110
	5.2	271	266	260	255	245	234	229	224	219	208	203	198	193	188	182	177	172	167	156	151	146	141	136	125	120	115
	5.5	286	281	275	270	259	248	242	237	231	220	215	209	204	198	193	187	182	176	165	160	154	149	143	132	127	121
	5.7	297	291	285	280	268	257	251	246	240	228	223	217	211	206	200	194	189	183	171	166	160	154	149	137	132	126
	6.0	312	306	300	294	282	270	264	258	252	240	234	228	222	216	210	204	198	192	180	174	168	162	156	144	138	132
	6.6	344	337	330	324	311	297	291	284	278	264	258	251	245	238	231	225	218	212	198	192	185	179	172	159	152	146
Residential glass wool insulation				10K			16K			20K			24K		32K												
High performance glass wool insulation													16K		24K	32K	40K	48K									
Blown glass wool insulation		GW-1・GW-2 (※)									30K・35K																
Residential rock wool insulation													Mat・Batt		Board												
Blown rock wool insulation						25K						65K															
Type A expanded polystyrene foam board insulation									No.4		No.3			No.2	No.1		Special										
Type A extruded polystyrene foam board insulation											Type 1						Type 2					Type 3					
Type A rigid urethane foam board insulation																					Type 1	Type 2 No.4	Type 2 No.3		Type 2 No.2	Type 2 No.1	
Spray rigid urethane foam for building insulation											Type A3								Type A1・Type A2								
Type A polyethylene foam board insulation										Type 1 No.1・Type 1 No.2			Type 2				Type 3										
Type A phenolic foam board insulation															Type 2 No.1	Type 3 No.1・Type 3 No.2	Type 2 No.2					Type 2 No.3					Type 1 No.1・Type 1 No.2
Blown cellulose fiber insulation											25K・45K・55K																
Insulation material group		A1		A2			B				C						D					E					F

K = kg/m³ (density) * GW-1: 13K installation density; GW-2: 18K installation density

Source: Explanation of Energy Conservation Standards for Housing (Third Revision), Institute for Building Environment and Energy Conservation, p.114

How to use Table 4 (example)

E.g. 1: To find the thermal conductivity of Type A polyethylene foam board insulation (Type 2), search Type 2 in the applicable row towards the right and go up the column until you reach 0.038 W/m・K of thermal conductivity at the top of the table.

E.g. 2: The required thickness for residential glass wool insulation 16K to achieve a thermal resistance value of 4.0 m²・K/W is 180 mm, which can be obtained by finding where the column of residential glass wool insulation 16K meets the row of target thermal resistance of 4.0. The thermal conductivity of residential glass wool insulation 16K is 0.045 W/m・K.

2) Basic structure of thermal barrier

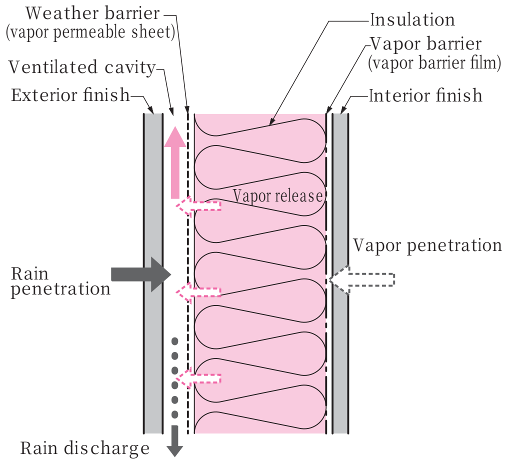
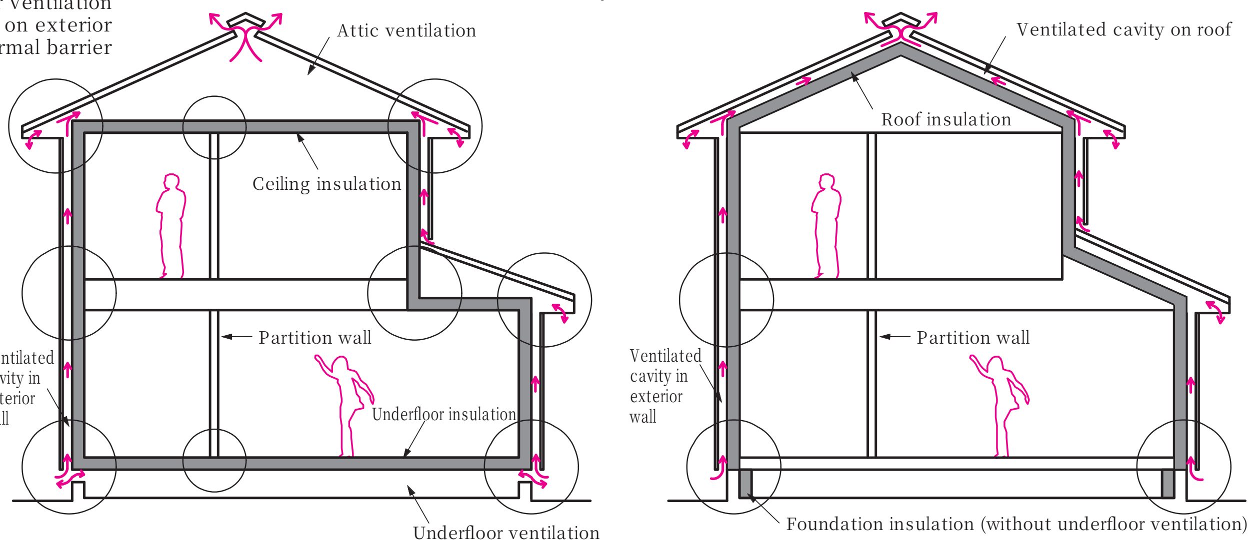


Fig. 12 Basic structure of thermal barrier (exterior wall)

- When there are four family members in the house, about 3 to 5 L of moisture is generated per day from their bodies and daily activities. If this moisture penetrates the walls and roof and remains there in winter, it is cooled and results in internal condensation. To prevent this, we need to take measures such as installing a vapor barrier[1] as continuous as possible on the interior side of the insulation.
- There is a risk of condensation caused by moisture that has seeped through small gaps in the vapor barrier as well as contained in insulation, wood and plywood that remains in the insulation. To prevent this and promote drying of the interior of the structure, a ventilated cavity is installed in the exterior wall and underfloor ventilation and attic ventilation are ensured to expose the exterior side of the insulation to the outside air (Fig. 13).
- When using glass wool and other fiber insulation materials, it is necessary to install a vapor-permeable weather barrier[2] which resists wind on the exterior side of the insulation. Waterproof or water-repellent materials should be selected for the weather barrier materials so that the rain seeping from the exterior finish and other materials does not wet the interior of the structure.
- As discussed above, the basic structure of the thermal barrier consists of a highly vapor resistant vapor barrier on the interior side of the insulation, a weather barrier that is vapor-permeable, wind-resistant and waterproof on the exterior side of the insulation, and a ventilated cavity (Fig. 12).
- Approximately 30 m^2 of lumber is used in an average wooden house. Once the house is built, moisture contained in the lumber is released into the walls and other structural components. Because of this moisture, there are quite a few risks of temporary internal condensation and it is important to use dried wood (gravimetric moisture content of 20% or below) for preventing internal condensation.

1. Vapor barrier : This building layer prevents moisture generated indoors from seeping into the structure. Vapor barrier films can be used as vapor barrier materials and plywood is also acceptable for some components. For vapor barrier films, you can either use an integral vapor barrier that is attached to an insulation material or install a separate vapor barrier.
2. Weather barrier : This building layer requires vapor permeability that removes moisture to maintain insulation effectiveness and structural durability, wind resistance to prevent cold air from entering into the structure, and waterproof or water-repellent properties to keep the rain leaked through an exterior finish and other materials from seeping into the structure. Vapor permeable sheets and other weather barrier materials are used to create this layer.

Fig. 13 Ventilated cavity and other ventilation schemes on exterior side of thermal barrier



3) Installing airflow blocking

In conventional timber frame construction, structural cavities, such as crawl space, inside the walls and attic space, were continuous, and airflow inside the envelope generated in these spaces helped keep pillars, beams and other structural lumber dry.

However, since the interior insulation method used in many of today's insulated houses requires insulation materials to be installed within the structure, a sufficient level of insulation may not be maintained if there is airflow inside the envelope. In order to fully demonstrate effective insulation, it is necessary to block the airflow from the crawl space to the walls (exterior and partition walls) as well as from the walls to the attic space. To achieve this, you can install airflow blocking along the top and bottom of the walls.

Airflow blocking is required for the interior insulation method, but unnecessary when insulating the roof and foundation in addition to using the exterior insulation method for exterior walls.

The following are four types of major airflow blocking methods:

Method 1 Airflow blocking by subfloor plywood, interior sheathing board and other sheet materials

This method blocks airflow by using sheet materials such as subfloor plywood, wall and ceiling plasterboard. If Level 3 or 4 insulation is desired, airflow blocking of connections between the exterior walls and the attic (ceiling) requires the use of both airflow blocking and vapor barrier film. Vapor barrier film is not needed for partition walls or if plywood or tongue and groove flooring is used for the floor.

Method 2 Airflow blocking by piece of wood

This airflow blocking method involves installation of the required size of lumber that can block the airflow path.

Method 3 Airflow blocking by vapor barrier film and bracing or other materials

This method blocks airflow by installing vapor barrier film. The edges of the vapor barrier film should not only simply be stapled, but also be firmly sandwiched between the backing (e.g. cross beam) or bolster and the vapor barrier film bracing (lumber of at least 40 mm wide by 15 mm thick).

Method 4 Airflow blocking by dedicated and other materials

With this method, airflow is blocked by simply installing dedicated glass wool materials and fastening the vapor barrier film to the cross beams. It can be used only for either Level 1 or 2, not Level 3 or 4 which requires more complete airflow blocking.

Table 5 summarizes the installation locations and methods of airflow blocking. The next pages will explain design examples of airflow blocking of each component by installation method. Any combination can be used, for example, Method 1 for the connections with the floor and Method 2 for the connections with the attic (ceiling). Please refer to these pages for planning airflow blocking design.

Glossary: Airflow blocking
Upon the revision of the energy conservation standards for housing in April 2009, airflow prevention of the interior of walls was included as part of the installation requirements. Although the same concept, the warm region edition guideline refers to it as "ventilation control" while this and future guidelines will call it "airflow blocking" in accordance with the energy conservation standards.

Table 5 Airflow blocking methods by component

Airflow blocking location		Airflow blocking method		Applicable insulation level
Exterior wall	Connections with attic (ceiling)	Method 1	Airflow blocking by vapor barrier film + interior sheathing board	Levels 1 – 4
		Method 2	Airflow blocking by piece of wood	
		Method 3	Airflow blocking by vapor barrier film and bracing	
		Method 4	Airflow blocking by vapor barrier film only	Levels 1, 2
	Connections with floor	Method 1	Airflow blocking by subfloor plywood	Levels 1 – 4
		Method 2	Airflow blocking by piece of wood	
		Method 3	Airflow blocking by vapor barrier film and bolster	
		Method 4	Airflow blocking by dedicated material	Levels 1, 2
Partition wal	Connections with attic (ceiling)	Method 1	Airflow blocking by vapor barrier film + ceiling sheathing board	Levels 1 – 4
		Method 2	Airflow blocking by piece of wood	
		Method 4	Airflow blocking by dedicated material	Levels 1, 2
	Connections with floor	Method 1	Airflow blocking by subfloor plywood	Levels 1 – 4
		Method 2	Airflow blocking by piece of wood	
		Method 4	Airflow blocking by dedicated material	Levels 1, 2

①Exterior wall – 1 (If interior wall is stud wall)

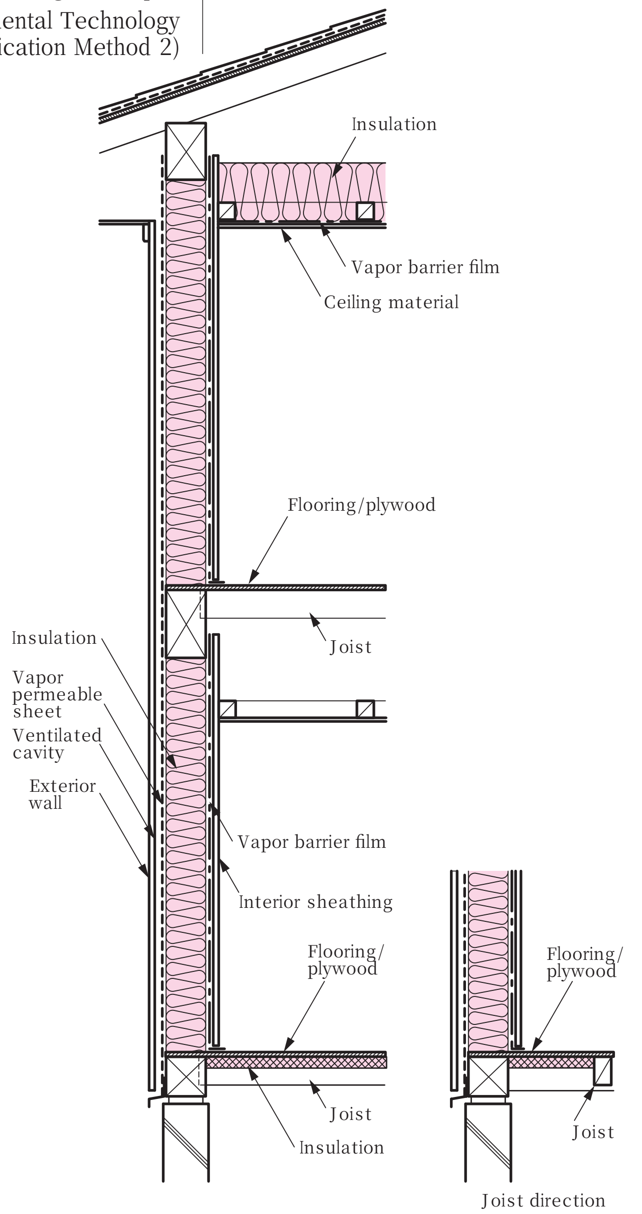


Fig. 14 Example of airflow blocking by Method 1

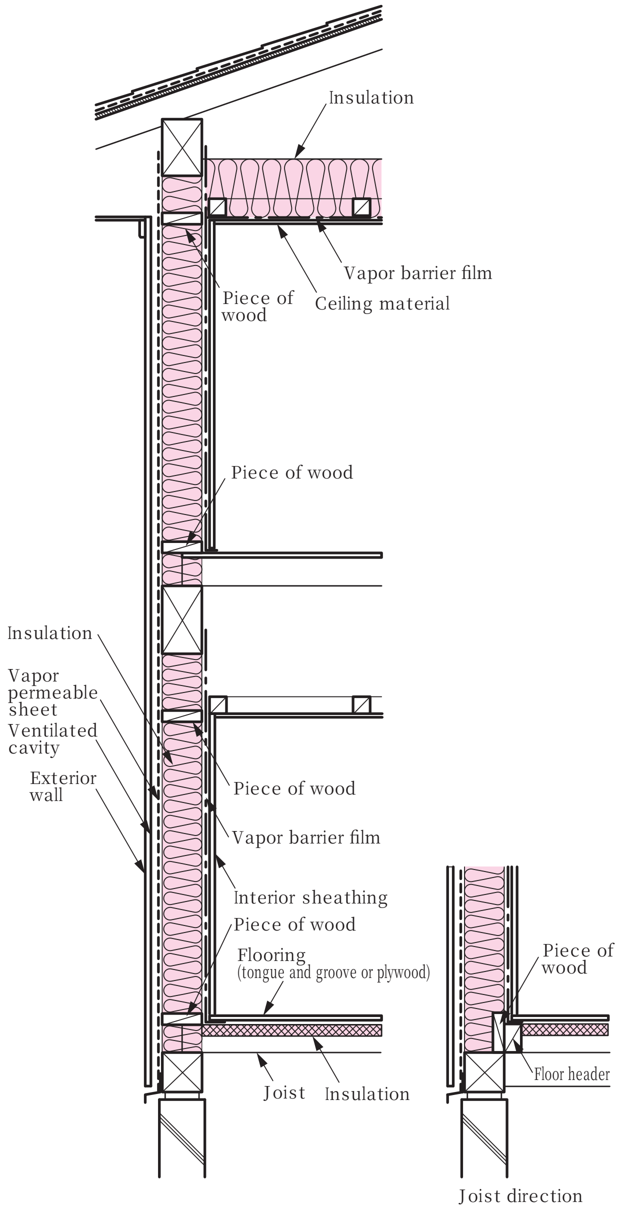


Fig. 15 Example of airflow blocking by Method 2

- Connections with attic (ceiling)
  (Airflow blocking by vapor barrier film + interior sheathing board)
- Connections with floor
  (Airflow blocking by subfloor plywood)

- Connections with attic (ceiling)
  (Airflow blocking by sticker)
- Connections with floor
  (Airflow blocking by sticker)

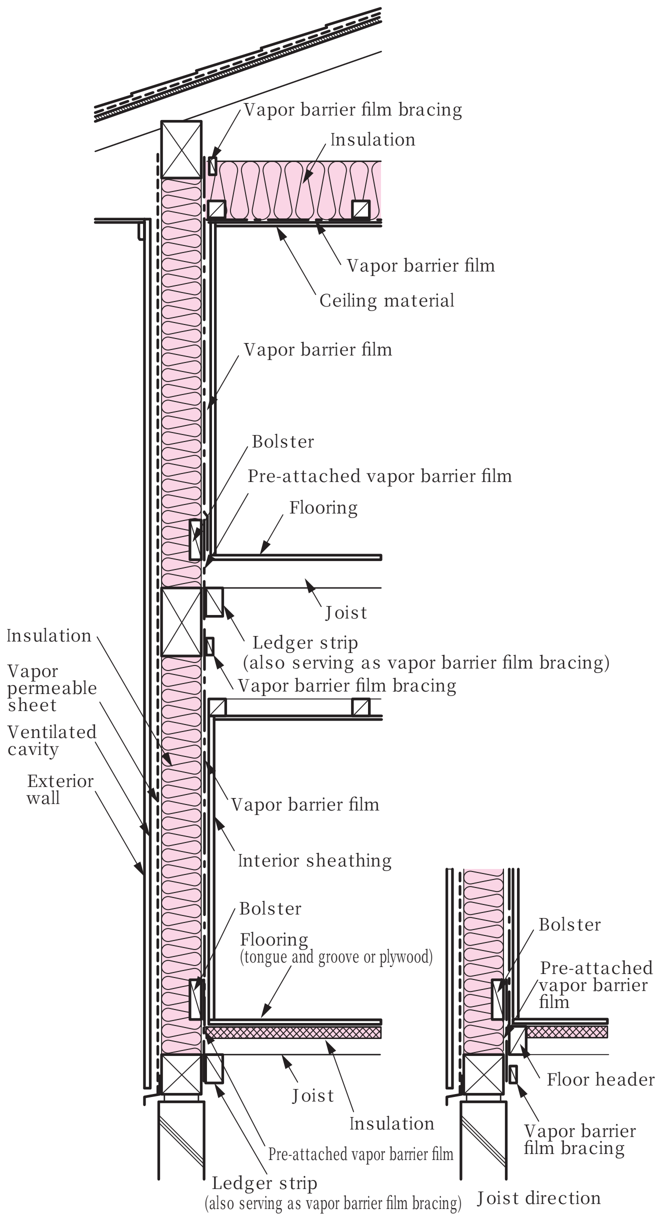


Fig. 16　Example of airflow blocking by Method 3

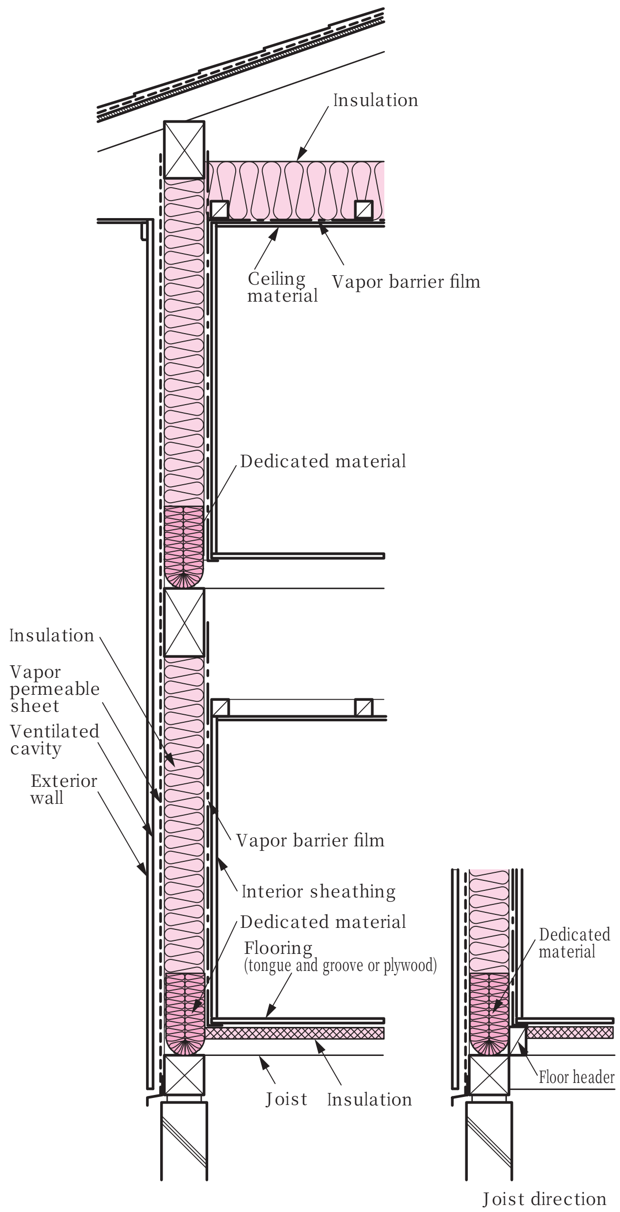


Fig. 17　Example of airflow blocking by Method 4

- Connections with attic (ceiling)
  (Airflow blocking by vapor barrier film and bracing)

- Connections with floor
  (Airflow blocking by vapor barrier film and bolster)

- Connections with attic (ceiling)
  (Airflow blocking by vapor barrier film only)
  <Applicable to Levels 1 and 2 only>
- Connections with floor
  (Airflow blocking by dedicated material)
  <Applicable to Levels 1 and 2 only>

②Exterior wall – 2 (If interior wall is stud wall covered with sheet material)

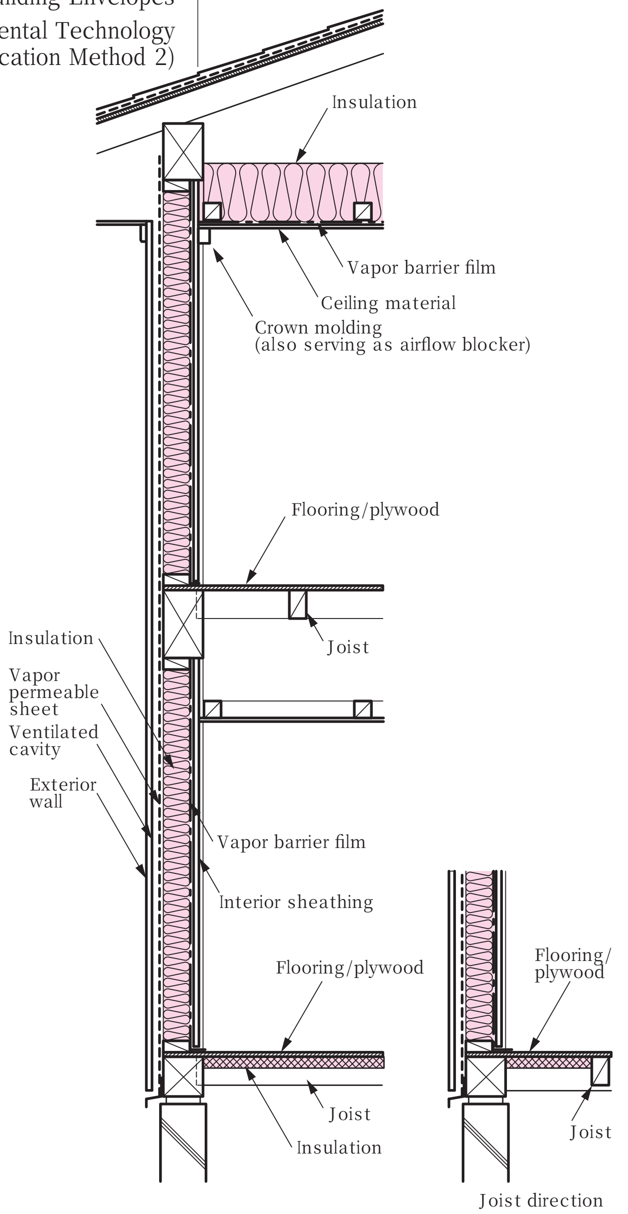


Fig. 18 Example of airflow blocking by Method 1

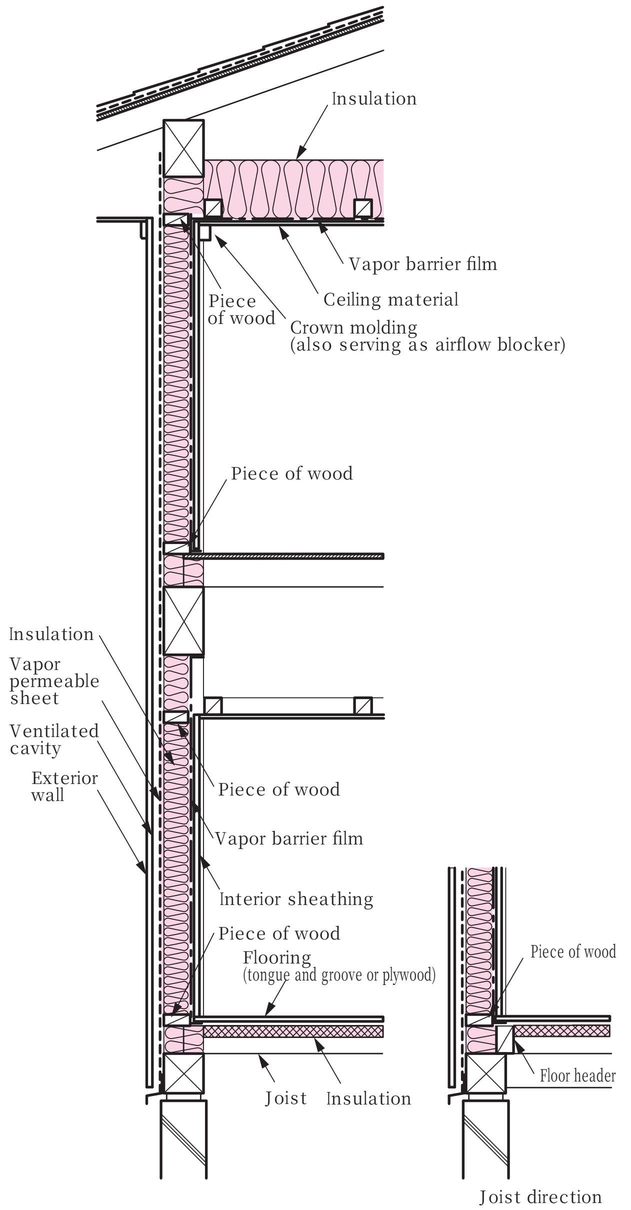


Fig. 19 Example of airflow blocking by Method 2

・Connections with attic (ceiling)
(Airflow blocking by vapor barrier film + interior sheathing board)
・Connections with floor
(Airflow blocking by subfloor plywood)

・Connections with attic (ceiling)
(Airflow blocking by piece of wood)
・Connections with floor
(Airflow blocking by piece of wood)

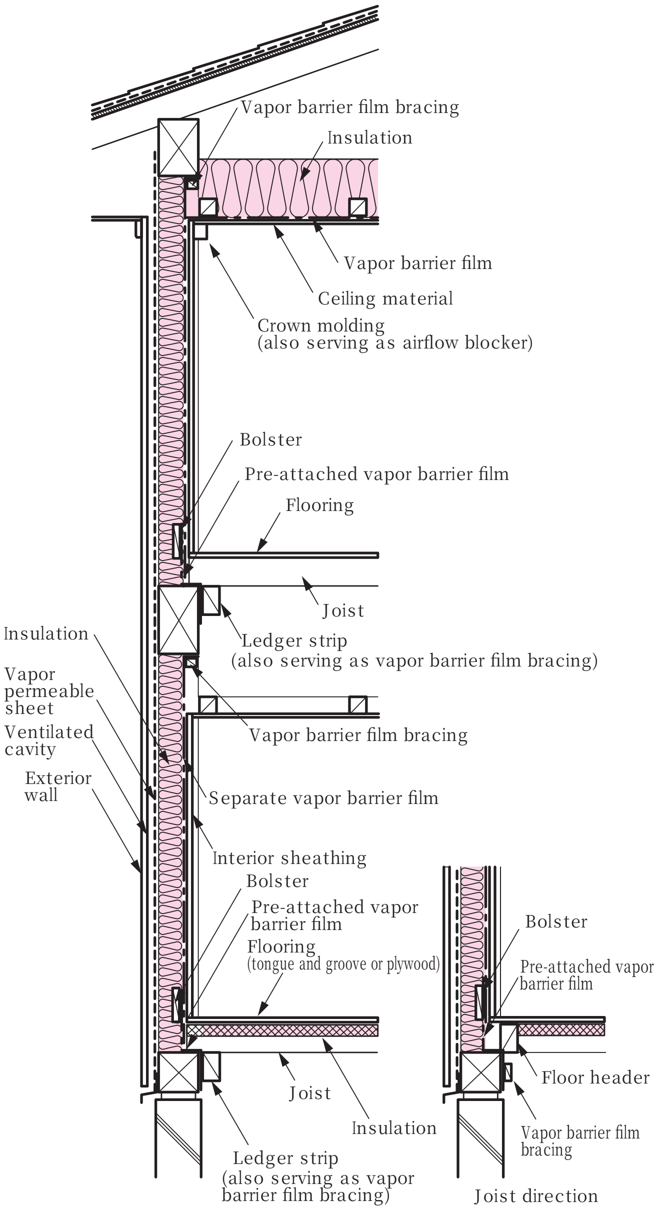


Fig. 20　Example of airflow blocking by Method 3

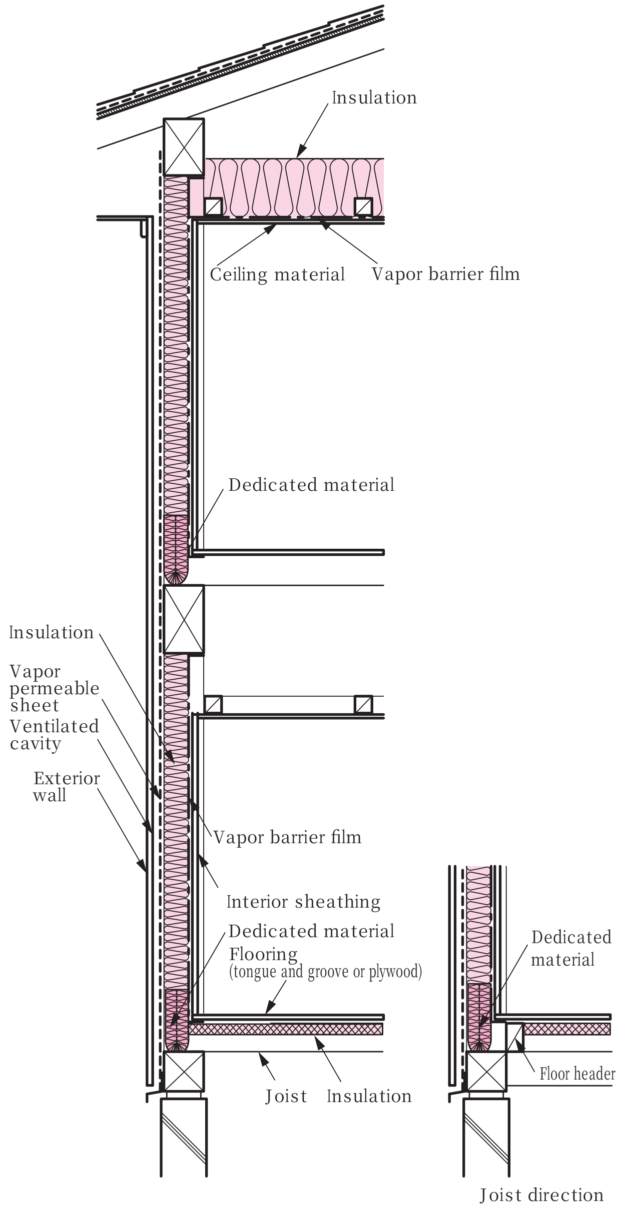


Fig. 21　Example of airflow blocking by Method 4

- Connections with attic (ceiling)
  (Airflow blocking by vapor barrier film and bracing)
- Connections with floor
  (Airflow blocking by vapor barrier film and bolster)

- Connections with attic (ceiling)
  (Airflow blocking by vapor barrier film only)
  <Applicable to Levels 1 and 2 only>
- Connections with floor
  (Airflow blocking by dedicated material)
  <Applicable to Levels 1 and 2 only>

③Exterior wall－3

(If interior wall is load-bearing stud wall panel)

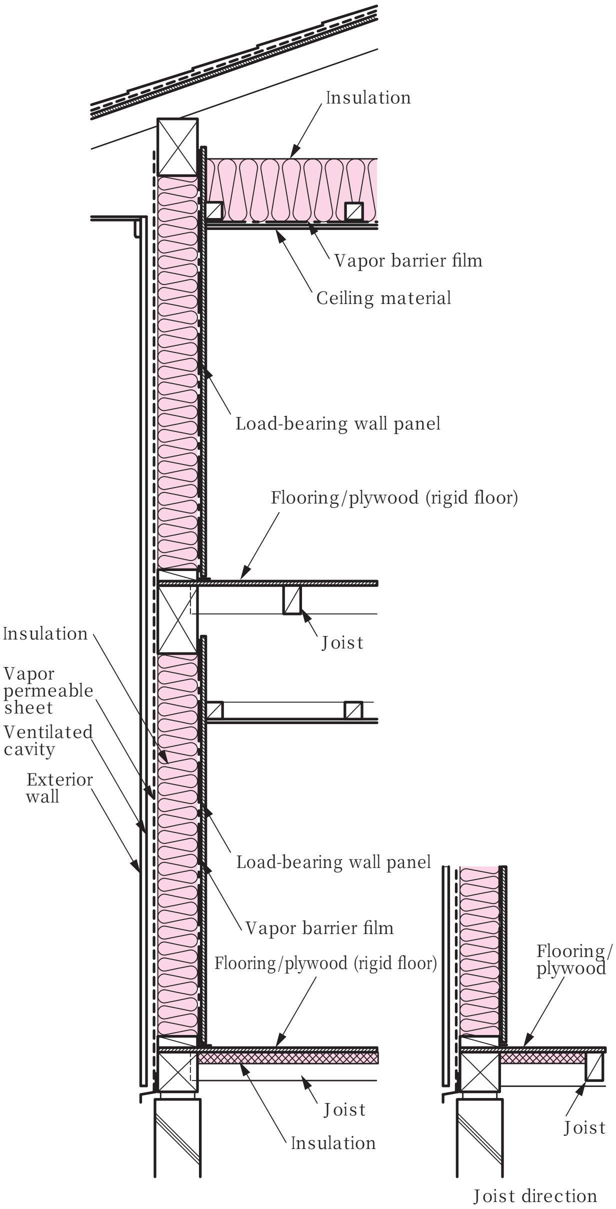


Fig. 22　Example of airflow blocking by Method 1

* This example uses load-bearing wall panel as interior wall although airflow blocking principles are the same as the example in Fig. 14.
・Connections with attic (ceiling)
(Airflow blocking by vapor barrier film + load-bearing wall panel)
・Connections with floor
(Airflow blocking by subfloor plywood)

④Exterior wall－4

(If interior wall is load-bearing Japanese style wall panel)

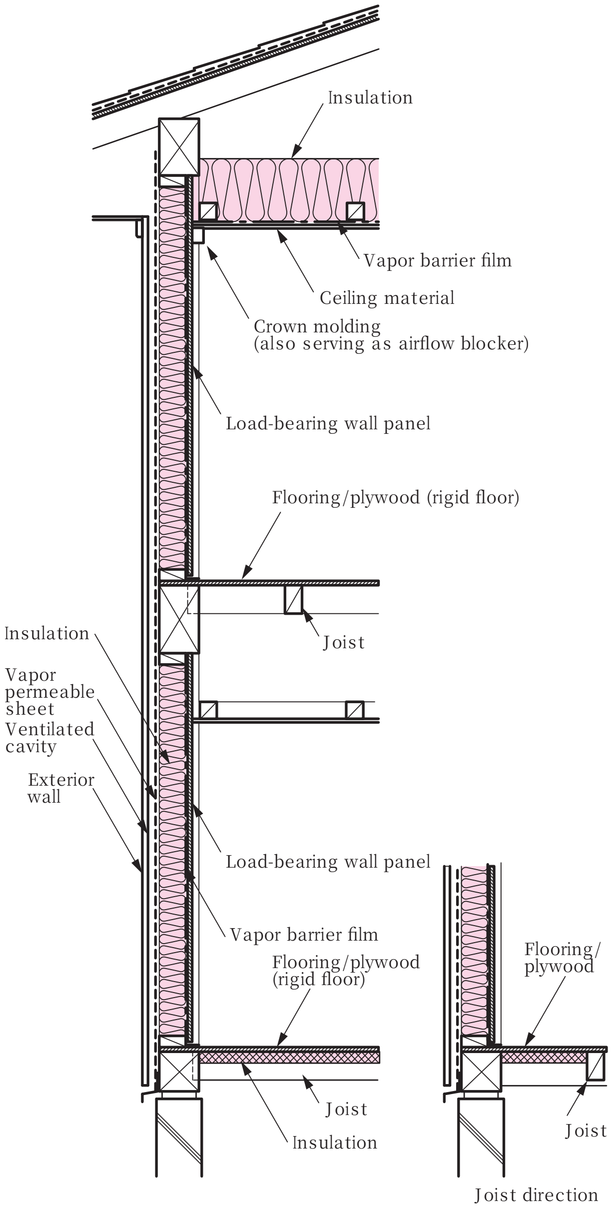


Fig. 23　Example of airflow blocking by Method 1

* This example uses load-bearing wall panel as interior wall although airflow blocking principles are the same as the example in Fig. 18.
・Connections with attic (ceiling)
(Airflow blocking by vapor barrier film + load-bearing wall panel)
・Connections with floor
(Airflow blocking by subfloor plywood)

⑤Exterior wall – 5 (In case of mud-plastered wall)

Figs. 24 and 25 show design examples of wall assemblies and connections between walls and floors and walls and ceilings. Since mud-plastered walls have a high moisture capacity, no vapor barrier film is required on the interior side. Moreover, as it structurally blocks airflow, there is no need to install airflow blocking.

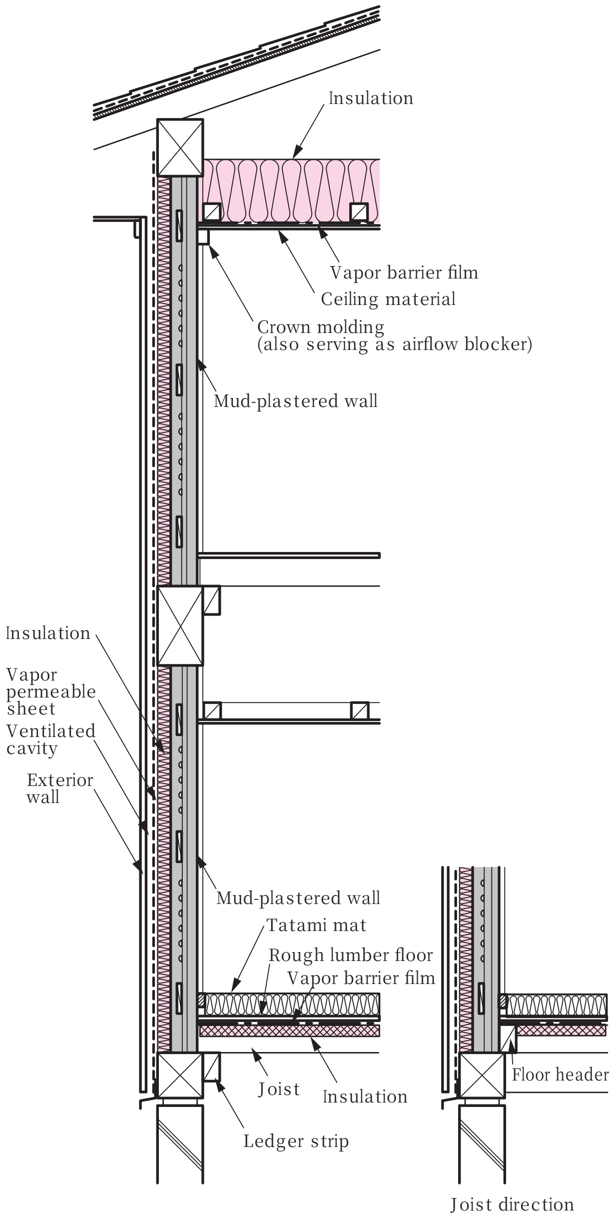


Fig. 24　Interior insulation

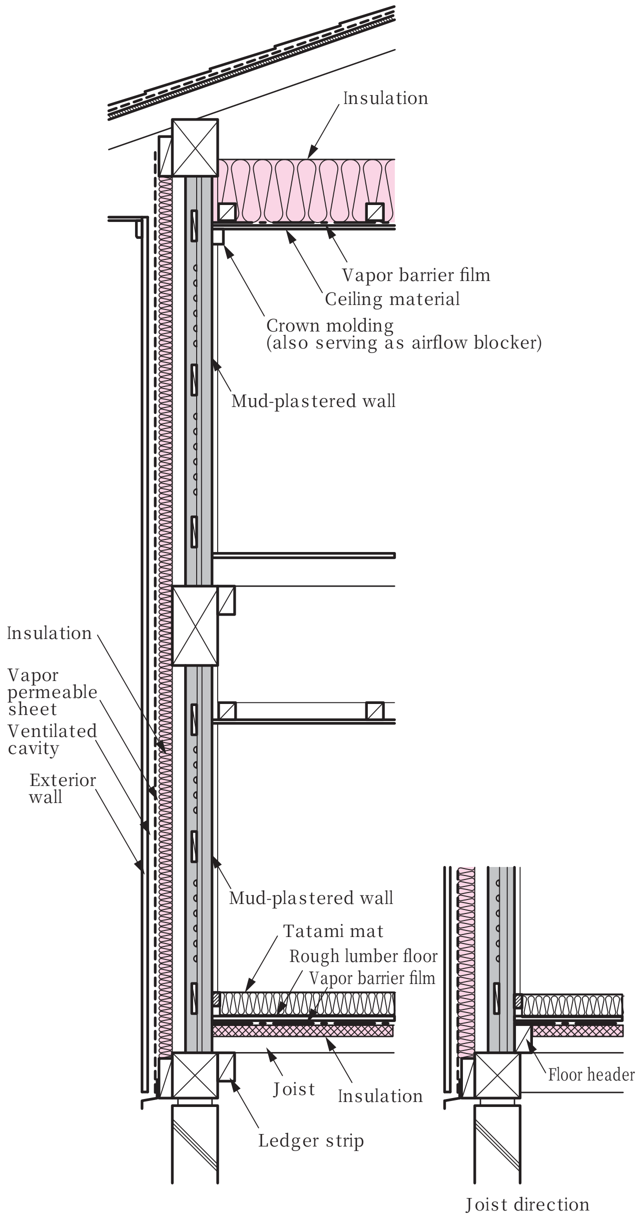


Fig. 25　Exterior insulation

⑥Partition wall – 1 (Non-load-bearing wall)

The ceiling crawl space on the first floor of a two-storey house that is not in contact with the outside air is thought to have the same thermal environment as the indoor space, thus airflow blocking is unnecessary. The areas that require airflow blocking of partition walls are connections between the crawl space of the lowest floor and the partition walls as well as between the partition walls and the attic space.

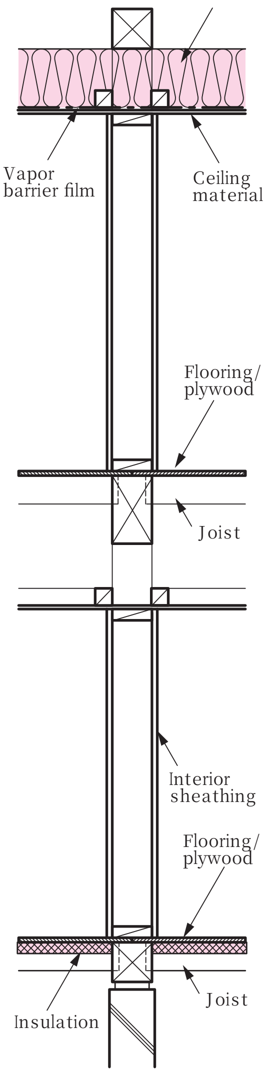


Fig. 26 Example of airflow blocking by Method 1

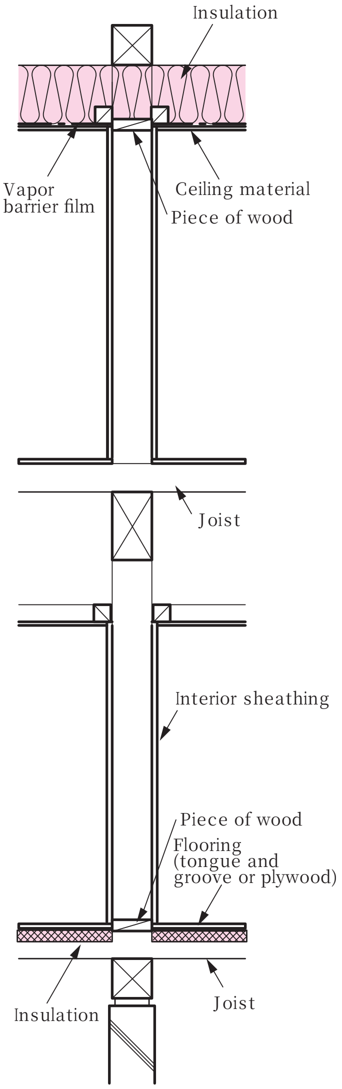


Fig. 27 Example of airflow blocking by Method 2

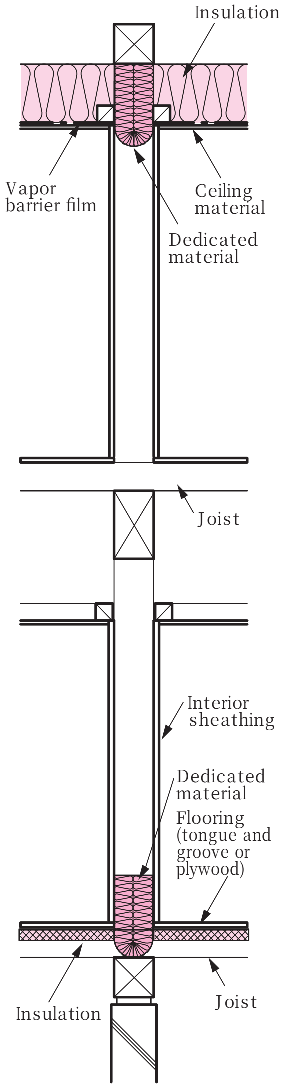


Fig. 28 Example of airflow blocking by Method 4

- Connections with attic (ceiling) (Airflow blocking by vapor barrier film + ceiling sheathing board)
- Connections with floor (Airflow blocking by subfloor plywood)

- Connections with attic (ceiling) (Airflow blocking by piece of wood)
- Connections with floor (Airflow blocking by piece of wood)

- Connections with attic (ceiling) (Airflow blocking by dedicated material) <Applicable to Levels 1 and 2 only>
- Connections with floor (Airflow blocking by dedicated material) <Applicable to Levels 1 and 2 only>

⑦Partition wall – 2
(Load-bearing stud wall panel)

⑧Partition wall – 3
(Load-bearing Japanese style wall panel)

⑨Partition wall – 4
(Mud-plastered wall)

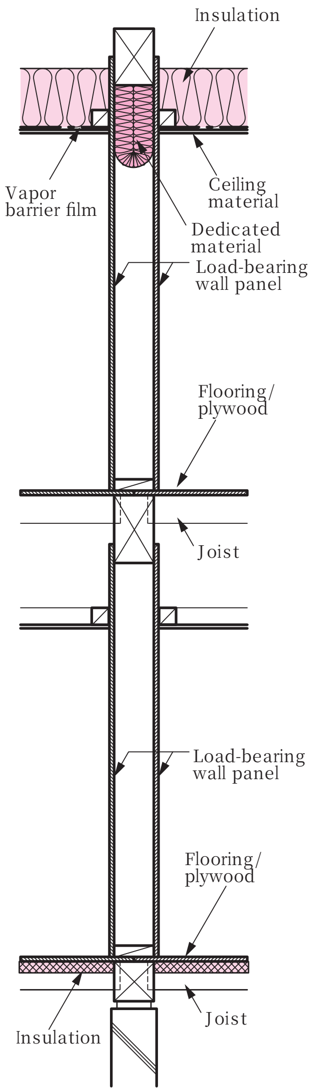


Fig. 29 Example of airflow blocking by Method 1

- Connections with attic (ceiling) (Airflow blocking by load-bearing wall panel)
- Connections with floor (Airflow blocking by subfloor plywood)

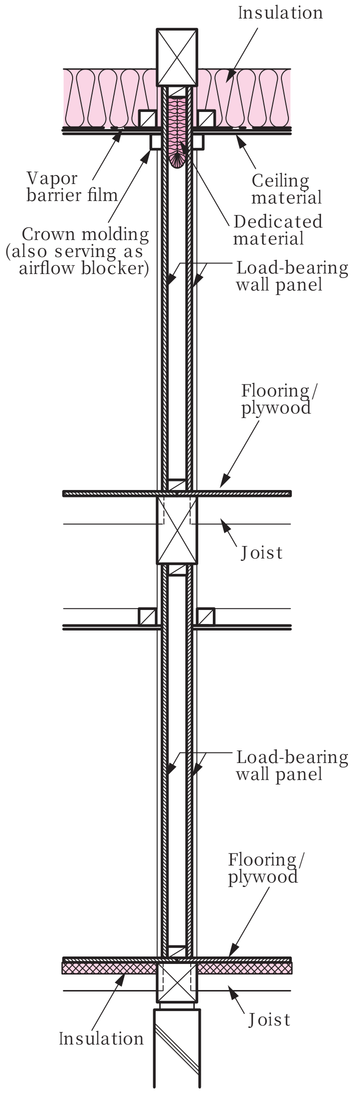


Fig. 30 Example of airflow blocking by Method 1

- Connections with attic (ceiling) (Airflow blocking by load-bearing wall panel)
- Connections with floor (Airflow blocking by subfloor plywood)

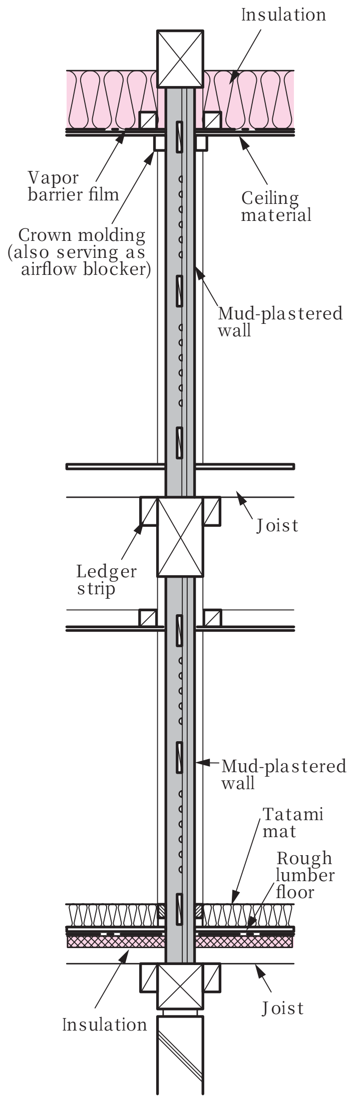


Fig. 31 Example of mud-plastered wall

- Mud-plastered walls structurally block airflow.

4) Installing insulation

Insulation should be installed ensuring that there is no gap (insulation deficiency) between it and the surrounding wood frame. When using insulation with an integral vapor barrier, sealed batt insulation that has large tabs is recommended (Fig. 32).

Generally, the minimum thickness of a separate vapor barrier film is 0.1 mm. Additionally, it is recommended that an integral vapor barrier should have the minimum thickness of 0.05 mm. When using either of these vapor barrier films, make sure to use the one that meets JIS A 6930 (Plastic films vapour barrier for residential use) to ensure long-term durability.

Fig. 32 Sealed batt insulation having vapor barrier film with large tabs


Product example


Installation example

5) Examining insulation method for each component

①Floor insulation

・Select insulation materials which do not cause harmful sagging, displacement or gaps between them and flooring after installation due to their own weight and drying shrinkage of wood, or install an insulation support that prevents sagging after installation.
・Perform moisture control for the ground under the floor and take underfloor ventilation measures including underfloor air vents.
・Installing subfloor plywood will ensure moisture control and air tightness.
・If Level 3 or 4 insulation is desired, either of the following moisture control measures is required:

If plywood is installed：Joints (seams) of plywood floor should be placed above the sheathing (floor joists, etc.) and the four corners of plywood floor should be nailed. If joining plywood without sheathing, seal the joints with airtight tape.

If plywood is not installed：Install an air and vapor barrier with a separate vapor barrier film unless tongue and groove flooring is used.

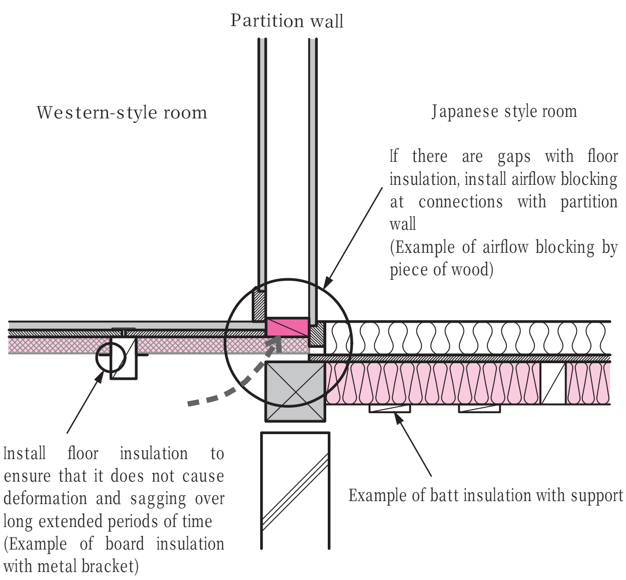


Fig. 33 Floor insulation

Fig. 34 Installation of board insulation

②Foundation insulation

- Insulation should be installed on the exterior, interior or both sides of the foundation. Insulation materials with low water absorption, such as plastic board insulation, should be used.
- In the case of foundation insulation, make sure to prevent gaps by installing airtight gasket between the upper surface of foundation and groundsill since the crawl space is used as the interior space. Underfloor air vent that is connected to the outside air is unnecessary. If directly fastening plywood floor to the groundsill, floor air vents should be installed in order to create a similar temperature and humidity environment in both indoor rooms and crawl space. Using decay and termite resistant wood for floor framing and slab on grade foundation for moisture control of the ground can eliminate the need for chemical preservatives in the crawl space (Fig. 35).
- Bathroom insulation is important in terms of energy conservation and occupant health. As it is difficult to insulate bathroom floors, foundation insulation is recommended instead (Fig. 36).

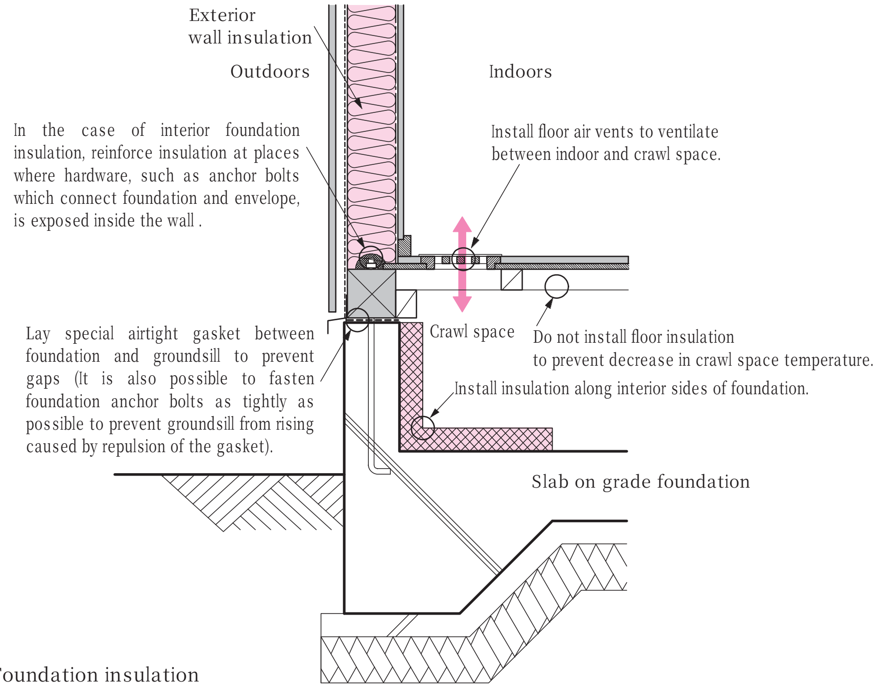


Fig. 35　Foundation insulation

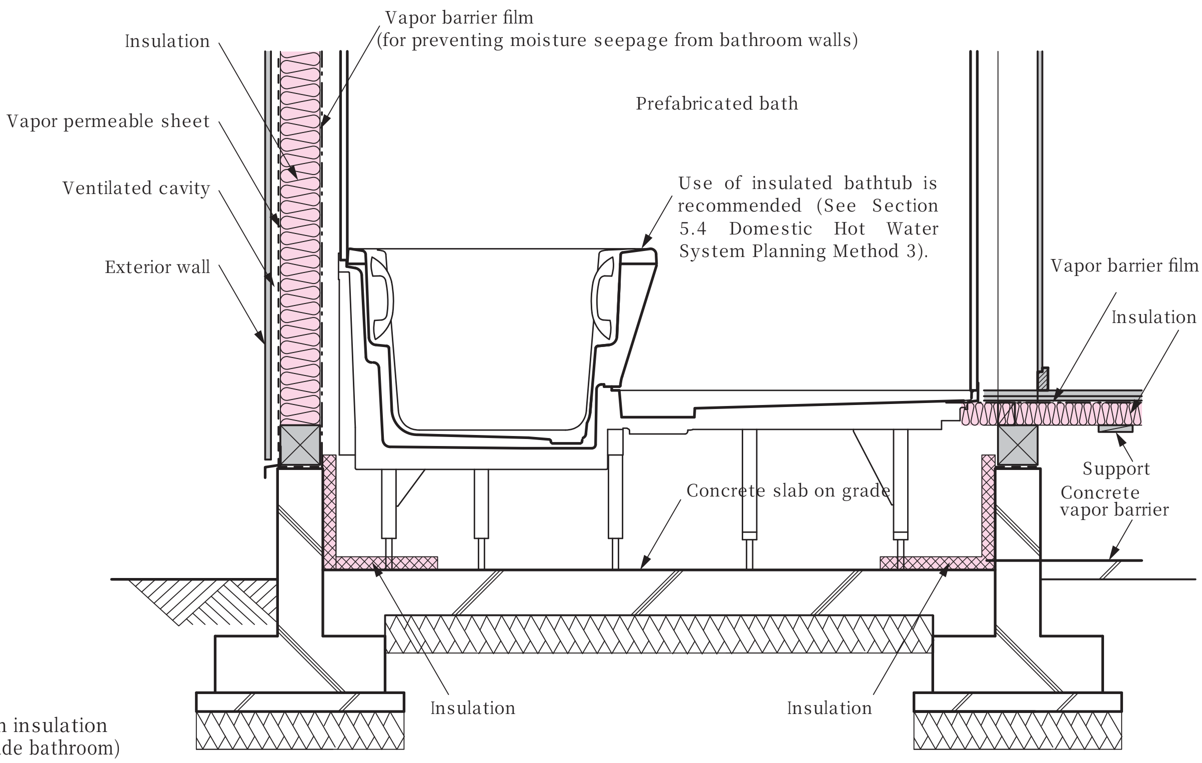


Fig. 36　Foundation insulation (slab on grade bathroom)

③Slab on grade insulation

・Insulation methods for slab on grade entrances include insulating the slab on grade floor along the foundation (i.e. foundation insulation) as well as installing low water permeable insulation under slab on grade (i.e. slab on grade insulation), as shown in Fig. 37. Considering the ease and reliability of installation, slab on grade insulation is suitable particularly for slab on grade entrances.
・Unlike other insulation methods, insulation is laid before placing concrete slab on grade in slab on grade insulation, so installation procedures require careful attention.

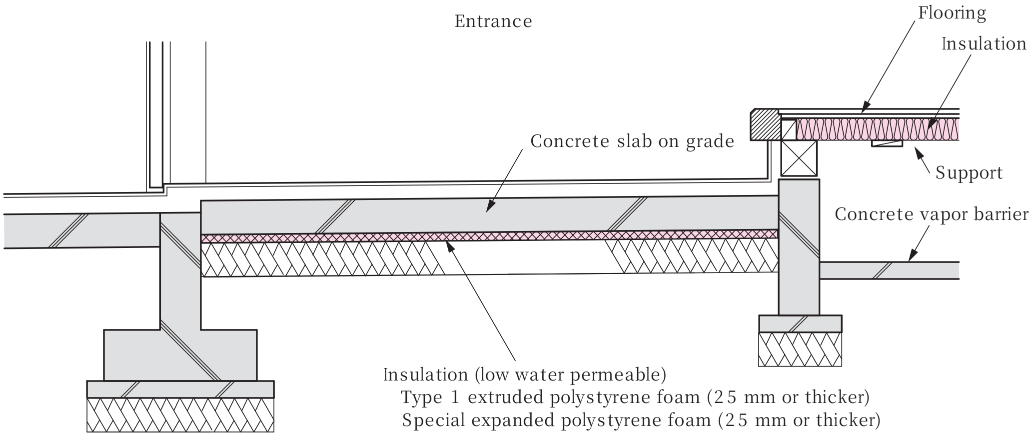


Fig. 37 Slab on grade insulation

④Exterior wall insulation

・Install airflow blocking along the top and bottom of the exterior walls.
・Lay insulation from the groundsill to the cross beam by ensuring that there will be no displacement or sagging over extended periods of time.
・Install insulation by ensuring that there is no gap between the diagonal brace and the piping.
・When using plastic board insulation, choose elastic insulation materials as much as possible and fill in the gaps.
・It is recommended to install a 15 – 20 mm thick ventilated cavity on the exterior side of the thermal barrier. The ventilated cavity prevents internal condensation in walls by removing moisture, eliminates water leakage from exterior finish, and expels heat in summer. When using a vapor permeable sheet for the weather barrier, make sure that sheathing is not covering the ventilated cavity.
・The following moisture control measures should be taken according to the target level:

Level 1, 2：When using glass wool and other fiber batt insulation, choose the one that has a vapor barrier film attached to it and overlay and staple both tabs to pillars or studs. If the insulation does not have top and bottom tabs, create tabs as shown in Fig. 39 and fasten them to the cross beams, girth, groundsill and other components.

Level 3, 4：When using glass wool or other fiber batt insulation that has a vapor barrier film attached to it, choose the one that has a solid vapor barrier film with wide tabs. Overlay both tabs at the wood sheathing and staple the four corners. If not using insulation with an integral vapor barrier, you need to control moisture using a separate vapor barrier film. When installing a vapor barrier film without an overlap at the ends, sandwich the ends between the sheathing and the vapor barrier film bracing.

・In the case of the exterior insulation, the installation of a ventilated cavity is recommended, as with interior insulation. When using plastic board insulation, seal the joints with airtight tape or lay weather barrier material (vapor permeable sheet).
・Mud-plastered wall does not require interior moisture control because of its high moisture capacity.

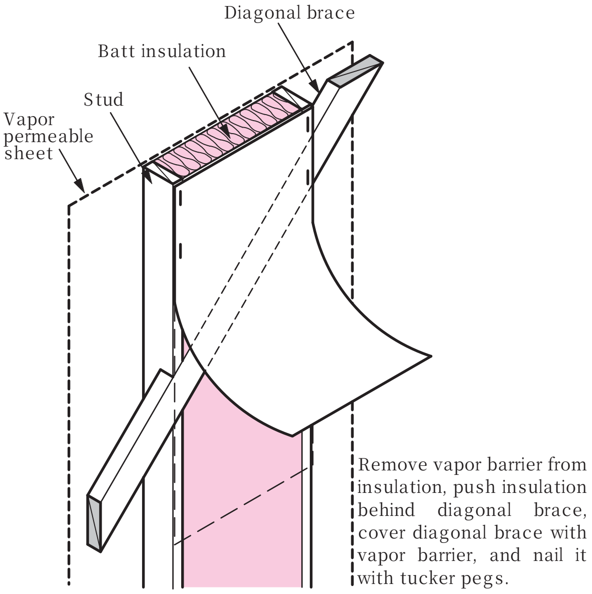


Fig. 38 Exterior wall insulation (insulation material with vapor barrier on load-carrying wall with diagonal brace)

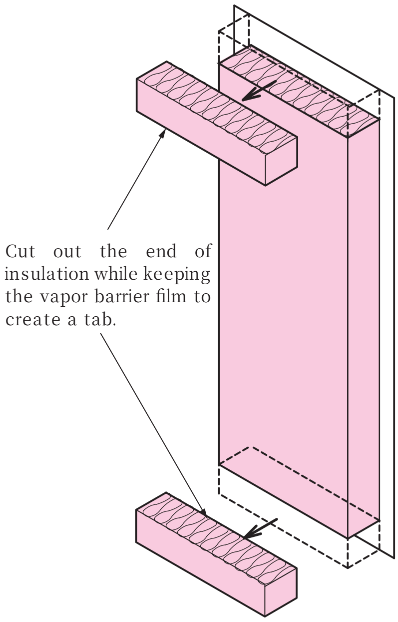


Fig. 39 Exterior wall insulation (installation of insulation material without tab)

⑤Ceiling insulation

- Insulation on the ceiling is prone to gaps at the connections between the ceiling and exterior walls, junctions with partition walls, areas around ceiling hangers, and between insulation materials. Install insulation over the entire ceiling seamlessly with the wall to prevent a gap.
- When using batt insulation over standard ceiling sheathing, lay insulation in parallel to the ceiling joist seats and install without any gaps by making slits in the ceiling hangers (Fig. 40). For moisture control measures, apply a separate vapor barrier film or use special plasterboard backed with a vapor barrier.

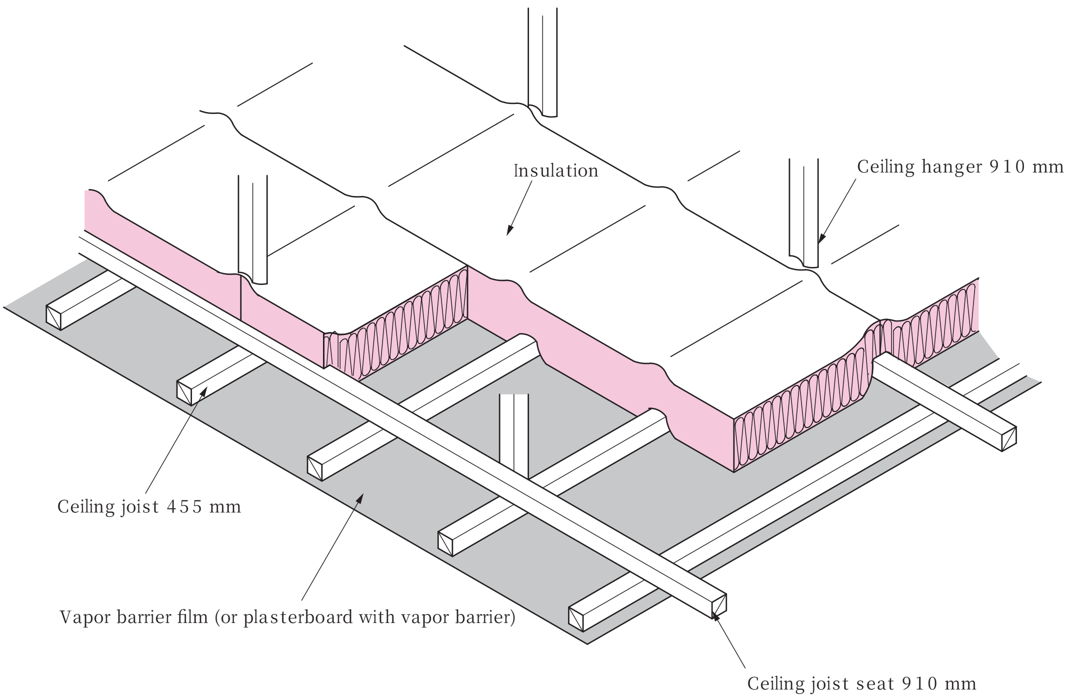


Fig. 40 Ceiling insulation – 1

- When using insulation with an integral vapor barrier, insert insulation between the ceiling joists and staple the overlaid tabs of the vapor barrier at the bottom surface of the ceiling joists. If insulation thickness of at least 150 mm is required, use two layers of insulation and lay the top layer in parallel to the ceiling joist seats then place the bottom layer between the ceiling joists under the ceiling joist seats and fasten the tabs (Fig. 41).
- It is also possible to adopt a suspended ceiling construction method so that insulation with an integral vapor barrier can be used (Fig. 42). This method reduces insulation deficiency.
- Since batt insulation often causes gaps, a blown-in insulation method (blowing method) is also recommended for ceiling insulation (Fig. 43).
- Proper attic ventilation must be ensured. If there is a possibility of ceiling insulation blocking the attic ventilation path when using blown-in insulation, install sheathing board where it is required (Fig. 43).

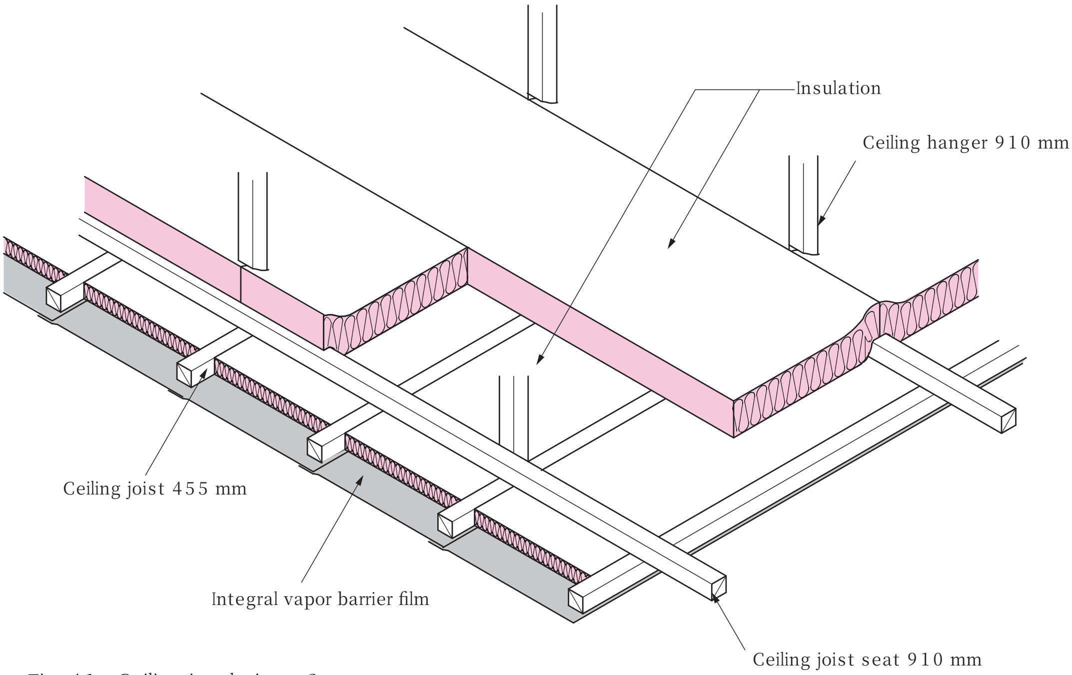


Fig. 41 Ceiling insulation – 2

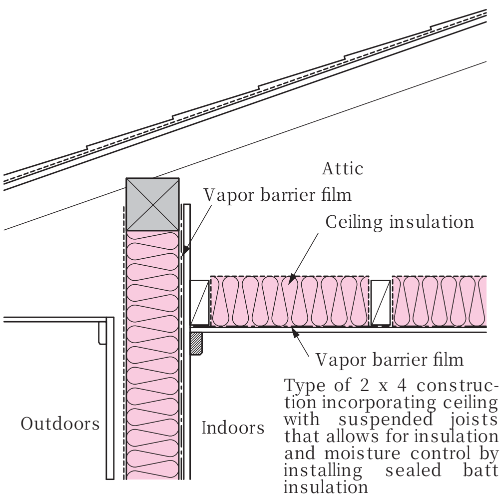


Fig. 42 Insulation of ceiling with suspended joists

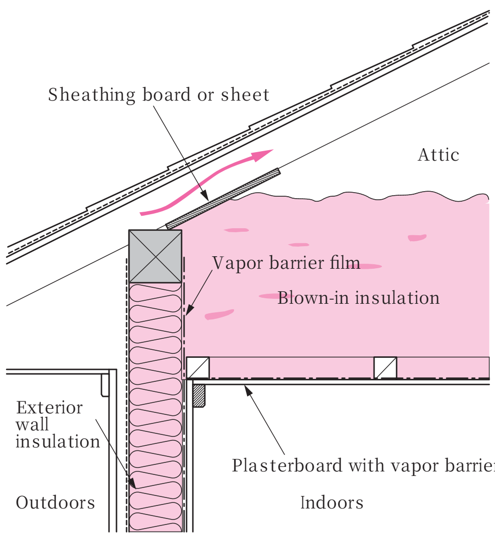


Fig. 43 Ceiling insulation by blowing method

⑥ Insulation above beams

- Insulation above beams is one of the exterior insulation methods in which insulation is installed above plywood that is placed over the aligned tops of cross beams and tie beams. The advantages of this method include unlimited types and thickness of insulation, ease of installation and no need for airflow blocking in partition walls (Fig. 44).
- Regarding moisture control, the plywood serves as a vapor barrier.
- Proper attic ventilation must be ensured in the same way as ceiling insulation. If the house has a low pitch roof, install sheathing board where it is required in order to prevent ceiling insulation from blocking the attic ventilation path.

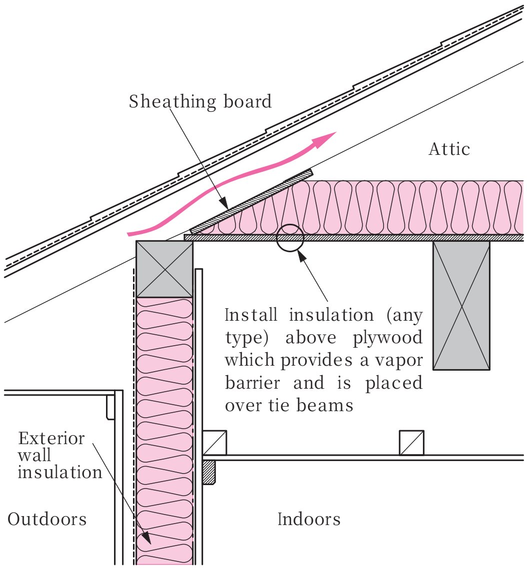


Fig. 44　Insulation above beams

⑦Roof insulation

- When applying roof insulation, installation of insulation and vapor barriers is the same as that for exterior walls.
- In order to prevent internal condensation and promote heat removal in summer, it is recommended to install a ventilated cavity with a thickness of at least 30 mm on the exterior side of the insulation. Particularly when using plastic board insulation (check heat resistance as it varies depending on the product type), the roof temperature becomes high and a proper ventilated cavity must be installed in order to prevent deterioration of insulation material (Fig. 45). However if the house has a tiled roof (no clay paste), there is a space between the roofing felt and tiles, and a ventilated cavity can be omitted.

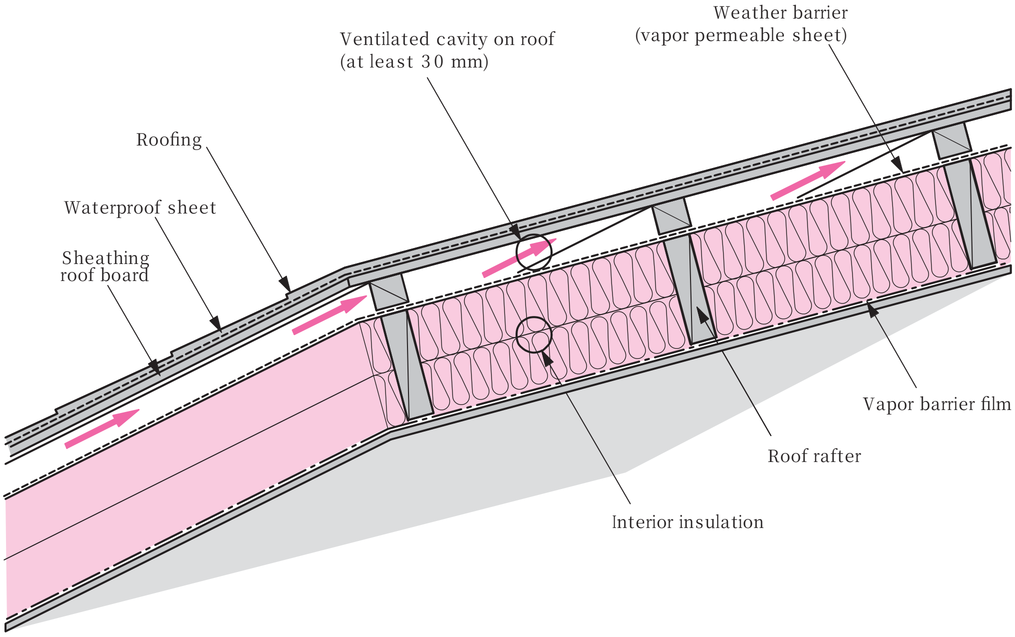


Fig. 45　Roof insulation

⑧Lean-to roof

- For a lean-to roof, since the hanging wall connected to the exterior wall of the upper floor is regarded as an exterior wall, install insulation with an integral vapor barrier as shown in Fig. 46.
- Airflow blocking is necessary in order to stop drafts from the attic of the lean-to roof from entering the area above the first floor ceiling .
- For airflow blocking, if Level 3 or 4 insulation is desired, fix a vapor barrier film with bracing as shown in the figure, or apply plywood or other sheet material to the same area and nail it at the four corners. If Level 1 or 2 insulation is desired, block airflow by making tabs that can be stapled at the four corners of the vapor barrier of the insulation with an integral vapor barrier.
- When insulating the ceiling of the attic of lean-to roof, use the same method as described in (v) Ceiling insulation.

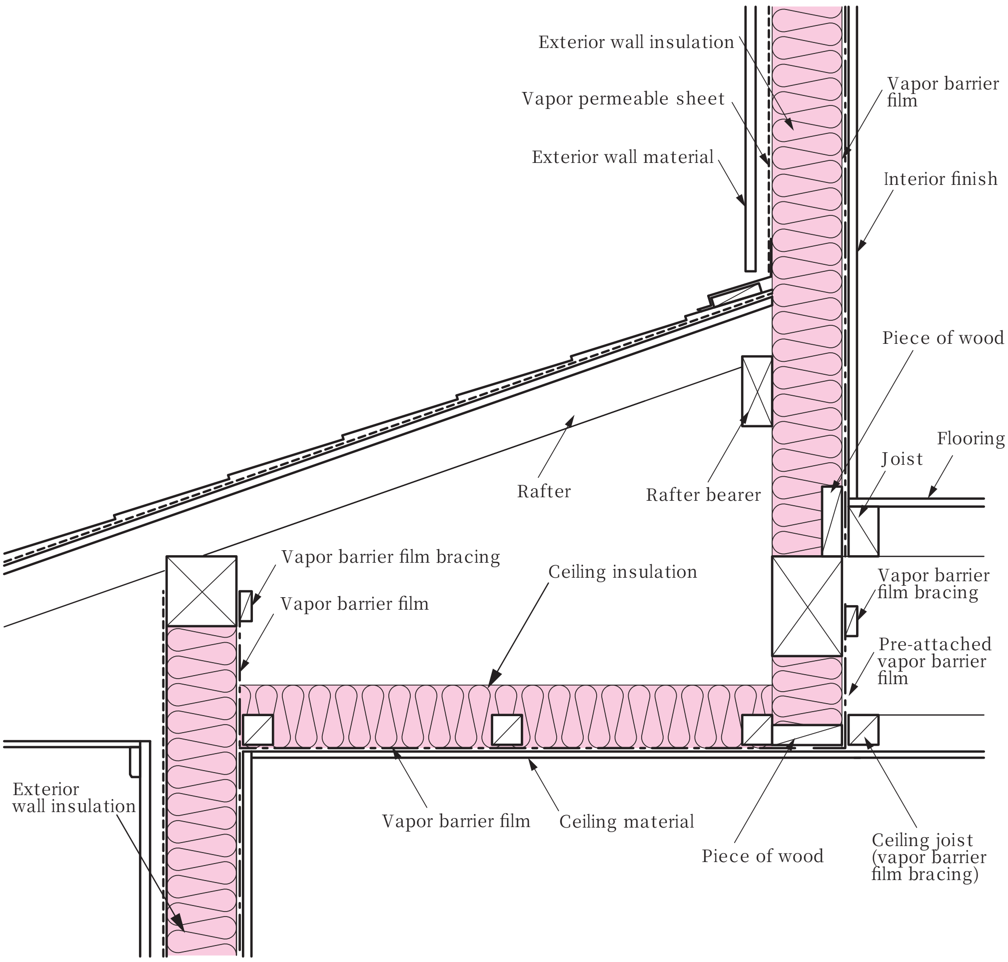


Fig. 46 Lean-to roof insulation

2 Examining insulation technology for openings

Openings such as window sashes and doors require functions that connect the indoors with the outdoors including heat, air, light and view, in addition to insulation performance and security as part of the building envelope. Among these required elements of openings, the insulation performance of openings is likely the weakness of the building envelope and it is important to choose the openings with appropriate performance of insulation materials according to the desired target level.

Table 6 Insulation performance of openings (heat transmission coefficient)

Frame structure		Typical heat transmission coefficient
Frame specification	Glazing specification	(W/m²•K)
Single: Wooden or plastic	Low-E double glazing (A12)	2.33
	Triple Double glazing (A12 x 2)	2.33
	Double glazing (A12)	2.91
	Double glazing (A6)	3.49
Single: Metal/plastic (or wooden) composite structure	Low-E double glazing (A12)	2.33
	Low-E double glazing (A6)	3.49
	Double glazing (A10 – A12)	3.49
	Double glazing (A6)	4.07
Single: Metal thermal break structure	Low-E double glazing (A12)	2.91
	Low-E double glazing (A6)	3.49
	Double glazing (A10 – A12)	3.49
	Double glazing (A6)	4.07
Single: Metal	Low-E double glazing (A6)	4.07
	Double glazing (A6)	4.65
	Double glazing (at least A12)	4.07
	Double glazing (below A12)	4.65
	Single glazing	6.51

* Numbers following A in parentheses: “A” as in (A12) indicated after double glazing, for example, stands for “Air” and the number after it indicates the thickness of air space between the glazing. A12 means an air space of 12 mm.

1) Selecting windows

Windows currently available in the market today include aluminum, resin, wood and their composite sash frames, and glazing comes in a wide variety such as double glazing, low-E double glazing and vacuum glazing. When designing and installing windows, it is necessary to consider construction areas, solar radiation level, sunshine hours, direction of the house, insulation performance and cost of windows, among other factors. Especially, the area of each window should be determined by taking into account the purposes and view of the room, thermal environment, light environment and cross ventilation performance. Table 7 summarizes the area of window and selection of glazing in terms of insulation performance of houses and solar radiation levels in winter. As the insulation performance of the house increases, so does the advantage of enlarging the openings.

Table 7 Selecting windows in terms of insulation performance of houses and solar radiation levels in winter

Regional characteristics	House with low insulation performance (Level 0) House with average insulation performance (Level 1)	House with high insulation performance (primarily Levels 2, 3, 4)
Region with high solar radiation level in winter	• Increased window area is effective in efficiently utilizing solar radiation heat. • Use double glazing (3-A 12-3), low-E double glazing, etc. Insulating shutters can be used if needed.	• Increased window area is highly effective in efficiently utilizing solar radiation heat. • Use both double glazing (3-A 12-3) and insulating shutters for south-facing windows. For other directions, use low-E double glazing, etc.
Region with low solar radiation level in winter	• Increased window area is less effective in efficiently utilizing solar radiation heat. • Use double glazing (3-A 12-3), low-E double glazing, etc.	• Increased window area is effective in efficiently utilizing solar radiation heat. • Use low-E double glazing, etc.

2) Selecting window sashes

①Insulating sashes (metal frames with thermal break, resin sashes, wood sashes)

Since commonly used aluminum sashes have an extremely high thermal conductivity, condensation often occurs on the sash frames. Metal frames with thermal break (insulating sashes) divide the sash frames into the exterior and interior sides and connect them with rigid urethane and other materials that are less heat conductive. If aluminum sashes are desired, the use of metal frames with thermal break is recommended (Fig. 46). Moreover, resin or wood sashes with a low thermal conductivity have even higher insulation performance.

②Double glazing

Double glazing refers to two panes of glass filled with dry air or argon or other inert gas in the air space between the two panes, and has significantly higher insulation performance compared to single glazing (Fig. 47). Low-E double glazing and vacuum glazing are also available, which provide increased insulation performance through treated glass surfaces.

Double glazing has different specifications according to air space thickness. There are two types of double glazing that have the same thickness of glass, and the type having 12 mm air space is superior to the type having 6 mm air space in terms of insulation performance. It is recommended to select the double glazing with 12 mm air space, if possible, in order to ensure insulation performance.


Fig. 46 Structure of metal frame with thermal break


Fig. 47 Structure of double glazing

3) Reinforced insulation by interior and exterior coverings

Normally, coverings are installed to the openings of the house, such as window screens and storm windows for the exterior and curtains and blinds for the interior of the windows. Even though little attempt has been made until recently to quantitatively estimate the effectiveness of these coverings in increasing insulation performance, an energy saving effect of nearly 10% has been confirmed.

4) Effectiveness of insulating shutters

Since openings have lower insulation performance than other housing components, the use of insulating shutters (insulating storm windows) dramatically increases comfort and energy efficiency (Fig. 48).

Interior insulating shutters require considerations in advance since they have some issues including condensation on the interior surface of the windows, heat warping of insulating shutters and their storage. In particular, as condensation leads to molds, taint damage or decay of building envelopes, it is important to consider controlling indoor humidity as well as air flow.

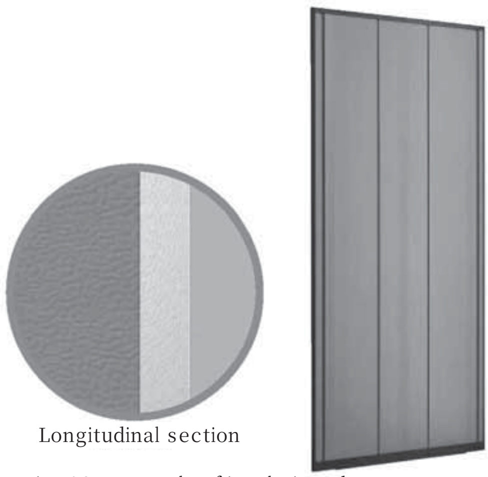


Fig. 48 Example of insulating shutter

4.1.6 Examples of Insulation Planning

Here, we will introduce examples of insulation planning for both partially reinforced insulation type and evenly distributed insulation type by target level. For the partially reinforced insulation type, planning examples of Level 3 insulation with different insulation methods for each component will be explained.

For the evenly distributed insulation type, we will show the planning examples of Level 1 to 3 insulation for average conventional timber frame houses and traditional mud-plastered timber frame houses. As previously mentioned, reinforcing insulation at the openings and ceilings will achieve the target level.

Even though no example of Level 4 insulation is given in this document, it is achievable if the insulation is further reinforced at the openings by increasing insulation performance of glazing and sash frames and incorporating insulating shutters based on the Level 3 insulation specifications.

Table 8 Correspondence between insulation level and insulation planning examples

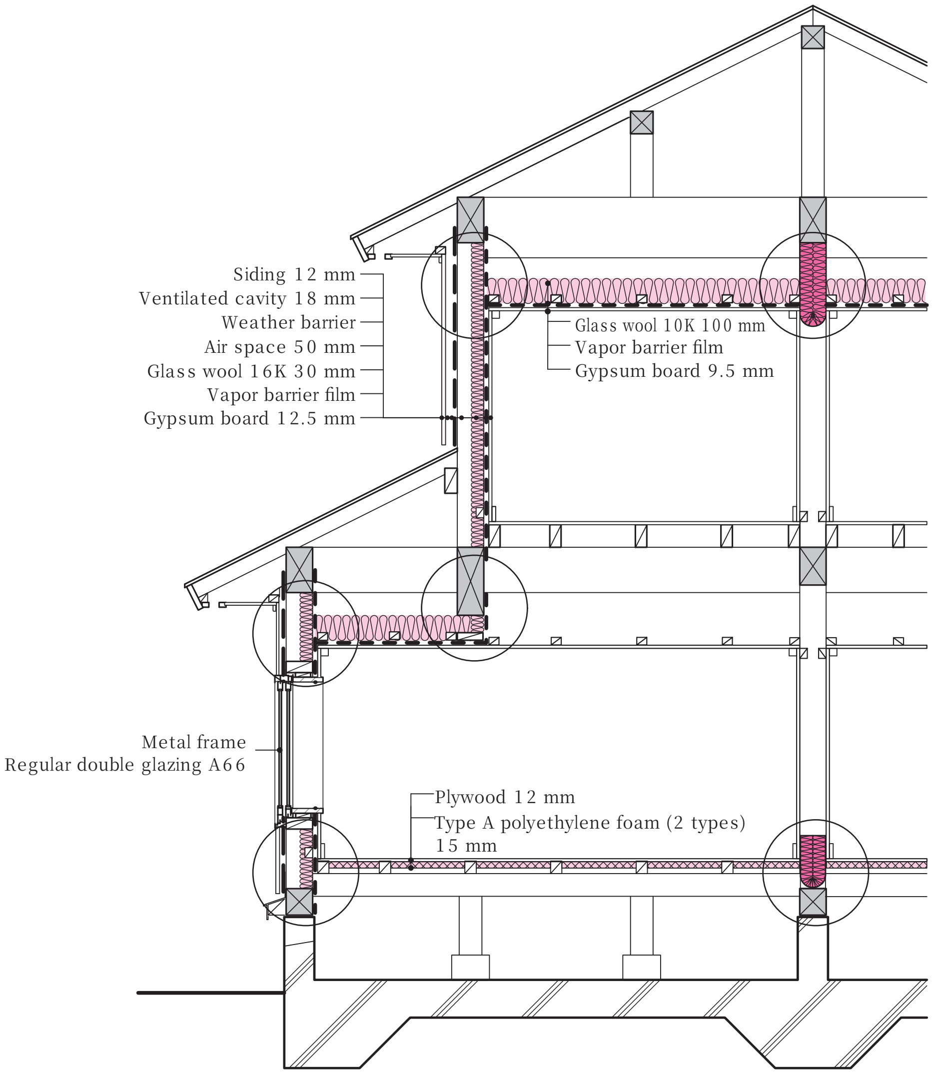
Insulation level	Evenly distributed insulation type	Partially reinforced insulation type	
		Average conventional timber frame house	Traditional conventional timber frame house (mud-plastered wall)
Level 1	–	Example (1) Reinforced opening insulation	–
Level 2	–	Example (2) Reinforced ceiling and opening insulation	Example (4) Reinforced opening insulation
Level 3	Example (6) Interior insulation	Example (3) Reinforced ceiling and opening insulation	Example (5) Reinforced opening insulation
	Example (7) Insulation above beams and foundation insulation		
	Example (8) Exterior insulation		

Of the various methods explained on pp. 137-145, we will present examples of the typical airflow blocking methods by insulation level as shown below:

- Airflow blocking methods using primarily vapor barrier films (exterior walls) and dedicated materials (partition walls) have been provided as examples of planning Level 1 or 2 insulation.
- Airflow blocking methods using primarily vapor barrier films, bracing (exterior walls) and piece of wood (partition walls) have been provided as examples of planning Level 3 insulation.

Insulation planning example (1): Level 1 – Partially reinforced insulation type (openings)

- This specification conforms to the 1992 energy conservation standard.
- Compared to the specification of partially reinforced insulation type, this specification is characterized by the less strict wall insulation specification achieved by the reinforced insulation of openings.
- Connections circled in the figure below require airflow blocking in order to prevent cold air from entering inside the thermal barrier (other examples follow the same convention).



Cross-sectional detail

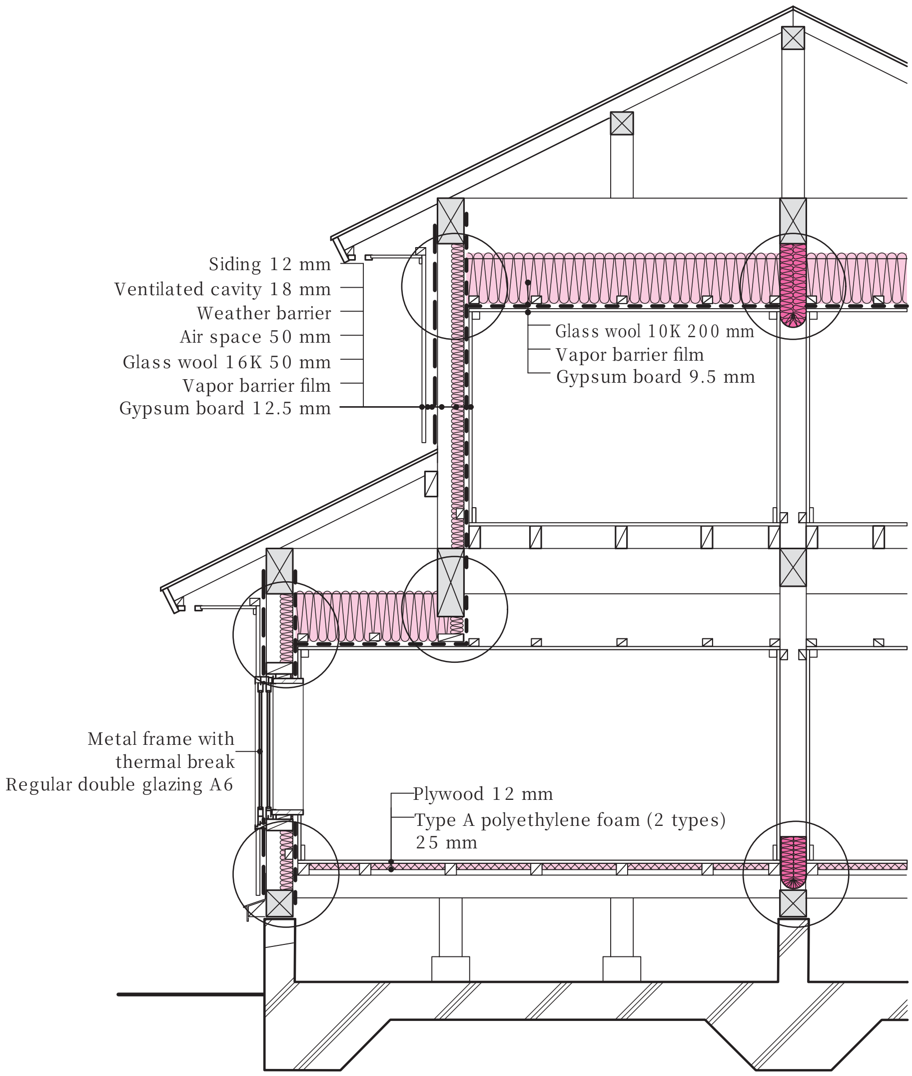
Insulation specifications of components

Component	Insulation specification	Thermal resistance value (m²•K/W) (Heat transmission coefficient for opening)	1992 thermal resistance standard (m²•K/W) (Heat transmission coefficient for opening)
Roof/Ceiling	Glass wool 10K 100 mm	2.0	1.8 or above
Exterior wall	Glass wool 16K 30 mm	0.67	0.7 or above
Floor/Foundation	Type A polyethylene foam (2 types) 15 mm	0.39	0.5 or above
Opening	Double glazing with 6 mm air space	4.65 (heat transmission coefficient (W/m²•K))	6.51 (heat transmission coefficient (W/m²•K)) or below
Air change rate (winter air leakage)	Approx. 0.5 – 0.7 ACH*		1.0 ACH

* Regarding insulation level achieved by combination of insulation and reinforced opening insulation, air tightness of the building envelope is expected to increase by installing airflow blocking to meet the 1992 standard level of insulation.

Insulation planning example (2): Level 2 – Partially reinforced insulation type (ceilings and openings)

- This specification conforms to the intermediate insulation level of the 1992 and 1999 energy conservation standards.
- In addition to the improved indoor thermal environment in winter, this specification is characterized mainly by the reinforced ceiling insulation that is aimed to increase summer heat protection performance in warm regions.



Cross-sectional detail

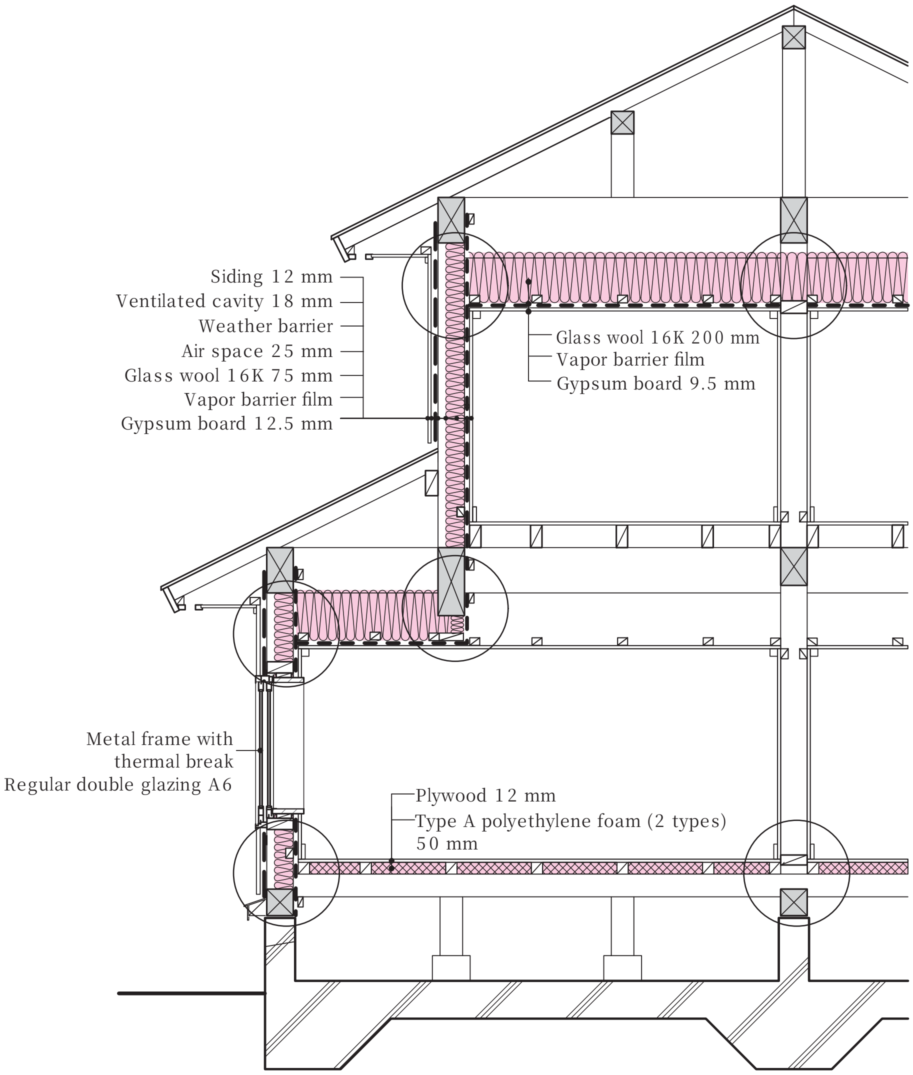
Insulation specifications of components

Component	Insulation specification	Thermal resistance value (m²•K/W) (Heat transmission coefficient for opening)	1992 thermal resistance standard (Zone III) (m²•K/W) (Heat transmission coefficient for opening)
Roof/Ceiling	Glass wool 10K 200 mm	4.0	1.8 or above
Exterior wall	Glass wool 16K 50 mm	1.1	1.8 or above
Floor/Foundation	Type A polyethylene foam (2 types) 25 mm	0.65	1.8 or above
Opening	Double glazing with 6 mm air space + metal frame with thermal break	4.07 (heat transmission coefficient (W/m²•K))	4.65 (heat transmission coefficient (W/m²•K)) or below
Air change rate (winter air leakage)	Approx. 0.5 – 0.7 ACH*		1.0 ACH

* Regarding insulation level achieved by combination of insulation and reinforced opening insulation, air tightness of the building envelope is expected to increase by installing airflow blocking to meet the 1992 standard level of insulation.

Insulation planning example (3): Level 3 – Partially reinforced insulation type (ceilings and openings)

- This specification conforms to the 1999 energy conservation standard.
- In addition to the improved indoor thermal environment in winter, this specification provides reinforced insulation in ceilings (roof) and openings in order to increase summer heat protection performance in warm regions. On the other hand, it is characterized by the reduced insulation performance requirements in exterior walls and floors (foundation) and the simplified installation of these components.



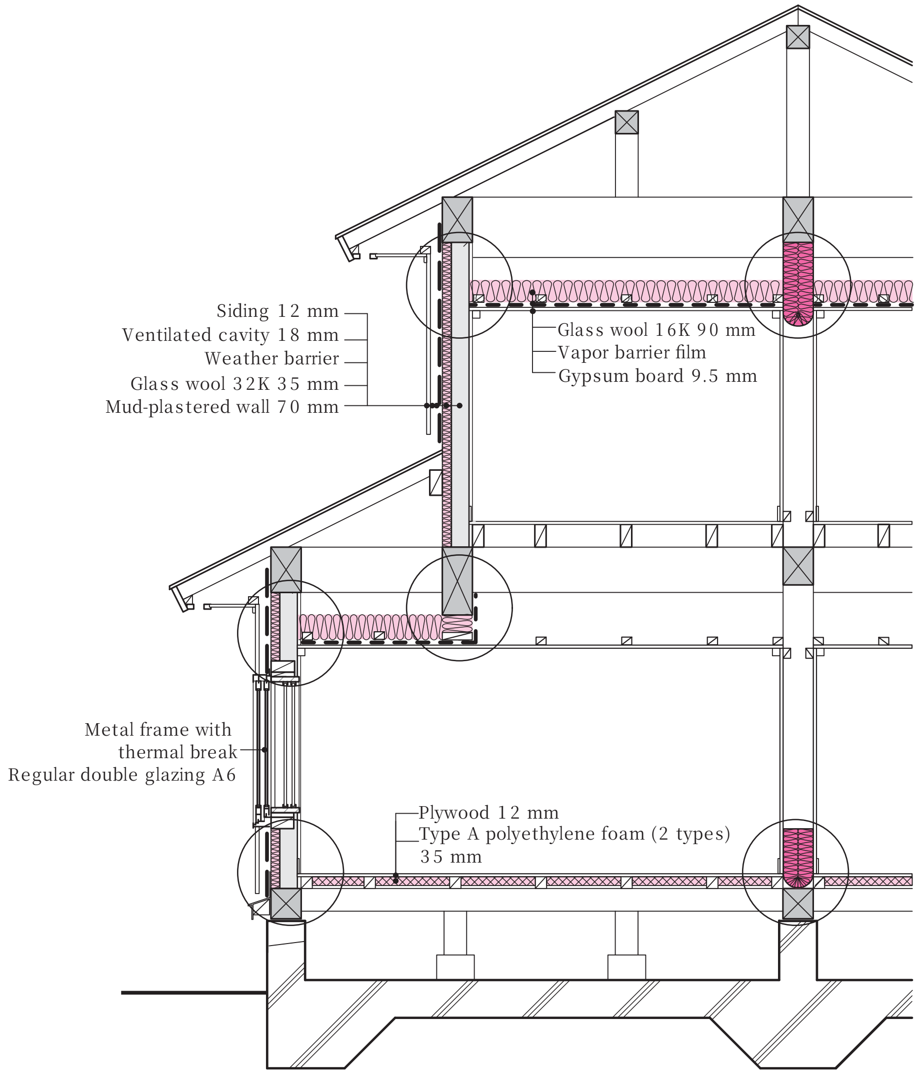
Cross-sectional detail

Insulation specifications of components

Component	Insulation specification	Thermal resistance value (m²•K/W) (Heat transmission coefficient for opening)	1999 thermal resistance standard (m²•K/W) (Heat transmission coefficient for opening)
Roof/Ceiling	Glass wool 16K 200 mm	4.44	4.0 or above
Exterior wall	Glass wool 16K 75 mm	1.97	2.2 or above
Floor/Foundation	Type A polyethylene foam (2 types) 50 mm	1.31	2.2 or above
Opening	Double glazing with 6 mm air space + metal frame with thermal break	4.07 (heat transmission coefficient (W/m²•K))	4.65 (heat transmission coefficient (W/m²•K)) or below
Air change rate (winter air leakage)	0.5 ACH		0.5 ACH

Insulation planning example (4): Level 2 – Partially reinforced insulation type of mud-plastered house (openings)

- This specification conforms to the intermediate insulation level of the 1992 and 1999 energy conservation standards.
- For insulating exterior walls, an insulation material equivalent to at least 35 mm of 32K glass wool board is installed in the structural cavity on the exterior side of the mud-plastered walls.
- If there are any interior walls other than mud-plastered walls, it is important to install airflow blocking at the top and bottom of the walls as shown in the figure below.



Cross-sectional detail

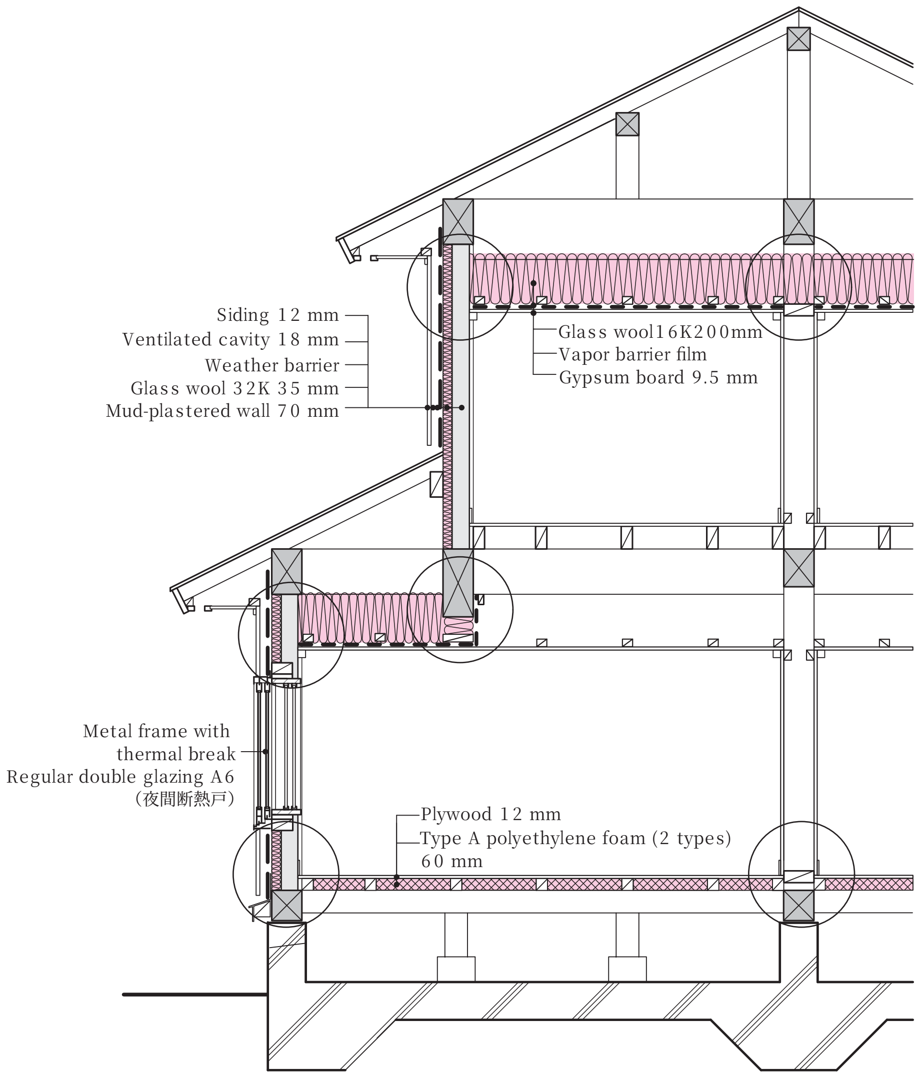
Insulation specifications of components

Component	Insulation specification	Thermal resistance value (m²•K/W) (Heat transmission coefficient for opening)	1992 thermal resistance standard (Zone III) (m²•K/W) (Heat transmission coefficient for opening)
Roof/Ceiling	Glass wool 16K 90 mm	2.0	1.8 or above
Exterior wall	Glass wool 32K 35 mm	0.97	1.8 or above
Floor/Foundation	Type A polyethylene foam (2 types) 35 mm	0.92	1.8 or above
Opening	Double glazing with 6 mm air space + metal frame with thermal break	4.07 (heat transmission coefficient (W/m²•K))	4.65 (heat transmission coefficient (W/m²•K)) or below
Air change rate (winter air leakage)	Approx. 0.5 – 0.7 ACH*		1.0 ACH

* Regarding insulation level achieved by combination of insulation and reinforced opening insulation, air tightness of the building envelope is expected to increase by installing airflow blocking to meet the 1992 standard level of insulation.

Insulation planning example (5): Level 3 – Partially reinforced insulation type of mud-plastered house (openings)

- This specification conforms to the 1999 energy conservation standards.
- For insulating exterior walls, an insulation material equivalent to at least 35 mm of 32K glass wool board is installed in the structural cavity on the exterior side of the mud-plastered walls.
- Insulation of openings is reinforced and insulating shutters are used at night.



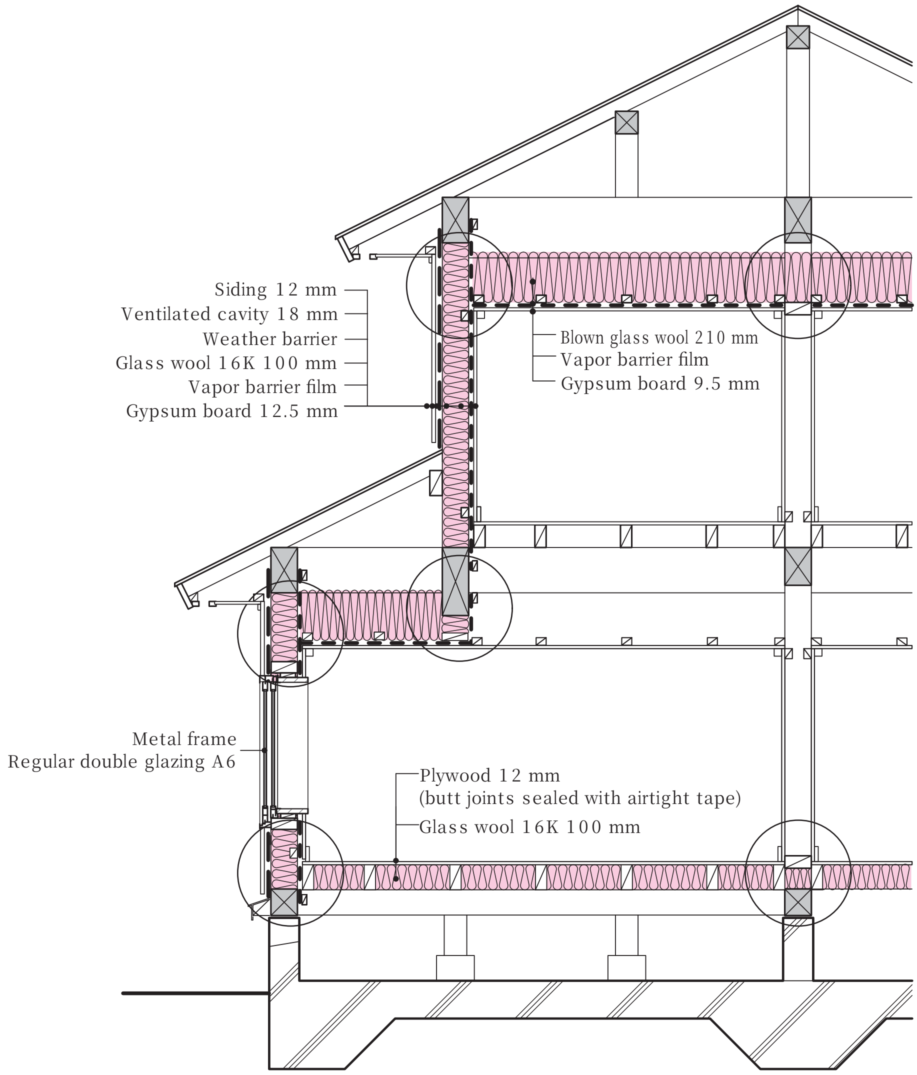
Cross-sectional detail

Insulation specifications of components

Component	Insulation specification	Thermal resistance value (m²•K/W) (Heat transmission coefficient for opening)	1999 thermal resistance standard (m²•K/W) (Heat transmission coefficient for opening)
Roof/Ceiling	Glass wool 16K 200 mm	4.44	4.0 or above
Exterior wall	Glass wool 32K 35 mm	0.97	2.2 or above
Floor/Foundation	Type A polyethylene foam (2 types) 60 mm	2.2	2.2 or above
Opening	Double glazing with 6 mm air space + metal frame with thermal break + insulating shutter at night (thermal resistance (R value) = 0.36 or greater)	3.06 (heat transmission coefficient (W/m²•K))	4.65 (heat transmission coefficient (W/m²•K)) or below
Air change rate (winter air leakage)	0.5 ACH		0.5 ACH

Insulation planning example (6): Level 3 – Evenly distributed insulation type (interior insulation)

- This specification conforms to the 1999 energy conservation standard.
- This example uses the interior insulation method for all the ceilings, exterior walls and floors.



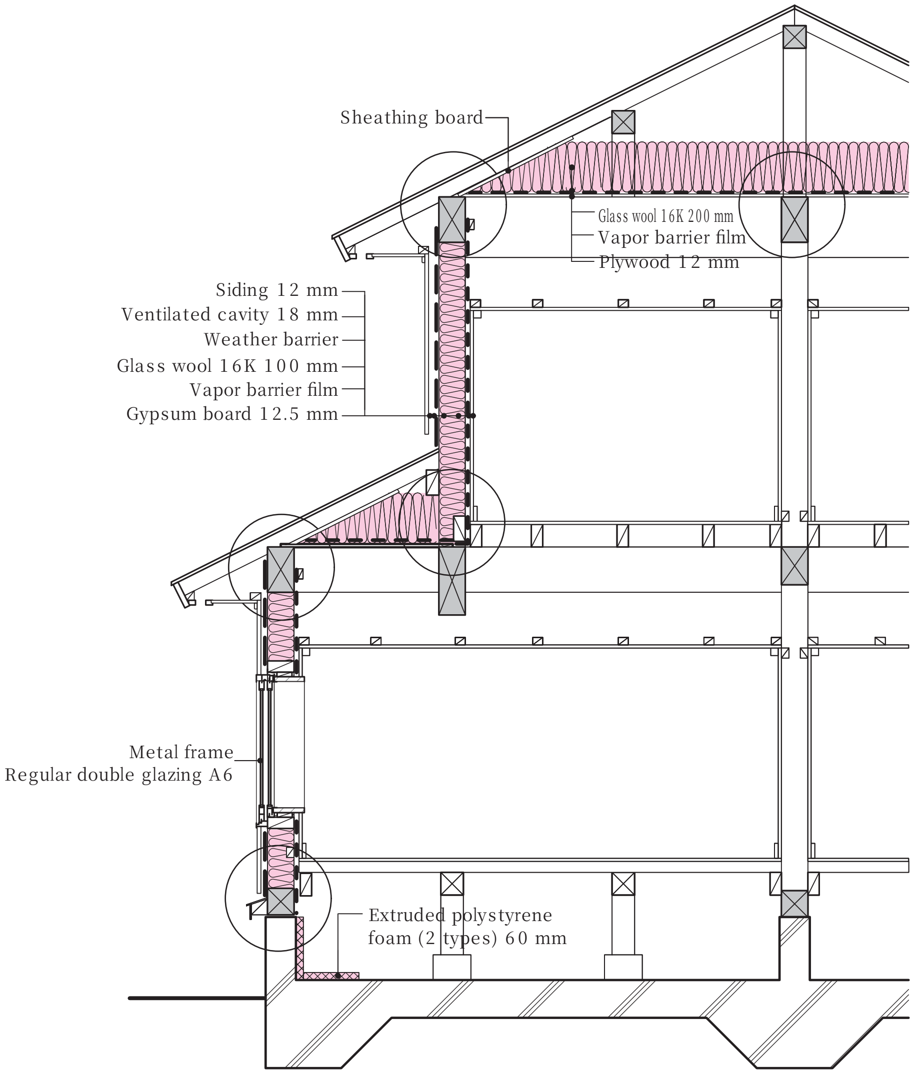
Cross-sectional detail

Insulation specifications of components

Component	Insulation specification	Thermal resistance value (m²•K/W) (Heat transmission coefficient for opening)	1999 thermal resistance standard (m²•K/W) (Heat transmission coefficient for opening)
Roof/Ceiling	Blown glass wool 16K 210 mm	4.0	4.0 or above
Exterior wall	Glass wool 16K 100 mm	2.2	2.2 or above
Floor/Foundation	Glass wool 16K 100 mm	2.2	2.2 or above
Opening	Double glazing with 6 mm air space	4.65 (heat transmission coefficient (W/m²•K))	4.65 (heat transmission coefficient (W/m²•K)) or below
Air change rate (winter air leakage)	0.5 ACH		0.5 ACH

Insulation planning example (7): Level 3 – Evenly distributed insulation type (insulation above beams and foundation insulation)

- This specification conforms to the 1999 energy conservation standard.
- This example adopts insulation above beams for the ceilings, interior insulation for exterior walls, and foundation insulation for the floor area.
- Insulation above beams is not yet commonly practiced, but this method was developed to reduce insulation loss. As plywood is installed over tie beams and insulation is laid on it, there is very little gap between insulation and it is easy to install a vapor barrier.



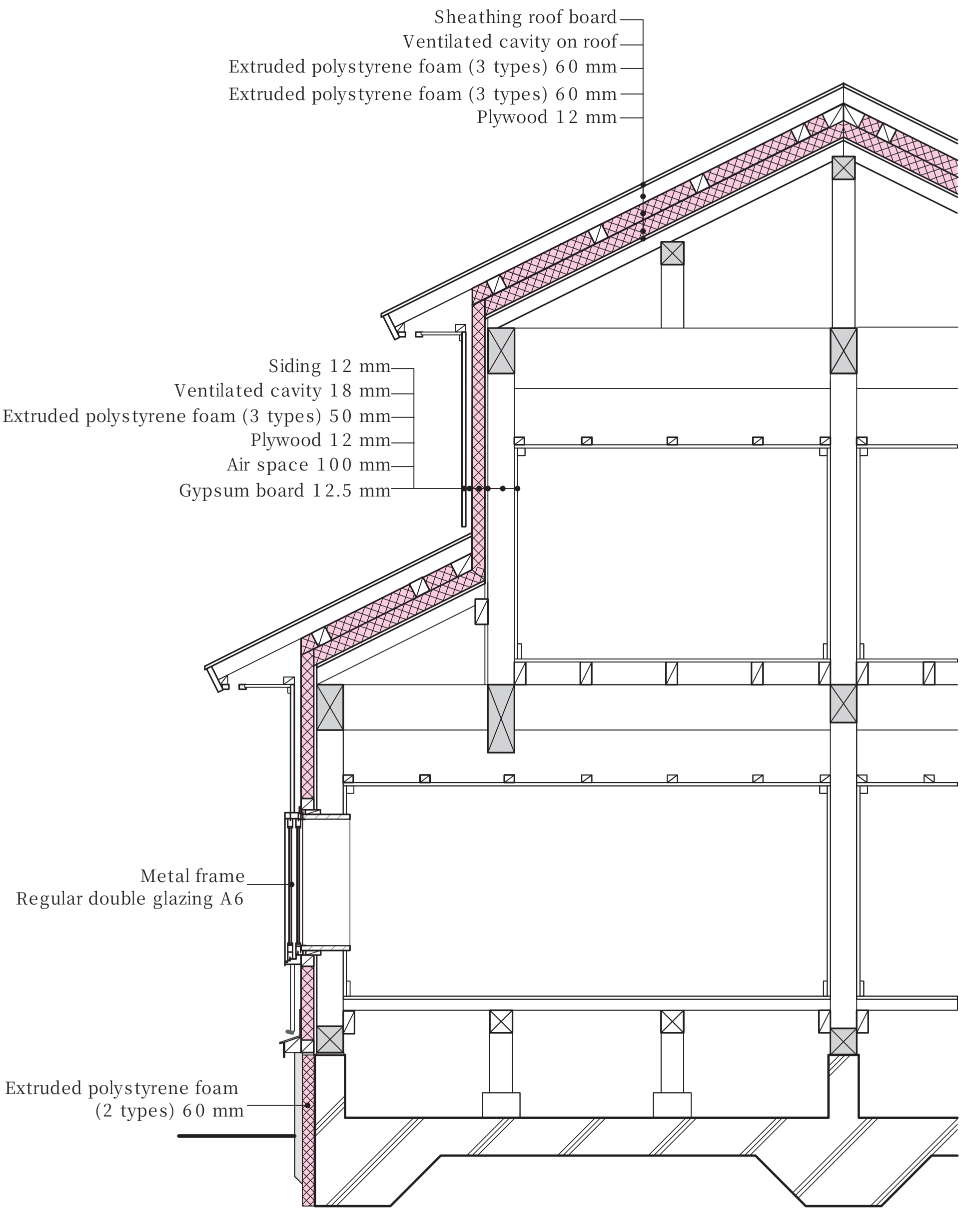
Cross-sectional detail

Insulation specifications of components

Component	Insulation specification	Thermal resistance value ($m^2 \cdot K/W$) (Heat transmission coefficient for opening)	1999 thermal resistance standard ($m^2 \cdot K/W$) (Heat transmission coefficient for opening)
Roof/Ceiling	Glass wool 16K 200 mm	4.44	4.0 or above
Exterior wall	Glass wool 16K 100 mm	2.2	2.2 or above
Floor/Foundation	Extruded polystyrene foam (2 types) 60 mm	1.75	1.7 or above
Opening	Double glazing with 6 mm air space	4.65 (heat transmission coefficient ($W/m^2 \cdot K$))	4.65 (heat transmission coefficient ($W/m^2 \cdot K$)) or below
Air change rate (winter air leakage)	0.5 ACH		0.5 ACH

Insulation planning example (8): Level 3 – Evenly distributed insulation type (exterior insulation)

- This specification conforms to the 1999 energy conservation standard.
- This example shows roof insulation, exterior insulation of exterior walls and foundation insulation.

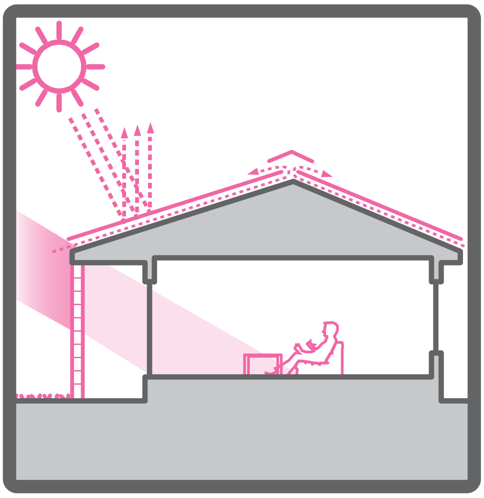


Cross-sectional detail

Insulation specifications of components

Component	Insulation specification	Thermal resistance value (m²•K/W) (Heat transmission coefficient for opening)	1999 thermal resistance standard (m²•K/W) (Heat transmission coefficient for opening)
Roof/Ceiling	Extruded polystyrene foam (3 types) 60 mm x 2	4.2	4.0 or above
Exterior wall	Extruded polystyrene foam (3 types) 50 mm	1.7	2.2 or above
Floor/Foundation	Extruded polystyrene foam (2 types) 60 mm	1.75	2.2 or above
Opening	Double glazing with 6 mm air space	4.65 (heat transmission coefficient (W/m²•K)	4.65 (heat transmission coefficient (W/m²•K) or below
Air change rate (winter air leakage)	0.5 ACH		0.5 ACH

4.2 Solar Shading Methods for Zone VI



Of the hot humid regions, most of the year is spent using either cross ventilation or cooling in Zone VI (Okinawa Prefecture), and in order to reduce the amount of energy used for cooling and improve comfort, "solar shading", which effectively shields solar radiation that would penetrate houses, is important.

Schemes for preventing solar penetration in temperate regions, which are not as hot as hot humid regions, focus on openings, but in Zone VI, it is also important to effectively use heat shielding on the roof or walls as well as the environment surrounding a building.

4.2.1 Purpose and Key Points of Solar Shading

1. Reducing amount of energy used for cooling

- Solar radiation has a major effect on the thermal environment in a house. In summer and in-between seasons, there is a greater need to use cross ventilation and cooling to reduce the room temperature, which increases because of solar radiation heat, but as the amount of such heat entering a room (amount of solar radiation penetration) increases, the usability of cross ventilation is limited and the amount of energy used for cooling increases.
- One purpose of solar shielding is, as the expression suggests, to shade from solar radiation, thereby reducing the amount entering a building and cutting the amount of energy used for cooling. There is a much greater need for cooling than heating in hot humid regions, meaning that solar shading in order to reduce the amount of energy consumed is extremely important.

2. Maintaining cool rooms

- In order to keep rooms cool in summer and in-between seasons, solar shading is important along with cross ventilation. In order to use solar shading efficiently, it is important to take into account the orientation of the components of the building envelope. By suppressing the amount of solar radiation entering rooms, it is possible to limit the increase in room temperature and also limit the surface temperature on the inside of the roof and exterior walls.

Key Point

Basic matters that are background knowledge for examining solar shading schemes

(1) Direct solar radiation and diffuse solar radiation

- Solar radiation includes direct solar radiation, which is incident directly from the sun, and diffuse solar radiation, which is incident after being diffused the atmosphere, clouds and the like (Fig. a). When the weather is good, the amount of direct solar radiation is high and the amount of diffuse

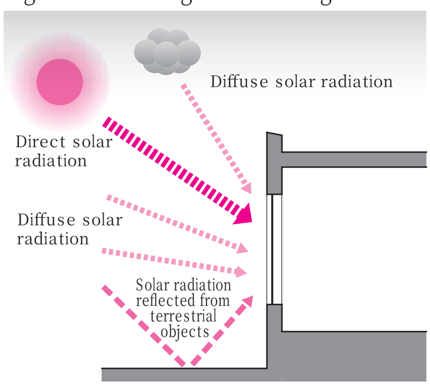
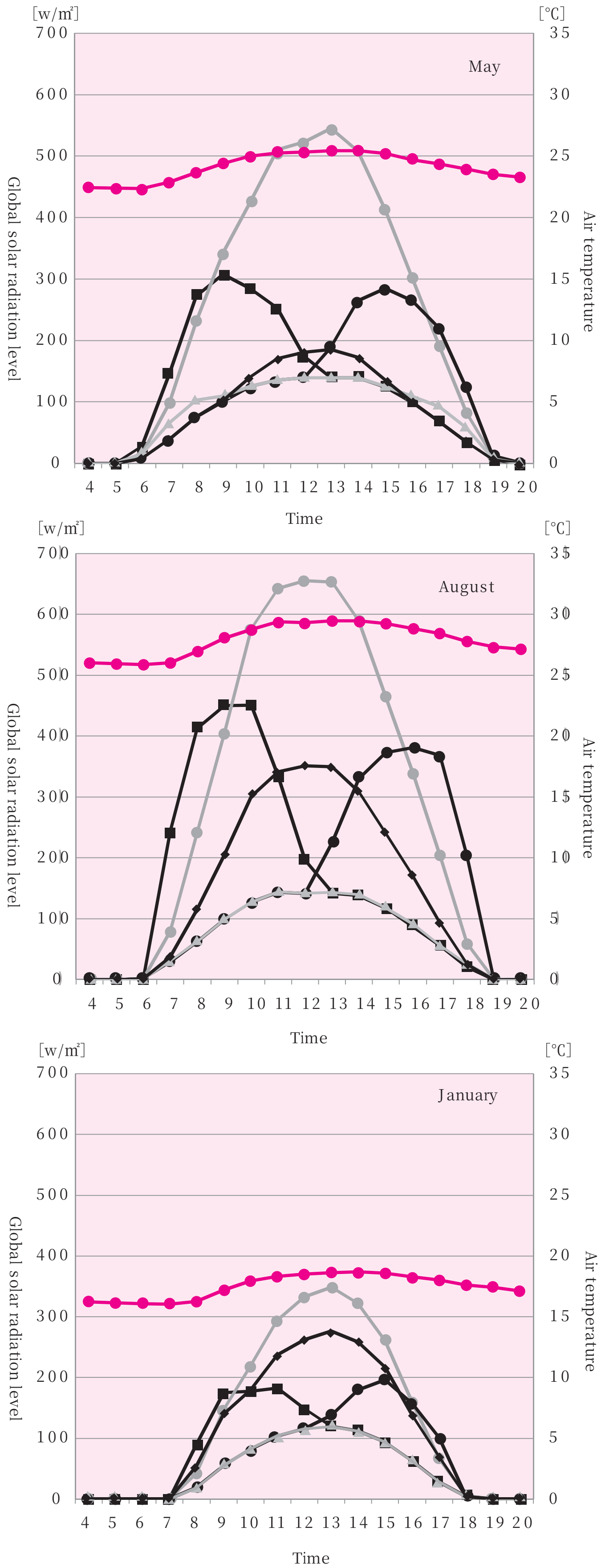


Fig. a Direct solar radiation and diffuse solar radiation solar radiation is low. In addition, the amount of solar radiation which is incident after being reflected from the ground and other outside surfaces cannot be ignored.

(2) Differences in the amount of solar radiation due to orientation

・The amount of solar radiation striking a building differs depending on the season and the orientation of the components of the building (Fig. b). The amount of solar

Fig. b
Global solar radiation level received by horizontal surfaces and exterior walls (Average values for May, Aug. and Jan. in Naha)



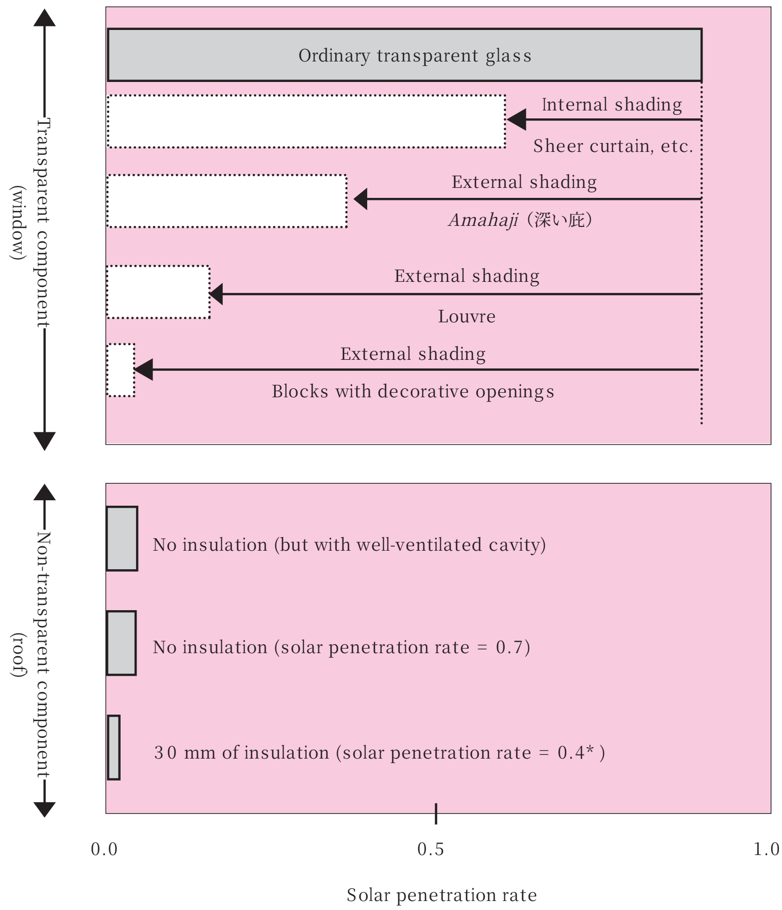
radiation in the summer, when the solar altitude is high in the sky, increases greatly on horizontal surfaces such as roofs, but for vertical walls, windows, etc., the amount of incident solar radiation is larger on east- or west-facing surfaces and smaller on south-facing surfaces. Understanding this characteristic of solar radiation is the key for effective solar shading schemes.

(3) Differences in the amount of transmitted solar radiation due to transparent and non-transparent components

- As shown in Fig. c, solar radiation levels from transparent components such as windows is far greater than from non-transparent components such as roofs or exterior walls. Therefore, transparent components such as windows are important for achieving adequate solar shading schemes.
- In addition, the effect of external shading, which shades solar radiation on the outside, is greater than that of internal shading, which shades solar radiation inside openings. In hot humid regions in particular, effective external shading is achieved by *amahaji* and blocks with decorative openings.
- For non-transparent components such as roofs, solar shading schemes are firstly to increase the solar radiation reflectance, to provide a ventilated cavity which insulates from the heat and ventilates well, and to enable attic ventilation.

Glossary: Solar penetration rate
The solar penetration rate is the proportion of heat that enters a room relative to the amount of incident solar radiation heat, and is also known as the solar heat gain coefficient. As this value decreases, the solar shading performance increases.

Fig c
Comparison of the solar penetration rates of windows and roofs



* From this diagram, it can be seen that insulation has a significant effect on reducing the solar penetration rate, but insulating performance is not necessarily the best way of reducing the cooling load and the amount of energy used for cooling since heat radiation via the building envelope when the air temperature is lower, such as at night, is also an important factor.

Note: Fig. c shows the proportion of solar penetration per unit area. Solar shading schemes in windows and roofs are important, and with typical house layouts, it is also useful to consider the area weighting for both these components, which is approximately 1:4.

4.2.2 Energy Conservation Target Levels for Solar Shading Schemes

1. Definition of target levels

- Energy conservation target levels for solar shading schemes have been set at levels 1-4 below and indicate the reduction rate of energy consumed by cooling systems (Table 1).
- The cooling energy reduction rate is closely related to the summer solar gain coefficient, which takes into account the effect of adjacent buildings and other factors (hereafter referred to as the "M value"), and by reducing the M value, the cooling energy reduction effect increases.
- The M value is a numerical value determined by the following design conditions and specifications of houses, A-C, and corresponds to the ratio of the solar radiation heat that penetrates the inside of a house, in relation to the global solar radiation incident upon a horizontal surface equivalent to the area of the total floor surface of the house.
    - A. Site conditions (related to orientation, adjacent buildings, etc.)
    - B. Outside shading devices – presence/absence of components such as overhangs attached to the building (Method 1)
    - C. Envelope solar shading schemes – schemes for ensuring solar radiation reflection, cavity ventilation, and insulation on the building envelope, particularly the roof (Method 2)
- The relationship between the M value and the cooling energy consumption differs depending on the type of envelope (roof) solar shading schemes.
- Increasing the solar radiation reflectance of the roof achieves a better effect for an equivalent M value than providing cavity ventilation or insulation schemes (See p.173). Please confirm the M values that can achieve the target levels for each roof solar shading scheme used and then consider solar shading schemes that enable M values smaller than these.

Table 1 Target levels for solar shading schemes and how to achieve them

Target level	Energy conservation effect (Cooling energy reduction rate)	M value	
		Roof solar shading schemes by ventilated cavity or insulation	Roof solar shading schemes by solar radiation reflection
Level 0	No reduction	>0.135	>0.150
Level 1	10% reduction	≤0.135	≤0.150
Level 2	20% reduction	≤0.10	≤0.125
Level 3	25% reduction	≤0.08	≤0.115
Level 4	30% reduction	≤0.065	≤0.105

- The standard cooling energy consumption as of 2000 was 10.3 GJ (approximately 16% of overall energy consumption) (See 6.1 on p.339).
- Level 0 assumes a house having no solar shading schemes, that is, located at a site where there are no adjacent buildings to shade the solar radiation, employing no outside shading devices such as overhangs, and lacking any particular envelope solar shading scheme. By combining conditions and specifications A-C above, it is possible to reduce the cooling energy by a maximum of approximately 30%.

Key Point

What is the M value ?

The summer solar gain coefficient that takes into account the effect of adjacent buildings and other objects is based on the standard "summer solar gain coefficient", which is used in the 1999 Energy Conservation Standards, and is an indicator of solar shading performance, which is newly defined in this document. The conventional summer solar gain coefficient indicates the average ratio during the cooling period of the amount of solar radiation heat actually gained by the inside of a building to the solar radiation heat level able to be gained by assuming that there is no shading by the building. The effects of shading objects such as other buildings around the building in question, the solar radiation reflectance of the surface of exterior finishing materials, and

Glossary: Exposure factor
The exposure factor indicates the ratio of the amount of solar radiation incident upon vertical surfaces (exterior walls), having the same area but facing in different directions, when considering the amount of solar radiation incident upon a horizontal surface having no shading objects around it as 1.

ventilated cavities on the outside of the building envelope, however, were generally not taken into account in the calculations. By considering factors such as these, the summer solar gain coefficient that takes into account the effect of adjacent buildings and other objects is an indicator that aims to include the effects of a wider range of solar shading schemes. The conventional summer solar gain coefficient is known as the μ value, but in order to avoid confusion, the summer solar gain coefficient that takes into account the effect of adjacent buildings and other objects is known as the M value.

2. Requirements for achieving target levels

Target levels are determined by M values, as mentioned above. However, because the calculations for obtaining these M values are quite complex, we have given examples of the site conditions, outside shading devices (Method 1) and building envelope solar shading schemes (Method 2) involved in determining M values in this document, and have made it possible to confirm whether or not the target levels can be achieved through the selection of these conditions and specifications.

We will clarify the methods for calculating and judging M values and the methods for calculating cooling loads from M values in this chapter.

1) Site conditions (solar shading by adjacent buildings and other objects)

- Solar radiation that strikes the exterior walls of a house is sometimes shaded by buildings and other objects surrounding the house (including adjacent buildings). In other words, even if the solar radiation is the same, the effect of the solar radiation incident upon a house can differ depending on the distance to adjacent buildings, the number of floors in adjacent buildings, surrounding vegetation and other objects.
- The effect of solar shielding by adjacent buildings and other objects is expressed by the exposure factor. The smaller the exposure factor, the higher the solar shading effect.
- In this document, we have set up three typical site categories, sites 1-3, which differ in terms of horizontal distance to adjacent buildings and other objects (Table 2). The susceptibility to the effects of solar radiation increases in the order of Site 1, Site 2 and Site 3.

  Site 1: Site in which adjacent buildings and other objects are close, such as in large cities

  Site 2: Site in which adjacent buildings and other objects are fairly close, such as in suburbs near cities

  Site 3: Site in which adjacent buildings and other objects are not close, such as in suburbs away from city centers

Table 2 Requirements and exposure factors for site categories (Naha, Mar. 25 – Dec. 14)

Site category	Orientation	Horizontal distance to adjacent buildings and other objects	Exposure factor
Site 1	North	6 m or less	0.31
	East	3 m or less	0.26
	South	6 m or less	0.41
	West	3 m or less	0.32
Site 2	North	6 - 10 m	0.34
	East	3 - 10 m	0.35
	South	6 - 10 m	0.44
	West	3 - 10 m	0.42
Site 3	North	More than 10 m	0.39
	East	More than 10 m	0.39
	South	More than 10 m	0.49
	West	More than 10 m	0.47
Horizontal surface		—	1.00

- Table 2 shows the horizontal distance to adjacent buildings and other objects in the directions north, east, south and west, which are the conditions for each site, and the exposure factors obtained from these distances. Select a site category in which the horizontal distances in all four directions are satisfied, and in cases where the site is more susceptible to the effects of solar radiation due to values for the horizontal distance in one direction exceeding those shown in Table 2, please regard this site as satisfying the horizontal distance in the direction in question (for example, if the horizontal distances to adjacent buildings and other objects are north 6 m, east 3 m, south 8 m and west 3 m, this is Site 2).

- In addition, please regard sides that are oriented within ±45° of true south as being south-facing.
- In cases where there is continuous vegetation surrounding the building and a clear solar shading effect is expected, it is considered appropriate to regard such sites as a site category that is less susceptible to the effects of solar radiation.
- Details of the solar shading effect of adjacent buildings and other objects are explained in Section 4.2.3: 2 Confirming site conditions and considering building location.

2) Solar Shading Methods

- The following methods have been adopted in this document as solar shading methods that have a cooling energy reduction effect.

Method 1	:	Solar shading methods using outside shading devices
Method 2	:	Solar shading methods using the building envelope

- The details of each method are explained in 4.2.4 Solar Shading Methods.
- In order to judge whether the target level has been achieved, specifications thought to be typical have been set for each method. Please refer to these specifications and consider design specifications.

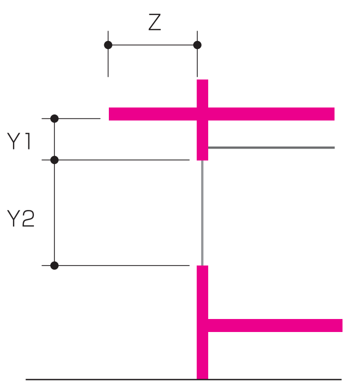
(1) Method 1: Outside shading devices

- Components such as overhangs, blocks with decorative openings, and external shading components (such as louvers, hereafter called "outside shading devices") have a solar shading effect. Of these, overhangs have an effect on the amount of solar radiation that penetrates the building depending on the window-overhang distance (the distance from the bottom of the window to the top of the overhang), the height of the window, the degree to which the overhang protrudes, the width of the overhang and other factors. Additionally, the solar shading effect increases dramatically if blocks with decorative openings are used.
- The solar shading effect from outside shading devices is indicated by the shading coefficient. A lower shading coefficient means a higher solar shading effect (See p.177).
- In this document, because the specifications of outside shading devices are set by dividing them into different classes, please select a class that corresponds to the design specifications (Table 3, Fig. 1). Class

Table 3 Classes and specifications of outside shading devices

Class of outside shading device	Orientation	Shading coefficient	Overhangs*1			Blocks with decorative openings, louvers etc.
			Window-overhang distance (mm)	Window height (mm)	Overhang protrusion (mm)	
Class −1	—	1.0 (all orientations)	Does not satisfy class 0			—
Class 0	North	0.64	0	≤900	≥200	—
	East	0.75	0	≤1300	≥200	—
	South	0.65	≤400	≤2000	≥600	—
	West	0.65	≤400	≤1300	≥600	—
Class 1	North	0.64	0	≤900	≥200	—
	East	0.65	≤400	≤1300	≥600	—
	South	0.52	≤400	≤2000	≥1000	—
	West	0.53	≤400	≤1300	≥1000	—
Class 2	North	0.49	≤400	≤900	≥600	—
	East	0.53	≤400	≤1300	≥1000	—
	South	0.43	≤400	≤2000	≥1500	—
	West	0.43	≤400	≤1300	≥1500	—
Class 3	North	0.49	≤400	≤900	≥600	—
	East	0.53	≤400	≤1300	≥1000	—
	South	0.43	≤400	≤2000	≥1500	—
	West	0.06	≤400	≤1300	≥1500	Block*2

* 1. The width of the overhang is assumed to be at least the width of the window.
* 2. The overhang is installed between the exterior wall and the decorative block.



Y1: Window-overhang distance
Y2: Window height
Z: Overhang protrusion

Fig. 1 Construction of overhang and each component

0 is a fairly basic specification, and the solar shading effect increases in the order of Class 1, Class 2 and Class 3.

- Table 3 shows the outside shading devices (overhangs, blocks with decorative openings, louvers and other features) facing in the directions north, east, south and west, which are the conditions for each class, and the shading coefficients obtained from these devices. Please select a class in which the outside shading device specifications in all four directions are satisfied. In cases where the outside shading device specification in one direction is regarded as having a solar shading effect lower than that shown in Table 3, please regard this as corresponding with the class satisfying the outside shading device specification in the direction in question.
- In addition, please regard sides that are oriented within ±45° of true south as being south-facing.

(2) Method 2: Solar shading methods using building envelope

- With regard to the concrete envelope of the roof and exterior walls, the presence or absence of ventilated cavities and insulating schemes, as well as the solar radiation reflectance of surfaces, affect the amount of solar radiation that penetrates the building. Various combinations of these solar shading schemes have been considered, but although schemes for roofs that are directly struck by solar radiation are particularly important in hot humid regions, the following characteristics have also been observed.
- Insulation has the effect of limiting the amount of solar radiation that penetrates a building, but because it also prevents heat from escaping from inside the building at night, it is not always recommended in hot humid regions.
- By raising the solar radiation reflectance of the surface of the roof, the effect of ventilated cavities and insulation is reduced.
- If insulation is applied to the roof, almost no effect is achieved by ventilated cavities.
- With these characteristics in mind, because the following four types of specification have been set for the envelope of the roof and the exterior walls, please select a specification that corresponds to the design specifications (Table 4). There is no exterior wall insulation in any of the specifications. In addition, Specification 1 corresponds to a standard specification in which no particular solar shading schemes have been incorporated.

Specification 1	:	No insulation, no schemes
Specification 2	:	No insulation, roof cavity ventilation (ventilated cavity maintained on roof surface)
Specification 3	:	Roof insulation (insulation incorporated into roof)
Specification 4	:	No insulation, roof reflection (raises solar radiation reflectance of roof surface)

Table 4 Building envelope specifications for solar shading schemes

Envelope specification type	Exterior walls				Roof				Ratio of solar radiation penetrating envelope[3]
	Ventilated cavity	Insulation schemes	Solar radiation reflectance[1]	Solar penetration rate	Ventilated cavity	Insulation schemes	Solar radiation reflectance[1]	Solar penetration rate	
Specification 1 (No insulation, no schemes)	No	No	0.4	0.097	No	No	0.4	0.118	100%
Specification 2 (No insulation, roof cavity ventilation)	No	No	0.4	0.097	Yes	No	0.4	0.054	58%
Specification 3 (Roof insulation)	No	No	0.4	0.097	No	Yes[2]	0.4	0.022	37%
Specification 4 (No insulation, roof reflection)	No	No	0.4	0.097	No	No	0.7	0.059	61%

1. The solar radiation reflectance of the finishing material on the outer surface of the exterior walls and the roof; the values have the following characteristics:
   0.4 = Moderate reflection (concrete, light-colored paints, etc.); 0.7 = High reflection (white paint, etc.)
2. The solar penetration rate when a type 2 extruded polystyrene foam insulating sheet (30 mm) is installed.
3. The ratio when Envelope Specification 1 is set to be 100% (standard); the amount of solar penetration is calculated from the following formula:
   Amount of solar penetration = (exterior wall area x exterior wall solar penetration rate) + (roof area x roof solar penetration rate)
   (Uses the areas from the Type A house model on p.344)
   The amount of solar radiation that penetrates the envelope corresponds to the contribution to the M value of the solar heat gain that passes through the envelope (if the exposure factor for more than 10m is assumed).

3. How to achieve target levels

- Based on a standard house model in hot humid regions, the results are shown for the M value calculations obtained by combining the envelope solar shading specifications and the outside shading device classes for each of Site 1, Site 2 and Site 3 (Table 5).
- The M values in Table 5 are calculated by setting the envelope and opening specifications as shown in Table 6.
- The different colors in Table 5 correspond with the level.
- Even if the envelope specifications are the same, the level may increase if the schemes using outside shading devices are enhanced.

Table 5 Solar penetration coefficient (M value) by combining outside shading devices and building envelopes

(1) Site 1

Envelope specification type	Outside shading devices*							
	Class 0		Class 1		Class 2		Class 3	
	North	≥200	North	≥200	North	≥600	North	≥600
	East	≥200	East	≥600	East	≥1000	East	≥1000
	South/West	≥600	South/West	≥1000	South/West	≥1500	South/West	≥1500 (decorative block (W))
Specification 1 (No insulation, no schemes)	0.166		0.159		0.151		0.148	
Specification 2 (No insulation, roof cavity ventilation)	0.102		0.095		0.087		0.084	
Specification 3 (Roof insulation)	0.070		0.063		0.055		0.052	
Specification 4 (No insulation, roof reflection)	0.107		0.100		0.092		0.089	

(2) Site 2

Envelope specification type	Outside shading devices*							
	Class 0		Class 1		Class 2		Class 3	
	North	≥200	North	≥200	North	≥600	North	≥600
	East	≥200	East	≥600	East	≥1000	East	≥1000
	South/West	≥600	South/West	≥1000	South/West	≥1500	South/West	≥1500 (decorative block (W))
Specification 1 (No insulation, no schemes)	0.173		0.165		0.156		0.151	
Specification 2 (No insulation, roof cavity ventilation)	0.109		0.101		0.092		0.087	
Specification 3 (Roof insulation)	0.077		0.069		0.060		0.055	
Specification 4 (No insulation, roof reflection)	0.114		0.106		0.097		0.092	

(3) Site 3

Envelope specification type	Outside shading devices*							
	Class 0		Class 1		Class 2		Class 3	
	North	≥200	North	≥200	North	≥600	North	≥600
	East	≥200	East	≥600	East	≥1000	East	≥1000
	South/West	≥600	South/West	≥1000	South/West	≥1500	South/West	≥1500 (decorative block (W))
Specification 1 (No insulation, no schemes)	0.180		0.171		0.161		0.155	
Specification 2 (No insulation, roof cavity ventilation)	0.116		0.107		0.097		0.091	
Specification 3 (Roof insulation)	0.084		0.075		0.065		0.059	
Specification 4 (No insulation, roof reflection)	0.121		0.112		0.102		0.096	

* Of the class requirements (Table 3 on p.167), the outside shading devices columns refer only to the hangover protrusior and the presence or absence of decorative blocks.

Level 0
Level 1
Level 2
Level 3
Level 4

Table 6 Standard specifications for envelopes and openings

No insulation	No insulation on exterior walls or roof
Roof cavity ventilation	Spreading blocks, sheet-like panels and other devices installed on roof (See Fig. 13 on p.183.)
Roof insulation	Type 2 extruded polystyrene foam insulating sheet (30 mm) installed (thermal resistance of insulating material = 0.8 m2•K/W).
Roof reflection	Solar radiation reflectance of roof = ≥0.7 (white paint)
Openings (shared)	Standard single layer glass + sheer curtains

1. Except for cases in which roof reflection is incorporated, the solar radiation reflectance of the surface of the roof and exterior walls is 0.4 (concrete, light-colored paints, etc.)
2. The solar penetration rate of openings is 0.56 (See p.72).

Comment ● Methods for determining M values by calculation

Energy conservation target levels by solar shading methods can be determined by using the summer solar gain coefficient (M value) as an indicator. In subsection 3 of Section 4.2.2, methods were shown in which M values determined by envelope (roof and exterior walls) specifications and outside shading device (overhangs, etc.) specifications are selected.

Here, we will explain methods for calculating M values according to design specifications.

M values can be calculated using the following formula:

M value = (sum of component/orientation-specific M values) / (total floor area of house)

Here, "component" means the building envelope (roof and exterior walls) and openings (windows, doors, etc.), but M values are obtained for each orientation in which these components face (vertical surfaces that face east, west, north and south as well as horizontal surfaces). These M values can be calculated using the following formula:

Component/orientation-specific M value
= exposure factor of component x shading coefficient of outside shading devices x solar penetration rate of component x area of component

* For the exposure factors of components, see Table 2 on p.168 and Fig. 3 on p.174.
For shading coefficients of outside shading devices, see Table 3 on p.169, Figs. 6 and 7 on p.178, Table 7 on p.179 and Fig. 11 on p.180.
For the solar penetration rates of components, see Table 4 on p.170, Table 8 on p.182, and Table 9 on p.186.
For the areas of components, please use the projected areas of the roof, exterior walls, windows, etc.

A calculation table and sample calculations are shown below. For the type A house model (standard model, see p.344) designed in order to calculate the energy conservation effect, the M value for the house as a whole was 0.096 (level 4), based on the following calculation conditions.

Component	Orientation	Exposure factor (A)	Shading coefficient of outside shading devices (B)	Solar penetration rate of component (C)	Area (m^2) (D)	M value (A x B x C x D)
Roof	Horizontal	1.0	1.0	0.059	134.51	7.936
Exterior walls	North	0.39	0.49	0.097	39.29	0.728
	East	0.39	0.53	0.097	21.18	0.425
	South	0.49	0.43	0.097	28.93	0.591
	West	0.47	0.06	0.097	22.74	0.062
Windows	North	0.39	0.49	0.56	6.18	0.661
	East	0.39	0.53	0.56	4.86	0.563
	South	0.49	0.43	0.56	12.95	1.528
	West	0.47	0.06	0.56	1.50	0.024
Doors	South	0.49	0.43	0.56	3.60	0.425
	West	0.47	0.06	0.56	1.80	0.028
Total (E)						12.971
Total floor area (m^2) (S)						134.510
M value (E/S)						0.096

■Calculation conditions
(A) Exposure factor: Site 3 (suburbs away from city center) exposure factor
(B) Shading coefficient of outside shading devices: Class 3
(C) Solar penetration rate of component: Specification 4 (No insulation, roof reflection)
(D) Area of roof, exterior walls, windows, etc., of Type A house model

Comment ● Methods for calculating cooling load from M value

- **The diagram shows the relationship between M value and cooling load, based on numerical simulations using a standard house in a hot humid region as a model. The gradient of the plot in cases where roof solar shading methods comprise insulation or cavity ventilation is different from that in cases where the solar radiation reflectance is used, and even if the M values are the same, the cooling load tends to be smaller when solar radiation reflection is used compared to when insulation or cavity ventilation is used.**
- **The relationship between M value and cooling load can be shown by the following formula for each roof solar shading scheme. By using this formula, it is possible to calculate an approximate cooling load by obtaining the M value of the house.**

(1)If the roof solar shading method comprises insulation or cavity ventilation:

Cooling load (MJ) = 77,289 x M value + 13,795

(2)If the roof solar shading method comprises solar radiation reflection:

Cooling load (MJ) = 125,473 x M value + 5,340.6

[Sample calculation]

If the M value obtained by using solar radiation reflection as the roof solar shading method is 0.096:

(From formula (2) above): Cooling load (MJ) = 125,473 x 0.096 + 5,340.6

= 17,386.0 (MJ)

Reference: Using a numerical simulation, the cooling load of a house corresponding to level 0 was approximately 27,100 MJ (standard value). From this, it can be seen that the cooling energy reduction rate of a house fitted with the schemes mentioned above is approximately 35%.

$$\text{Cooling energy reduction rate (\%)} = \left(1 - \frac{17{,}386}{27{,}100}\right) \times 100$$

$$= 35.8\ (\%)$$

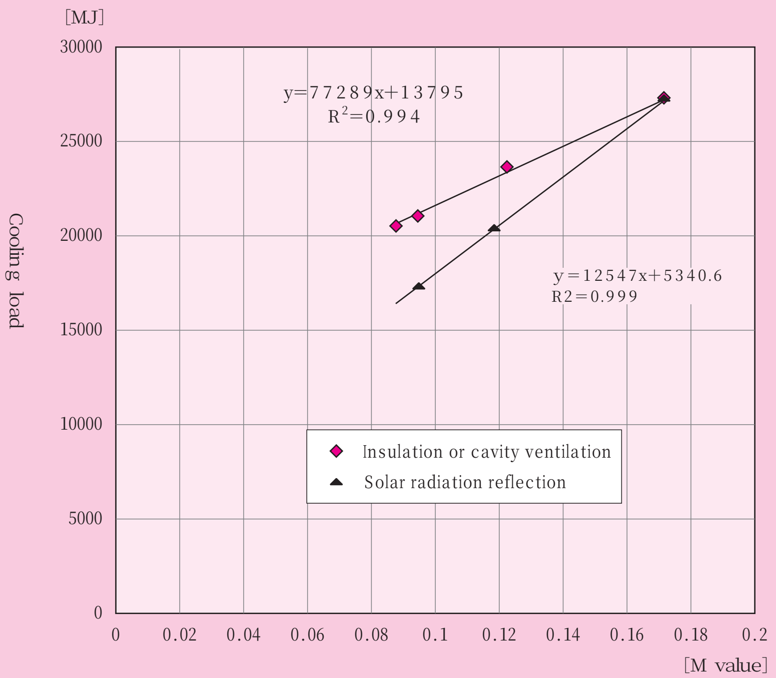


Fig. Relationship between M value and cooling load in houses in hot humid regions

4.2.3 Steps for Examining Solar Shading Technology and Confirmation of Site Conditions

1 Steps for examining solar shading technology

Step 1 Set the target level

- Set the cooling energy reduction rate.

▼

Step 2 Confirm site conditions and consider building location

- Confirm conditions around building site and consider building location.
- Select corresponding “site conditions”.

▼

Step 3 Consider applying solar shading methods using outside shading devices

- Confirm the amount of solar radiation incident upon the exterior walls and roof.
- Taking into account orientation, consider incorporating overhangs, blocks with decorative openings, external solar shading components and other devices.
- Select corresponding “outside shading device class”.

▼

Step 4 Consider applying solar shading methods using building envelope

- Consider roof solar shading specifications.
- Consider exterior wall solar shading specifications.

▼

Step 5 Confirm cooling energy reduction rate from applying solar shading methods

- Investigate M value and confirm cooling energy reduction rate.

2 Confirming site conditions and considering building location

- Solar radiation that strikes the exterior walls of a house can be shaded by adjacent buildings or, in the case of hilly land, diagonal surfaces (hereafter called “adjacent buildings”). The effect of this shading can be more or less determined by the ratio of the difference in elevation of an adjacent building that acts as a shading object divided by the horizontal distance to the adjacent building. If the horizontal distance between the exterior wall of the house in question and that of the adjacent building is 10 m or less, a solar shading effect takes place.
- The relationship between the adjacent building and the difference in elevation is roughly classified into three cases, and the solar shading effects (exposure factors) differ as shown below (Figs. 2 and 3).
- As shown in Case (1), if there are no adjacent buildings within 10 m of the house in question (for example, if there is no house opposite a one-storey house, or in the case of a second-floor room, if there is a one-storey building opposite a two-storey house), the solar radiation is not shaded.
- As shown in Case (2), if there is an adjacent building that has the same number of stories as the house in question (for example, if there is a one-storey building opposite a one-storey house or if there is a two-storey building opposite a two-storey house), the solar radiation is shaded.
- As shown in Case (3), if there is an adjacent building that has one storey more than the house in question (for example, if there is a two-storey building opposite a one-storey house), the solar shading effect is stronger than that is Case (2).
- By taking into account this type of situation surrounding a house and applying solar shading methods by focusing on those components that are more susceptible to solar radiation, it is possible to effectively improve solar shading performance.
- On the other hand, solar radiation on the roof can also be shaded by adjacent buildings and other objects. However, solar radiation on a roof surface shaded by adjacent buildings occurs when the sun is low in the sky and the amount of solar radiation is small, such as early in the morning or in the evening. Little shading occurs during the middle of the day, when the amount of solar radiation incident upon the surface of a roof is large. In addition, it is the edges of the roof that are shaded, with the center of the roof having little sun shadow. Therefore, solar shading of roofs by adjacent buildings and other objects is not taken into account; in other words, the exposure factor of the roof is regarded as being 1, regardless of the surrounding conditions (Fig. 4).

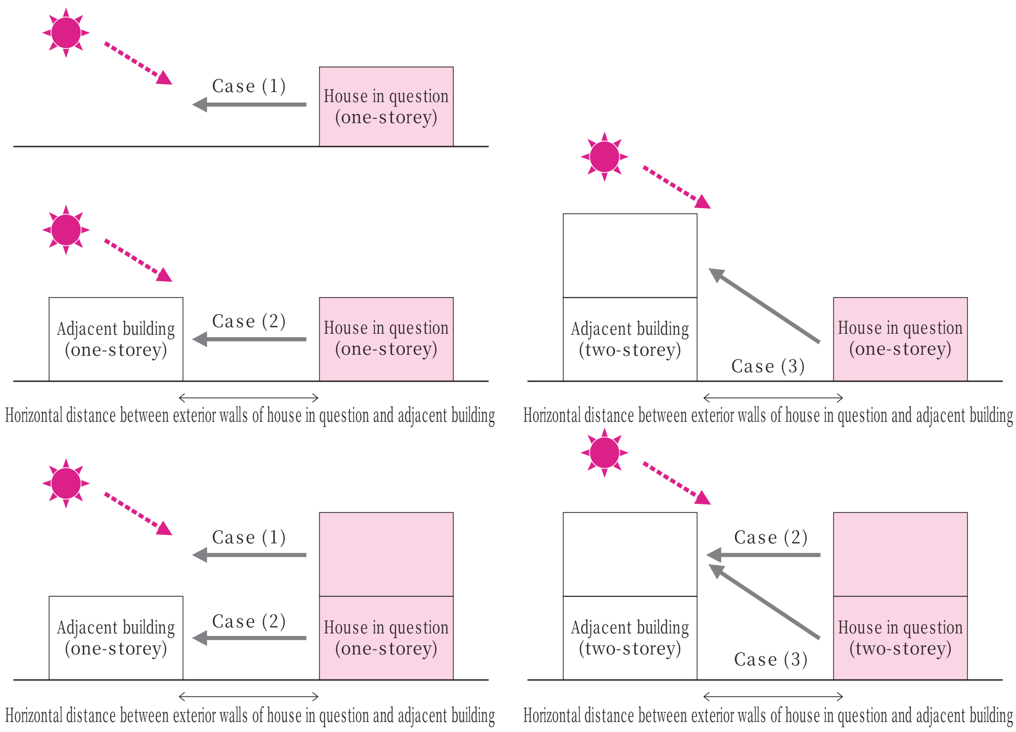
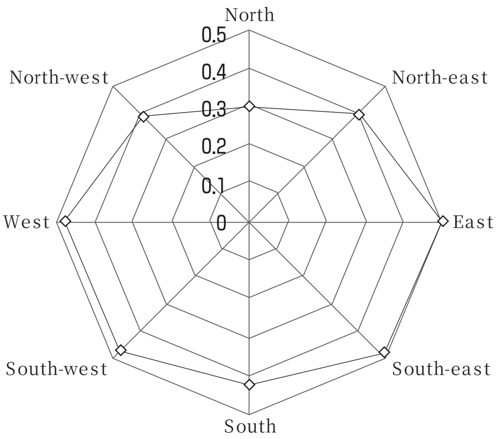
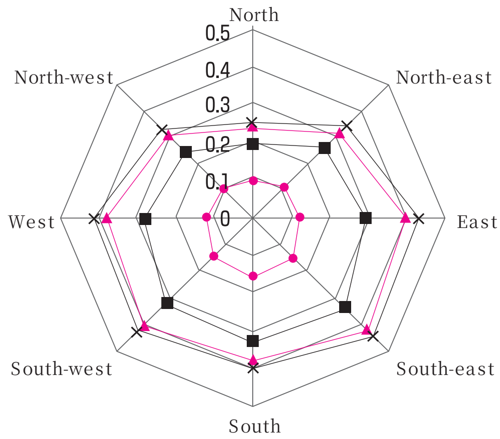


Fig. 2 Relationship between adjacent buildings and difference in elevation



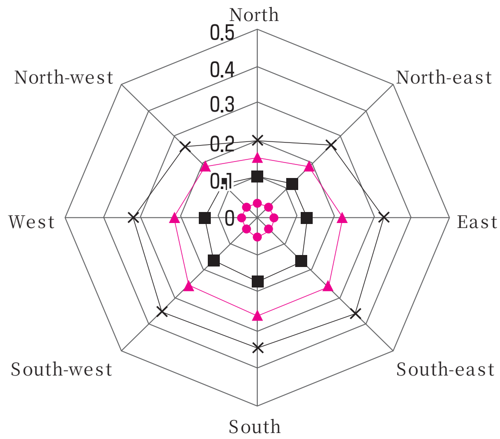
Case (1): No adjacent building within 10 m



Case (2): Adjacent building that has the same number of storeys as the house in question

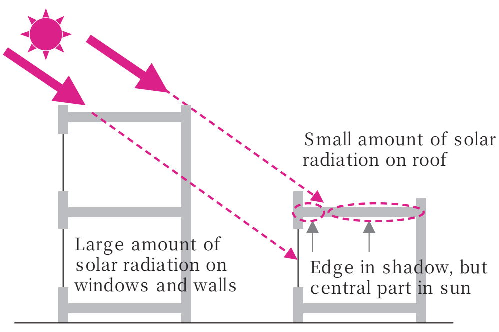
Horizontal distance between exterior wall and adjacent building
- 1 m
- 3 m
- 5 m
- 10 m
- No adjacent building etc. within 10 m

The orientations in the graphs indicate the orientations of the walls.

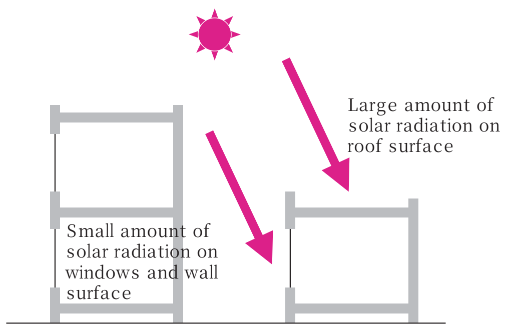


Case (3): Adjacent building one storey higher than the house in question

Fig. 3 Differences in exposure factor due to presence/absence of adjacent buildings
; Naha, Mar. 25 – Dec. 14 (cooling period)



(A) Sun low in sky: Solar radiation shaded by adjacent buildings



(B) Sun high in sky: Solar radiation not shaded by adjacent buildings

Fig. 4 Shading of roof by adjacent buildings

4.2.4 Solar Shading Methods

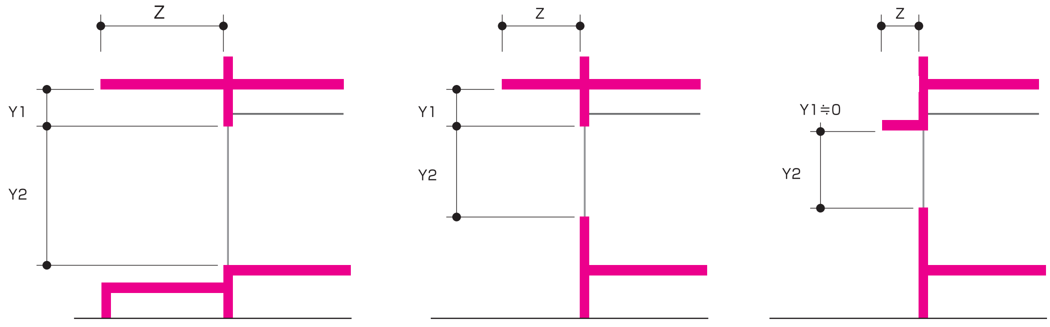
Method 1 : Solar shading methods using outside shading devices

- This method shades solar radiation through the use of devices mounted outside the windows; for example, external solar shading components such as overhangs, blocks with decorative openings or louvers. Once solar radiation heat enters a room, it causes the temperature inside the room to increase until discharged, and solar shading must therefore be applied on the outside of the windows.
- If using blocks with decorative openings that cover the whole of the *amahaji* or wall surface, this has the effect of shading solar radiation that enters the room not only from the windows, but also from the wall surface.
- The effect of solar shading by outside shading devices is indicated by the shading coefficient. A smaller shading coefficient means a higher solar shading effect.

$$\text{Shading coefficient} = \frac{\text{Amount of solar radiation penetrating the window if outside shading devices are fitted}}{\text{Amount of solar radiation penetrating the window if outside shading devices are not fitted}}$$

1. Overhangs

- Overhangs mainly shade solar radiation that strikes windows and walls from above. As a result, the solar shading effect of overhangs is at its highest when direct solar radiation strikes the south side of a building when the sun is high in the sky and the weather is fine. In addition, the greater the degree of protrusion of the overhang, the higher the shading effect (Figs. 5 and 6).
- Solar radiation strikes windows and wall surfaces from the side as well as from the front. Therefore, installing a wide overhang that covers more than one window achieves a higher shading effect than fitting a small, narrow overhang to each window (Fig. 6).
- Because solar radiation strikes east- and west-facing surfaces when the sun is low in the sky, the shading effect due to overhangs is less for the lower parts of windows (Figs. 6 and 7). In such cases, also using a block with decorative openings increases the shading effect for those lower parts of windows that are not shaded by overhangs.
- Fitting overhangs immediately above windows increases the shading effect (Fig. 7). It is possible to achieve a solar shading effect even with small overhangs by installing them as near as possible to the tops of windows.



Amahaji

Overhangs fitted to large- or medium-sized windows (overhangs that protrude at the same level as roof slabs)

Small overhangs (often used on medium- and small-sized windows)

Y1: Window-overhang distance
Y2: Window height
Z : Overhang protrusion

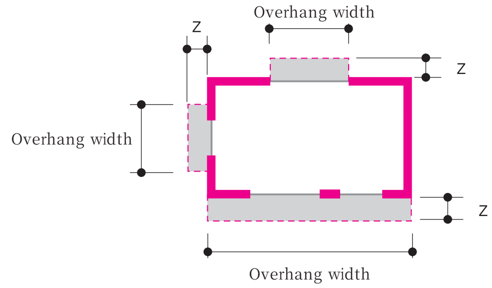
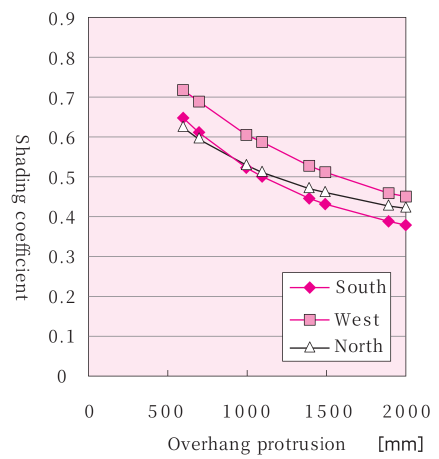
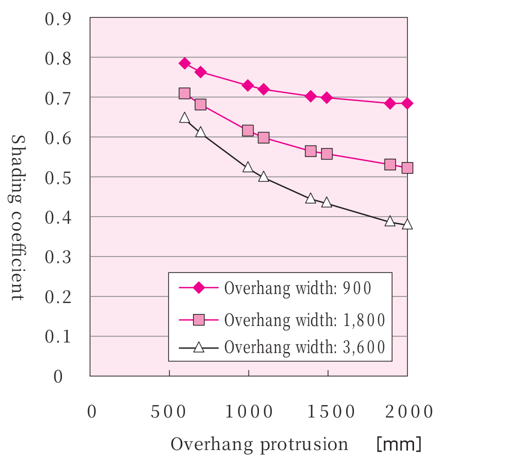


Fig. 5 Typical form and dimensions of overhangs

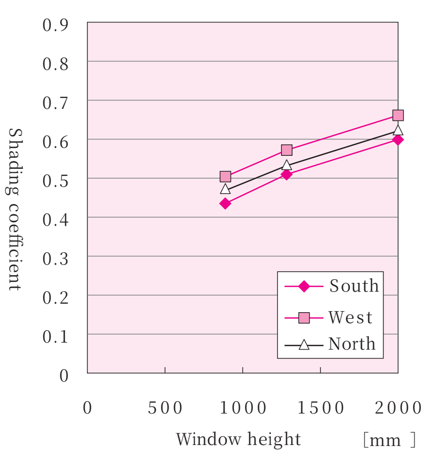


(A) Differences in shading coefficient due to differences in installation orientation
Window-overhang distance 400 mm; Window height 2,000 mm; Overhang width 3,600 mm

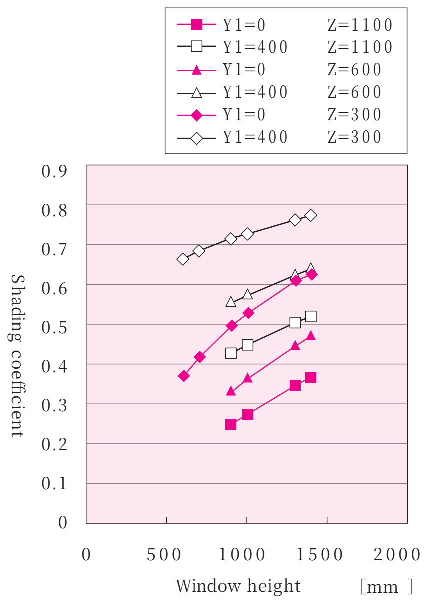


(B) Differences in shading coefficient due to differences in overhang width
Window-overhang distance 400 mm; Window height 2,000 mm; Installation orientation: south

Fig. 6 Relationship between overhang protrusion dimensions and shading coefficient



(A) Y1 = 400; Z = 1,100; Overhang width = 1,800



(A) Overhang width = 1,800; Installation orientation: south

Fig. 7 Relationship between window height and shading coefficient

2. Blocks with decorative openings

- Blocks with decorative openings achieve a high solar shading effect for components such as those on west-facing surfaces struck by solar radiation when the sun is low in the sky.
- The shading coefficient is 0.1 or lower for blocks with decorative openings that have dimensions such as those shown in Fig. 8 (Table 7). This value assumes that solar radiation does not enter the room from above, between blocks or window surfaces, due to the additional use of overhangs and other components.
- Blocks with decorative openings achieve a higher solar shading effect if the area of the openings is smaller. On the other hand, because shading solar radiation means shading natural light, the brightness inside the room must be taken into account. South-facing components that are struck by solar radiation when the sun is high in the sky allow in diffused light while shading direct solar radiation through the use of overhangs, but by using blocks with decorative openings or louvers (See next section) on west-facing components that are struck by direct solar radiation when the sun is low in the sky, it is easier to achieve solar shading that strikes a balance with daylighting.

Table 7 Shading coefficients of blocks with decorative openings

Orientation	Shading coefficient
North	0.03
East	0.06
South	0.02
West	0.06

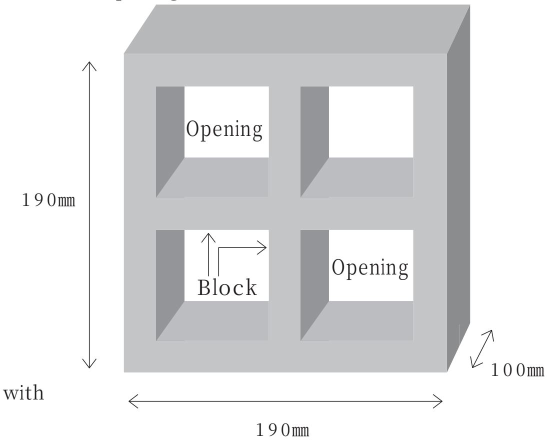


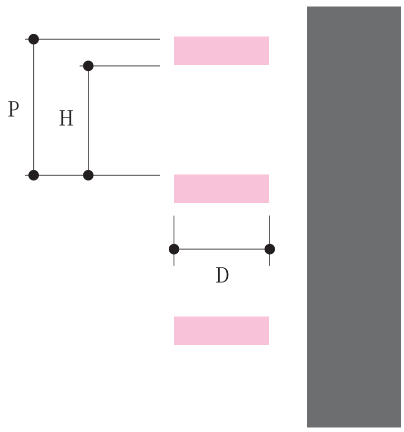
Fig. 8 Example of shape of block with decorative openings



Fig. 9 Examples of usage of blocks with decorative openings

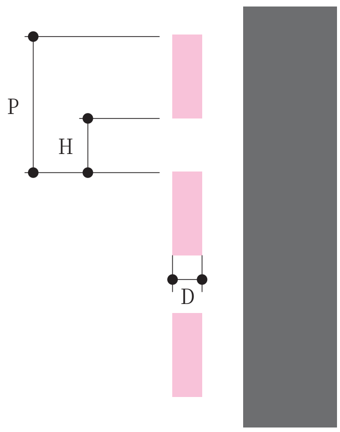
3. External solar shading components (louvers, etc.)

- External solar shading components such as louvers achieve solar shading by covering windows and other openings in the same way as blocks with decorative openings, and achieve a high solar shading effect even for west-facing components that are struck by direct solar radiation when the sun is low in the sky. In addition, with movable louvers, it is possible to prioritize solar shading when the amount of solar radiation is high according to the time or the weather, and to prioritize daylighting and maintaining the view when the amount of solar radiation is low.
- The solar shading effect is higher if the holes (H) in the louver are smaller and the depth (D) of the louver is larger (Figs. 10 and 11).
- As shown in (A), in the case of a louver having large holes (H), diffused light can easily enter through the holes in the louver, improving the view outside. If louvers are fitted to habitable room windows and there are no other windows, a balance needs to be struck between lighting/view and solar shading.
- As shown in (B), louvers with small holes (H) have a higher solar shading effect and are effective if used in cases where east- and west-facing surfaces receive a large amount of sun.



Shading coefficient = approximately 0.25 if P = 100, H = 80, and D = 50

(A) Type of louver that allows light in and improve the outside view



Shading coefficient = approximately 0.15 if P = 100, H = 30, and D = 15

(A) Type of louver that increases the solar shading effect and keeps the louver thin

Fig. 10 Types and dimensions of louvers

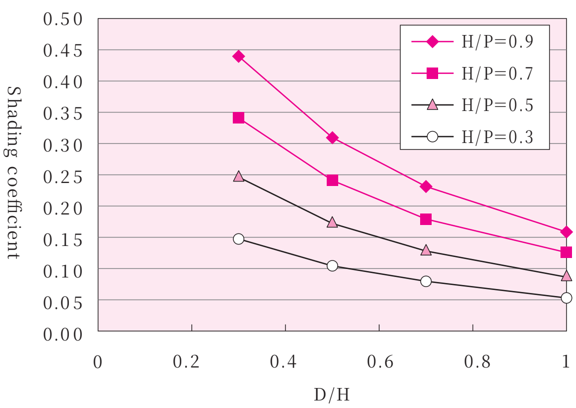


Fig. 11 Shading coefficients when louvers are installed
(Ratio of the amount of solar radiation when louvers are fitted; where no louvers are fitted the value is 1)

Fig. 12 Examples of usage of louvers

Chapter 4
Heat Control Technology of Building Envelopes
(Elemental Technology Application Method 2)

Method 2 : Solar shading methods using building envelopes

1. Building envelope solar shading performance and schemes

- Building envelopes of concrete structures, which account for the majority of housing structures in Zone VI, have large heat capacities, and because it is difficult to cool these building envelopes due to their being warmed by solar radiation heat, an unpleasant heat environment can occur due to this heat being released inside the building at night if some sort of scheme to tackle solar radiation heat is not incorporated.
- In order to prevent this, it is essential to incorporate either of the following: (1) a scheme in which ventilated cavities are provided in the roof and the walls, by which heat is ventilated to the outside of the concrete envelope, thereby inhibiting the influx of solar radiation heat by expelling heat via the ventilated cavities (cavity ventilation); (2) a scheme in which a insulating material is applied to the outside or inside of the building envelope (insulation); or (3) a scheme to increase the solar radiation reflectance of the outer surface of the building envelope (solar radiation reflection).
- Heat that penetrates walls in the summer is roughly divided into the two types of transmitted heat, one of which is generated by the difference in temperature between a room and the outside air, and the other by the penetrating solar radiation heat (the sum of the amount of direct solar radiation and the amount of diffuse solar radiation). Insulation is effective against both types, whereas solar radiation reflection and cavity ventilation are effective at reducing the amount of penetrating solar radiation heat.

- The characteristics of each scheme are as follows.

(1) Cavity ventilation

Schemes involving cavity ventilation are related to the air change rate in the ventilated cavity parts. Ventilated cavities that involve laying spreading blocks, sheet-like panels and other materials in the roof are generally provided with holes allowing heat to escape to the air outside, thereby maintaining the required degree of ventilation.

(2) Insulation

Schemes involving insulation are effective for areas such as roofs, where the temperature on the outer surface increases due to direct solar radiation. Although increasing the insulation throughout the whole house has the advantage of improving the heat environment during the winter, this has the side effect of preventing heat from escaping from the rooms during the summer.

(3) Solar radiation reflection

Schemes involving solar radiation reflection are aimed at improving the solar radiation reflectance of exterior finishing materials for reflecting direct solar radiation. One method is to apply ordinary white or pale-colored paints, which have high solar radiation reflectance, or heat-shielding paints to the surface of the building envelope. However, since performance is believed to decrease due to long-term deterioration caused by UV radiation and soiling of the surface of the paint, maintenance such as periodic cleaning or repainting is necessary in such cases.

- Various combinations of these schemes, which are aimed at the roof and the exterior walls of the building envelope, are possible, but implementing multiple measures or enhancing the standards of the measures will not necessarily lead to a reduction in cooling energy.

- In subsequent chapters, we will explain the solar shading performance of the roof and the exterior walls of the building envelope, and schemes related to this performance. Windows are components which are penetrated by large amounts of solar radiation (See Key Point (3) on p.166), but because schemes involving the selection of types of window glass and frames in temperate regions (See Section 4.3 for the use of double glazing and low-E double glazing) prevent heat from escaping from inside the room to the outside, these cannot be said to be suitable for hot humid regions. Metal (aluminum) sash windows using ordinary single glazing are generally used in hot humid regions.

2. Roofs

1) Methods and effects of solar shading

- Roofs are the component most susceptible to solar radiation, and are therefore the component most in need of solar shading measures, after windows, in the building envelope.
- Correlations between roof solar shading schemes have the following characteristics:
- If solar radiation reflection is increased, insulation has no significant effect.
- If solar radiation reflection is increased or insulation is incorporated, cavity ventilation has no significant effect.
- Therefore, selecting and incorporating one of solar radiation reflection, insulation, or cavity ventilation is considered to be effective.
- In cases where it is not possible to use brightly colored building materials (for reasons of design or in order to prevent inconvenience to neighbors due to solar radiation reflection), it is possible to use a method that involves applying heat-shielding paints, as explained in Method 3 (Solar shading methods for exterior walls).
- Roofs on roofed balconies, which are common in Okinawa, can be regarded as providing a ventilated cavity having sufficient ventilation, and are considered effective as a roof solar shading scheme for the first floor of a house. Skylights are effective in terms of cross ventilation only if this type of solar shading device is present, but cannot be recommended without a solar shading scheme.
- Table 8 shows differences in solar penetration rates due to differences in roof specifications. Thermal resistance values of insulating materials and corresponding differences in specification are arranged in the vertical direction, the presence/absence of ventilated cavities and differences in solar radiation reflectance are arranged in the horizontal direction, and solar penetration rates under these various conditions are shown.
- Even without insulation, Table 8 demonstrates that incorporating cavity ventilation or solar radiation reflection schemes makes it possible to reduce the solar penetration rate compared to no insulation with no improvements.
- In addition, even if cavity ventilation or solar radiation reflection schemes are not incorporated, Table 8 demonstrates that it is possible to reduce the solar penetration rate by installing insulation. By increasing the level of insulation, the solar penetration rate decreases. But since maintaining a insulating material with a thermal resistance value of 0.8 m2•K/W (corresponding to a 30 mm type 2 extruded polystyrene foam insulating sheet installed) means that heat is prevented from escaping during the night or at other times, the cooling energy reduction effect from increasing the thickness of the insulation is slight.
- The solar penetration rates in Table 8 can be used when calculating M values by numerical calculation (See Comment on p.170).

Table 8 Differences in solar penetration rates due to differences in roof specifications

Thermal resistance value of insulating material (m^2•K/W)	Corresponding energy conservation standards	Example of insulating material specification	No ventilated cavity			Ventilated cavity		
			Solar radiation reflectance 0.1	Solar radiation reflectance 0.4	Solar radiation reflectance 0.7	Solar radiation reflectance 0.1	Solar radiation reflectance 0.4	Solar radiation reflectance 0.7
0	—	No insulation	0.179	0.118	0.059	0.082	0.054	0.026
0.5	1980 Standards	20 mm type 2 extruded polystyrene foam insulating sheet	0.048	0.032	0.016	0.039	0.025	0.013
0.8	—	30 mm type 2 extruded polystyrene foam insulating sheet	0.033	0.022	0.011	0.029	0.019	0.009
1.1	Standard interest rates	40 mm type 2 extruded polystyrene foam insulating sheet	0.025	0.017	0.008	0.023	0.015	0.007
1.3	1992 Standards	50 mm type 2 extruded polystyrene foam insulating sheet	0.022	0.015	0.007	0.020	0.013	0.006
1.7	—	50 mm type 3 extruded polystyrene foam insulating sheet	0.017	0.011	0.006	0.016	0.010	0.005
2.5	1999 Standards	75 mm type 3 extruded polystyrene foam insulating sheet	0.012	0.008	0.004	0.011	0.007	0.004

Note 1: Solar radiation reflectance values
0.1 = low reflectance (dark colored paints, etc.); 0.4 = moderate reflection (concrete, light colored paints, etc.); 0.7 = high reflection (white paints, etc.)
Note 2: Standard interest rates by the Okinawa Development Finance Corporation; construction specifications for houses for which the basic interest rate is applicable (supplemental financing construction specifications were the same in the 1999 standards)

Key Point

Changes in ceiling surface temperature due to differences in roof specifications

- The diagram shows ceiling surface temperatures in summer for a roof having typical specifications.
- Compared to the condition whereby no schemes are incorporated (no ventilated cavity, no insulation, normal solar radiation reflectance), increasing the solar radiation reflectance lowers the ceiling surface temperature by approximately 4°C during the day, and by approximately 0.4°C even at dawn. In addition, schemes that incorporate insulating materials lower the ceiling surface temperature by approximately 3.5°C during the day, and by approximately 1°C at midnight.
- On the other hand, schemes that incorporate ventilated cavities lower the ceiling surface temperature by approximately 3.5°C during the day, but cause the surface temperature to rise above the temperature if no schemes are incorporated between 10.00 p.m. and 8.00 a.m. The reason for it being difficult for the surface temperature to fall during the night is thought to be that heat discharge due to nocturnal radiation is inhibited by ventilated cavities.

Glossary: Nocturnal radiation
Radiation energy transferred between objects at the same temperature as the outside air and the atmosphere above. On clear nights during the summer, there is a cooling effect equivalent to the outside air temperature falling by 2°C or more.

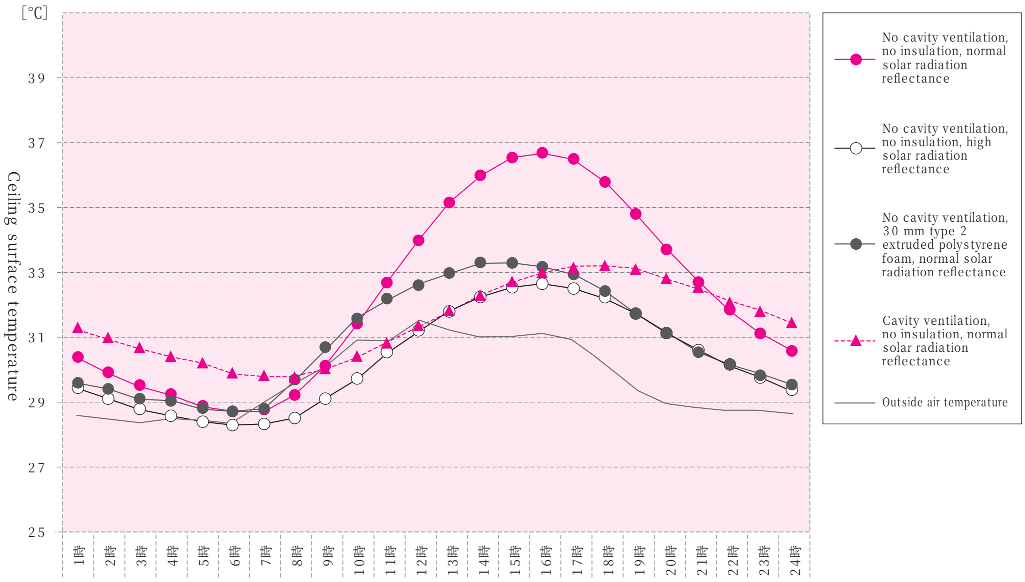


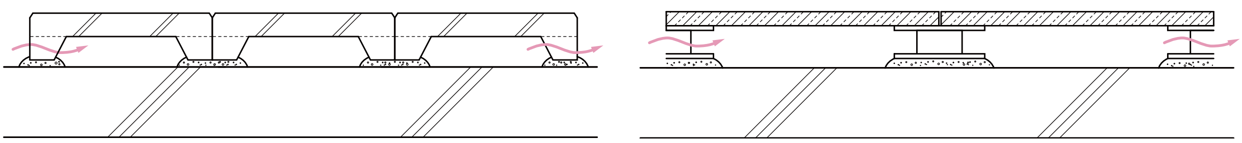
Fig. Changes in ceiling surface temperature due to differences in roof specifications

■Calculation conditions
Average values for each time period between Aug. 1 and 10
Room used for test: South-east-facing Japanese style room (without cooling)
Exterior walls: No cavity ventilation, no insulation, normal solar radiation reflectance, no overhangs

2) Typical solar shading specifications

Of the roof solar shading methods, here are examples of typical ventilated cavity specifications (Fig. 13).

- In addition to be being a solar penetration countermeasure, this method in which a ventilated cavity is provided by placing spreading blocks at the top of the roof greatly contributes to improving the durability of roof slabs.
- The edges of spreading blocks and other components need to be open to the outside air and constructed so as to allow sufficient ventilation within the ventilated cavity. Additionally, the thickness of the ventilated cavity is preferably at least 30 mm. Use materials having excellent corrosion resistance (anti-rust properties) for metal objects that fasten the roof bed and roofing materials.
- In Zone VI, standard methods using spreading blocks can be applied relatively easily to both existing and new houses, but care must be taken if applying to an existing roof so as not to exceed the maximum allowable load of the roof.



(A) Example using spreading blocks (B) Example using tiles or sheet-like panels of stone
Fig. 13 Examples of roof ventilated cavities

4

Chapter 4
Heat Control Technology of Building Envelopes (Elemental Technology Application Method 2)

Glossary: Solar radiation reflectance
The ratio of the energy reflected to the incident solar radiation energy between the visible region and the near-infrared region.

Glossary: Long-wave radiation emissivity
Any object radiates an energy proportional to its temperature (absolute temperature) raised to the power of four. However, because this differs depending on the surface condition (color, etc.) of an object, even for objects having the same surface temperature, the emissivity is the ratio of the energy radiated by an object to the energy radiated by a perfectly black body (a theoretical object that completely absorbs all radiation). Long-wave means thermal radiation having a relatively long wavelength of approximately 3 μm or longer, which excludes solar radiation.

Key Point

Solar radiation reflectance and long-wave radiation emissivity of material surfaces

- The diagram shows numerical values for the solar radiation reflectance and long-wave radiation emissivity of commonly used construction materials.
- The solar radiation absorbance values (A1) of material surfaces are plotted along the lower horizontal axis, and the solar radiation reflectance values (A2) are plotted along the upper horizontal axis. For construction materials that block the passage of solar radiation, A1 + A2 = 1. When investigating the shading performance of the surface of exterior finishing materials, refer to the values for these materials.
- The long-wave radiation emissivity values (B1) of material surfaces are plotted along the left-hand vertical axis, and the long-wave radiation reflectance values (B2) are plotted along the right-hand vertical axis. For construction materials that block the passage of solar radiation, B1 + B2 = 1. When investigating shading designs for the inside of ventilated cavities or air space, these values are used.

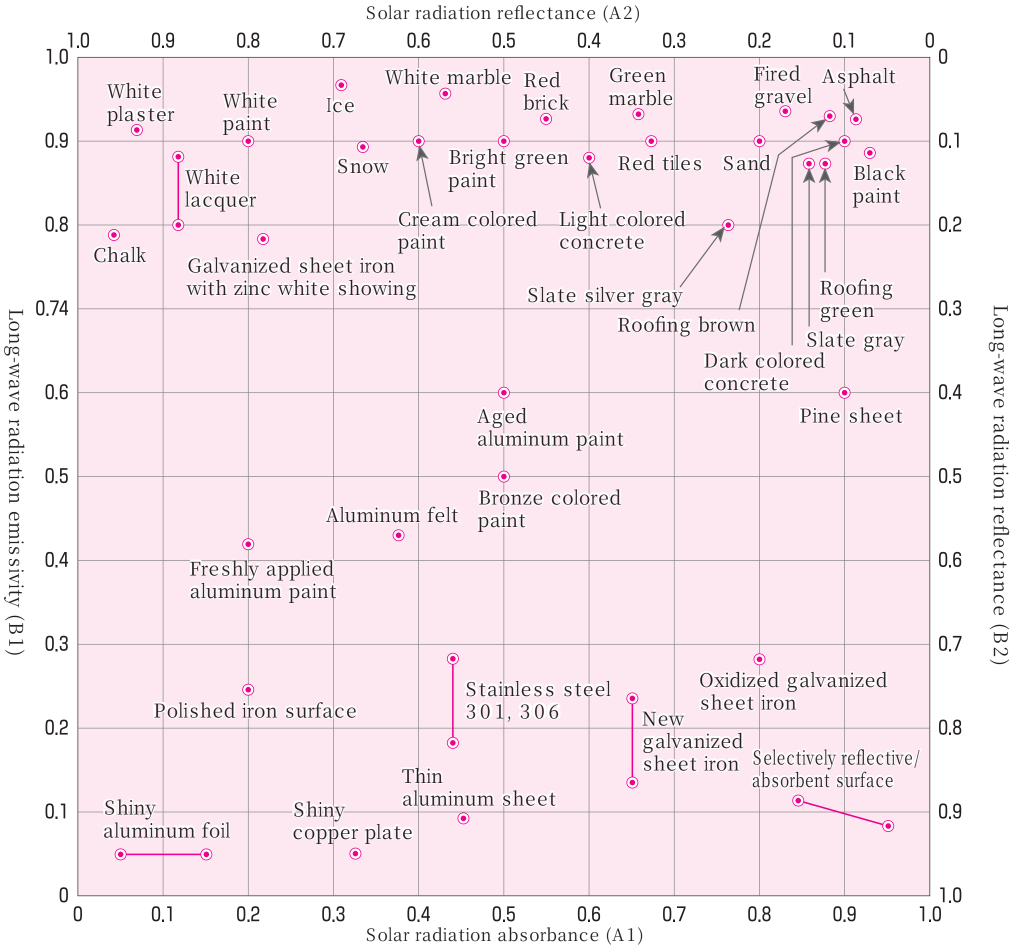


Fig. Solar radiation reflectance and long-wave radiation emissivity of material surfaces
Reference: p.122, *Architectural Design Data Corpus 1, Environment*, The Architectural Institute of Japan, Maruzen, 1978

Comment ● Schemes involving increasing long-wave radiation reflectance

One method of increasing the thermal resistance of the inside of a building envelope is to improve the long-wave radiation reflectance. This method involves fitting a material that faces into a ventilated cavity in the building envelope, that is, employing a material (or paint) having a high long-wave radiation reflectance either on the behind the exterior finishing material or on the surface of the concrete, thus enabling a significant reduction in the solar penetration rate. This method can be used not only on ventilated cavities, but also on sealed air space.

Methods have been considered in which a ventilated cavity is provided and an exterior finishing material lined with aluminum foil is then used, which can be applied relatively easily to existing as well as new houses, but because measures to counteract damage caused by salt and other factors must be taken into account in hot humid regions in particular, it can be said that more study is needed in terms of construction methods and materials.

Comment ● Green roofs

1. Advantages of green roofs

Green roofs have the effect of limiting temperature increases on roof surfaces by using latent heat caused by a thermal transpiration effect from plants or the ground. Green roofs are often wrongly thought to alleviate indoor temperature fluctuations by making use of the insulating properties of soil, but because moist soil has a thermal conductivity that is equal to, or greater than, that of concrete, it can be said the effect of green roofs is more based on a thermal transpiration effect than insulation. In addition, it is hoped that it will be possible to improve the durability of building envelopes made of concrete and other materials by covering roofs with soil or plants.

Moreover, the solar shielding effect of green roofs can generally be thought of as equivalent to providing a ventilated cavity.

2. Points to note when installing green roofs

Because there are many reinforced concrete houses in Okinawa, it is easy to install green roofs on both new and existing houses, but consideration must be given to design, construction, and maintenance matters.

- With regard to the selection of plants, it is important to choose ones that are resistant to salt damage. Greening with grasses is also recommended from the perspective of dealing with high winds and heavy rain during typhoons. The table below gives examples of plants used for green roofs in Okinawa.
- At the design stage, it is essential to consider the maximum allowable load on a roof by taking into account the load from the plants after they have grown. In addition, providing adequate drainage schemes and using construction methods that do not damage the waterproof surface of the roof are important factors in preventing water leakage.

- It is important to make sure that occupiers are aware that post-occupancy maintenance is particularly important. In order for plants to grow healthily, daily care such as pruning, watering and fertilizing is essential. For reasons of structural limitations and cost, examples of thin layer greening (100-300 mm of light soil) have been seen, but controlling the moisture in the soil is difficult in such cases, meaning that the plants sometimes die. In order to prevent this, it is essential to install a drainage system on the roof so as to control the moisture content of the soil on a day-to-day basis. In addition, diligently removing fallen leaves to prevent them from blocking drains is an essential water leakage countermeasure.
- An assistance program has been established in Naha to promote the greening of roofs and walls of buildings. For green roofs, a degree of financial assistance is provided for installing greening facilities of 3 m2 or more or planters of 1 m2 or more, namely 50% of the construction costs or 5,000 yen per square meter of greening, whichever is smaller, to a maximum of 300,000 yen (***Source: Naha City Rooftop and Wall Greening Assistance Guidelines***).

Table: Plants used for green roofs

Vitality	Woody plants	Herbaceous plants
5	—	*Zoysia matrella*, El Toro/grass (hybrid)
4	*Ligustrum tamakii Hatusima, Berchemia racemosa, Thuarea involuta*	*Ophiopogon japonicus Ker-Gawler, Miscanthus sp., Salvia splendens sp., Nephrolepis auriculata*
3	*Scaevola frutescens, Crossostephium artemisioides, Zanthoxylum beecheyanum, Euonymus trichocarpus Hay*	*Ruellia brittoniana Leonard, Wedelia biflora, Wedelia prostrata, Portulaca okinawensis, Sesuvium portulacastrum*
2	*Psychotria serpens*	*Phyla nodiflora*
1	—	*Lobelia loochooensis, Sedum uniflorum, Blutaparon wrightii, Hedyotis biflora, Peperomia japonica*

Source: *New Okinawan Housing Proposals*, Okinawa Development Finance Corporation, September 2007
* The plants selected had been planted for two years and were suitable for green roofs (as of March 2005). Plants with a vitality of three or more are suitable for green roofs (based on the Okinawa Commemorative National Park Management Foundation ' s Tropical Plants Research Report No. 26).

3. Exterior walls

- Regarding the solar shading of exterior walls, it is important to implement an external solar shading scheme on both exterior walls and openings using such means as *amahaji* (semi-outdoor space with a deep overhang) and blocks with decorative openings.
- If it is found by confirming the exposure factor due to site conditions (Fig. 3 on p.176) that the solar shading effect due to adjacent buildings and other factors is sufficient even compared to cases in which amahaji and blocks with decorative openings have been installed, it is possible to omit these features.
- If schemes involving *amahaji* and blocks with decorative openings have not been incorporated, the use of schemes similar to roof schemes (cavity ventilation, insulation, solar radiation reflection) must be considered. However, since cavity ventilation and insulation have the drawback of preventing heat from escaping during the night, detailed confirmation using M values is necessary. In addition, because solar radiation reflection involves the use of bright colors or materials that reflect light, the effect on neighbors must be taken into account.
- When suppressing the reflection of visible light and increasing the reflection of solar radiation, one method is to utilize the characteristics of heat shielding paints (See Comment on p.187).

- Table 9 shows differences in solar penetration rates due to differences in exterior wall specifications. Thermal resistance values of insulating materials and corresponding differences in specification are arranged vertically, the presence/absence of ventilated cavities and differences in solar radiation reflectance are arranged horizontally, and solar penetration rates under these various conditions are shown.

Table 9 Solar penetration rates by exterior wall specifications

Thermal resistance value of insulating material (m²•K/W)	Corresponding energy conservation standards	Example of insulating material specification	No ventilated cavity			Ventilated cavity (reference)		
			Solar radiation reflectance 0.1	Solar radiation reflectance 0.4	Solar radiation reflectance 0.6	Solar radiation reflectance 0.1	Solar radiation reflectance 0.4	Solar radiation reflectance 0.6
0	1980 Standards 1992 Standards	No insulation	0.157	0.097	0.064	0.077	0.050	0.032
0.3	1999 Standards	15 mm bead method polystyrene foam insulating sheet	0.067	0.043	0.029	0.045	0.030	0.019

Note 1: Solar radiation reflectance values
0.1 = low reflectance (dark colored paints, etc.); 0.4 = moderate reflection (concrete, light colored paints, etc.); 0.6 = fairly high reflection (heat shielding paints, etc.)
Note 2: Ventilated cavity construction method; selection of materials involved taking durability and other factors into account, but it is thought that more study is needed.

Comment ● Heat shielding paints

Paints have become increasingly sophisticated in recent years. One such type of material is heat shielding paints that have increased solar radiation reflection. The diagram shows examples of reflectances of standard paints and heat shielding paints at a variety of wavelengths. With these two types of paint, there is little difference in terms of reflectance (10-40%) in the visible light region, but in the near-infrared region, which has wavelengths of longer than 800 nm, standard paints exhibit a reflectance of 20-30%, whereas heat shielding paints exhibit a reflectance of up to 80%.

It is true that many manufacturers are selling heat shielding paints by stressing their insulation performance, but it should be noted that the effect of these materials is heat shielding performance, not insulation performance.

In addition, heat shielding paints suffer from long-term UV degradation and soiling in the same way as ordinary paints, and therefore also require periodic cleaning and maintenance such as repainting. Please refer to the manufacturer's application instructions for details.

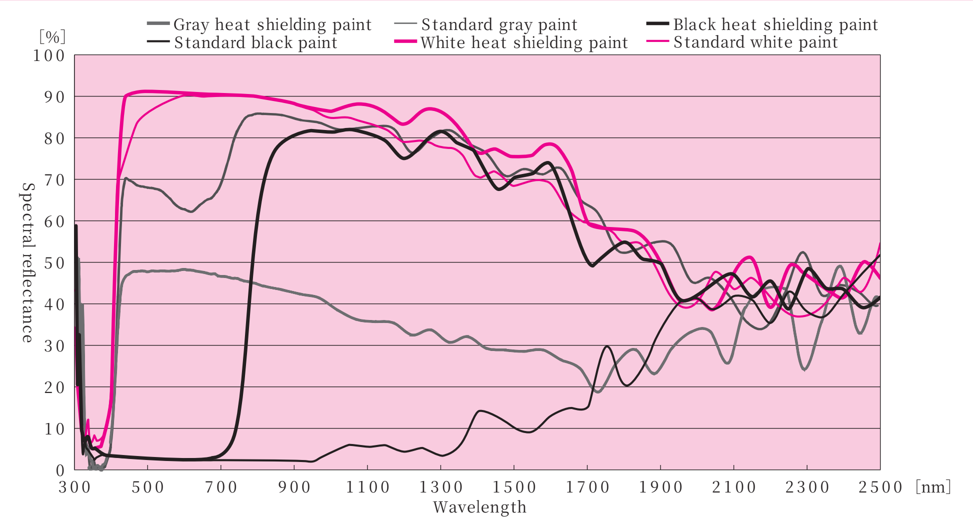
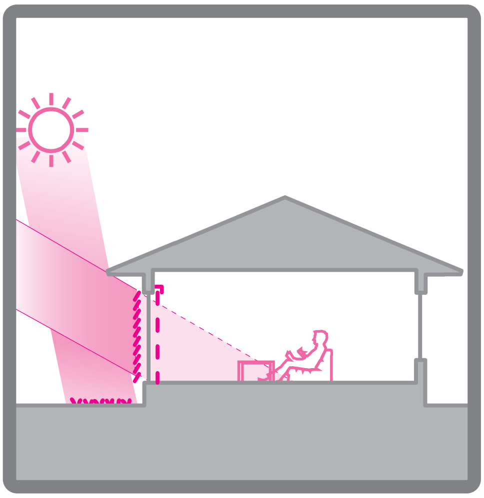


Fig. Results of reflectance measurements using heat shielding paints

4.3 Solar shading methods for Zone V



Solar shading is a technology that aims to control the excessive inflow of solar heat, reduce the amount of energy used for cooling and improve comfort by effectively shielding solar radiation that would penetrate buildings in summer and in-between seasons.

With regard to solar shading for openings, it is important to plan them in a way that solar gain in winter is also achieved while cross ventilation and daylight utilization are maintained.

4.3.1 Purpose and Key Points of Solar Shading

1. Reducing amount of energy used for cooling

- Solar radiation has a major effect on the thermal environment in a house. In winter, heating energy can be reduced as the room temperature can be increased by gaining increased amounts of solar radiation heat. In summer, however, since there is a need to use cooling to reduce the room temperature, which increases because of solar radiation heat, the greater the amount of solar radiation is, the greater the amount of energy used for cooling becomes.
- The purpose of solar shielding is, as the expression suggests, to shade from solar radiation, thereby reducing the amount of solar radiation heat entering a building and cutting the amount of energy used for cooling.

2. Maintaining cool rooms

- In order to keep rooms cool in summer and in-between seasons, solar shading is important along with cross ventilation. In order to use solar shading efficiently, it is important to take into account the directional characteristics of the components of the building envelope. By suppressing the amount of solar radiation heat entering rooms, it is possible to limit the increase in room temperature and also limit the surface temperature on the interior walls and other surfaces.

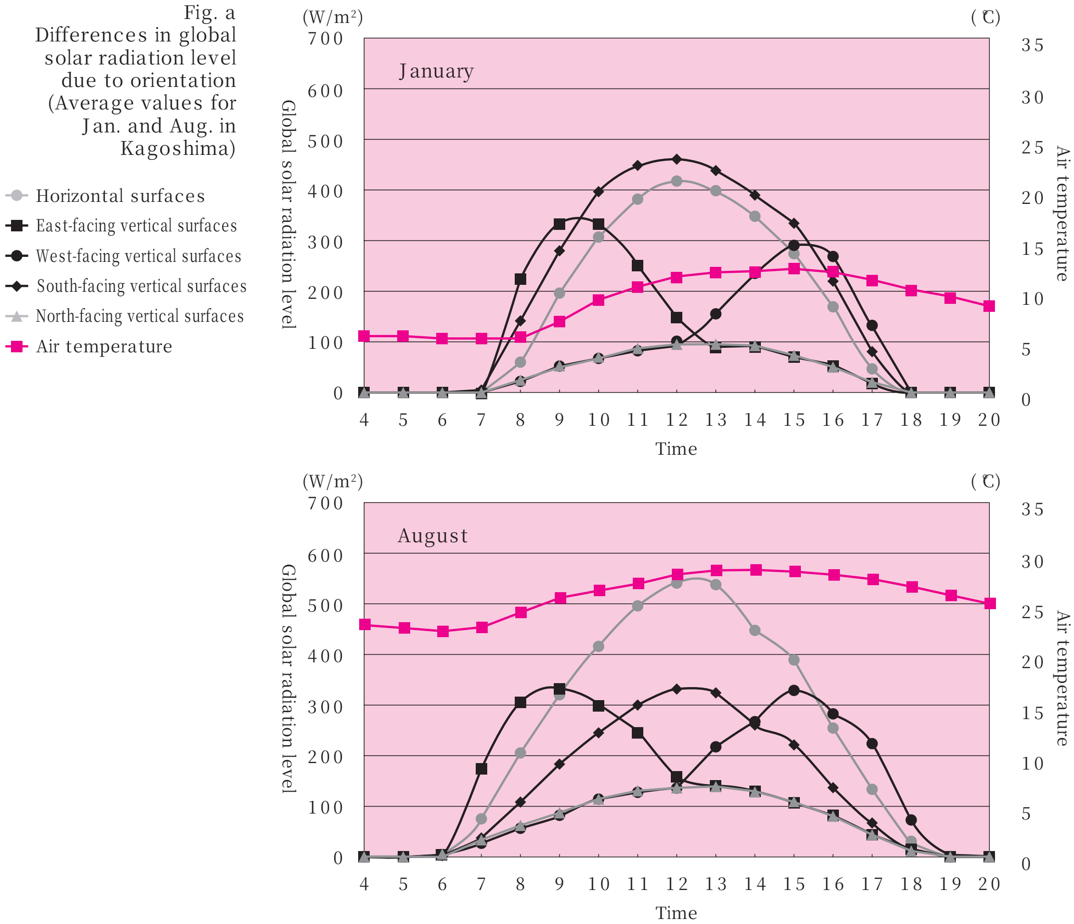
Key Point

Basic matters that are background knowledge for examining solar shading schemes

①Differences in the amount of solar radiation due to orientation

- The amount of solar radiation striking a building differs depending on the season and the orientation of the components of the building (Fig. a). The amount of solar radiation in the summer, when the solar altitude is high in the sky, increases greatly on horizontal surfaces such as roofs, but for vertical walls, the amount of incident solar radiation is larger on east- or west-facing surfaces and smaller on south-facing surfaces. Understanding this characteristic of solar radiation is the key for effective solar shading schemes.

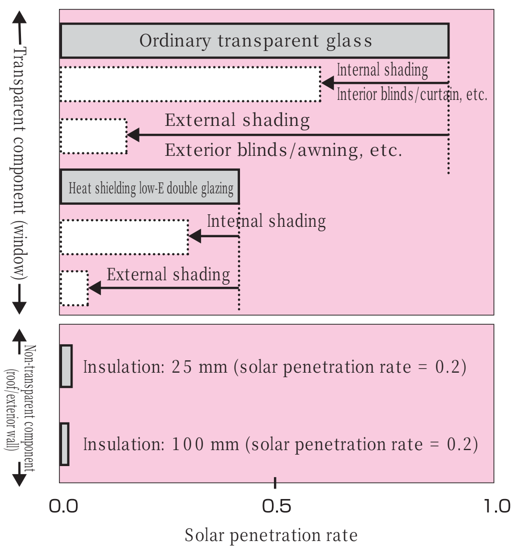
Fig. a
Differences in global solar radiation level due to orientation (Average values for Jan. and Aug. in Kagoshima)



②Differences in the amount of transmitted solar radiation due to transparent and non-transparent components

- As shown in Fig. b, solar radiation levels from transparent components such as windows is far greater than from non-transparent components such as roofs or exterior walls. Therefore, transparent components such as windows are important for achieving adequate solar shading schemes.
- In addition, the effect of external shading, which shades solar radiation on the outside, is greater than that of internal shading, which shades solar radiation inside openings.
- For non-transparent components such as roofs and exterior walls, solar shading scheme is firstly to achieve insulation. In particular, roofs receive a large amount of solar radiation heat, with their surface temperatures in summer reaching 60 to 70 degrees. However, extra insulation can enhance solar shading effect. Secondly, methods should be considered such as using materials with high solar reflectance.

Fig. b
Comparison of the solar shading performance of windows, roofs and exterior walls



Glossary: Solar penetration rate
The solar penetration rate is the proportion of heat that enters a room relative to the amount of incident solar radiation heat, and is also known as the solar heat gain coefficient. As this value decreases, the solar shading performance increases.

4.3.2 Energy Conservation Target Levels for Solar Shading Schemes

1. Definition of target levels

- Energy conservation target levels for solar shading schemes have been set at levels 1-3 as below and indicate the reduction rate of energy consumed by cooling systems (Table 1).
- The cooling energy reduction rate can vary even at the same level depending on which direction the main opening surface faces. Select the main opening surface and confirm which direction it faces out of south, southeast or southwest, or east or west. If it faces an in-between direction, select the closest direction.
- Among openings facing each direction (we are referring to windows here), the main opening surface must have a significantly larger opening area than the other directions. Please use the following conditions as references when selecting the main opening surface (one of the following must be met).
  a. The percentage of opening area facing the direction concerned compared to the total area of a building is about 15% or higher.
  b. The opening area facing the direction concerned is three times larger than opening areas facing the other directions.
- As for the cooling energy reduction rate, the state at level 0 where solar shading measures are not particularly implemented is used as a reference in the case of main opening surface facing the south. When the main opening surface faces southeast or southwest, or east or west, special attention is required as cooling energy increases at level 0.

Table 1 Target levels for solar shading schemes and energy saving effects

Target level	Direction of main opening surface		
	South	Southeast or southwest	East or west
Level 0	No cooling energy reduction (standard conditions)	30% cooling energy increase rate	10% cooling energy increase rate
Level 1	15% cooling energy reduction rate	20% cooling energy reduction rate	20% cooling energy reduction rate
Level 2	30% cooling energy reduction rate	25% cooling energy reduction rate	25% cooling energy reduction rate
Level 3	45% cooling energy reduction rate	35% cooling energy reduction rate	35% cooling energy reduction rate

- In the case of partial intermittent cooling, the standard cooling energy consumption as of 2000 was 5.7 GJ (approximately 8% of overall energy consumption) (See Section 6.1 on p.339).
- Several components such as openings, roofs and exterior walls are related to solar shading. In this document, of these components, the focus is placed on "solar shading methods for openings" where cooling energy reduction effects are confirmed through trial calculation. For each target level, values of "solar penetration rate at openings" obtained by implementing solar shading methods at openings are used as guidelines.

2. How to achieve target levels

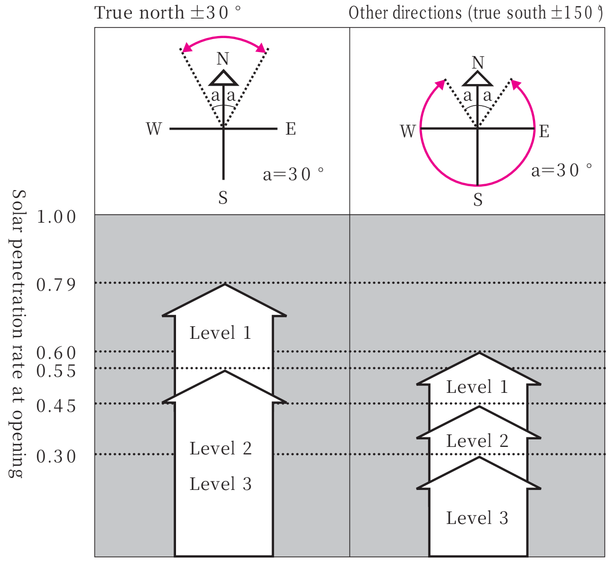
1) Target levels and solar penetration rate at openings

- The target level for energy conservation through solar shading can be achieved by implementing measures that meet standard values of solar penetration rate at openings (Table 2).
- Solar penetration rate indicates the ratio of heat that flows into a building out of incoming solar radiation heat. It is also called solar heat gain coefficient. The smaller it is, the higher solar shading performance is.
- The standard value of solar penetration rate at openings varies depending on the directions of openings. The amount of heat gain at an opening facing north (within the range of true north ±30°) is smaller than that at openings facing other directions (See Fig. a on p.189). Therefore, the necessity of solar shading schemes becomes relatively smaller while the standard value of solar penetration rate becomes greater than those of openings facing other directions.
- In order to achieve target levels, be aware that it is necessary to implement solar shading schemes which correspond to standard solar penetration rates for openings facing true north ±30° as well as other directions (true south ±150°).
- Solar penetration rates at openings are set in accordance with the existing energy conservation standard. Level 1 conforms to the 1992 energy conservation standard and level 2 conforms to the 1999 energy conservation standard. Level 3 is based on performance levels superior to them.
- Fig. 1 shows the differences between these three levels.

Table 2　Target levels of solar shading schemes and how to achieve them

Target level	Standard values of solar penetration rates at openings		Energy conservation standard to conform to
	True north ±30°	Range other than the direction listed in the left column	
Level 0	Approx. 0.79	Approx. 0.79	—
Level 1	0.79 or below	0.60 or below	1992 energy conservation standard
Level 2	0.55 or below	0.45 or below	1999 energy conservation standard
Level 3	0.55 or below	0.30 or below	—

Fig. 1
Standard values of solar penetration rate at openings by direction



2)　Methods for calculating solar penetration rates at openings

- Solar penetration rates at openings are determined by how thoroughly measures are implemented for solar shading components, such as glazing, curtains and blinds, as well as for overhangs/eaves (hereinafter referred to as "overhangs"). When these factors are combined, the solar penetration rate is obtained by using the following simple calculation method.
  Solar penetration rate at opening = Solar penetration rate of glazing × shading coefficient of solar shading components × shading coefficient of overhangs
- Solar penetration rate of glazing, shading coefficient of solar shading components, and shading coefficient of overhangs each have determined values according to glazing specifications, component types, and whether overhangs exist or which directions they face, respectively (See Comment on p.193). Substitute relevant values to the formula above to obtain solar penetration rate at opening.
- The performance improvement rate of each solar shading component, such as glazing and blinds, will appear as the difference in solar shading performance in cases where they are combined.
- When there are no overhangs, etc., or when conditions in Fig. 2 are not met even if there are overhangs, etc., the shading coefficient is 1, which means that a decrease in solar penetration rate through overhangs, etc. cannot be expected. It is necessary to adjust the projection of overhangs and eaves according to the height of openings.
- Table 3 shows the result of calculating the solar penetration rate of openings which combine glazing, solar shading components and

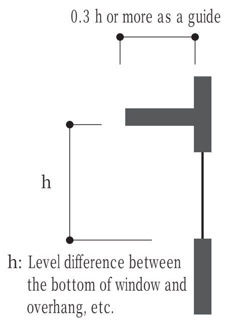


Fig. 2 Overhangs, etc. effective for solar shading

Glossary: Low-E double glazing
The glass coated with special metal film (low-emissivity: low-E film) is generally known as low-E glazing. A structure wherein this low-E double glazing is used for the outer pane of double glazing (a special metal film faces the air space) is called “heat shielding low-E double glazing”, since it offers high solar shading performance. Furthermore, a structure wherein low-E glazing is used for the inner pane is called “insulating low-E double glazing”, since it places a higher value on insulation performance than heat shielding performance.

Glossary: Heat shielding double glazing
Double glazing which uses glass with high solar shading performance for the outer pane is called heat shielding double glazing. Heat reflecting glazing or heat absorbing glass may be used for the outer pane of double glazing.

overhangs.

- The differences in color in the table indicate the correspondence relationship with levels.

Direction of true north ±30°	Range	Other directions (true south ±150°)
Level 1	0.6～0.79	
Level 1	0.55～0.6	Level 1
Level 2	0.45～0.55	Level 1
Level 2	0.3～0.45	Level 2
Level 3	0.3 or below	Level 3

Table 3 Solar penetration rate obtained through the combination of glazing, solar shading components and overhangs, etc.

(1) Without overhangs, etc.

Glazing specifications	Solar shading component type				
	None	Sheer curtain	Internal blinds	Paper sliding door	External blinds
Regular single glazing	0.88	0.56	0.46	0.38	0.19
Regular double glazing	0.79	0.52	0.44	0.37	0.17
Regular triple glazing	0.71	0.50	0.44	0.38	0.16
Insulating low-E double glazing (12 mm air space)	0.63	0.48	0.43	0.37	0.15
Insulating low-E double glazing (6 mm air space)	0.62	0.47	0.43	0.37	0.15
Heat shielding low-E double glazing (12 mm air space)	0.42	0.32	0.29	0.26	0.11
Heat shielding low-E double glazing (6 mm air space)	0.43	0.33	0.30	0.26	0.11
Heat shielding double glazing (2 types of heat reflecting glazing, 6 mm air space)	0.39	0.31	0.28	0.25	0.10
Heat shielding double glazing (3 types of heat reflecting glazing, 6 mm air space)	0.28	0.23	0.21	0.19	0.08
Heat shielding double glazing (Heat absorbing glazing, 6 mm air space)	0.57	0.41	0.36	0.31	0.13
2 types of heat reflecting single glazing	0.48	0.38	0.34	0.31	0.12
3 types of heat reflecting single glazing	0.35	0.31	0.28	0.25	0.10
Heat absorbing single glazing	0.68	0.47	0.41	0.35	0.15

(2) With overhangs, etc./Directions other than true south ±30°

Glazing specifications	Solar shading component type				
	None	Sheer curtain	Internal blinds	Paper sliding door	External blinds
Regular single glazing	0.62	0.39	0.32	0.27	0.13
Regular double glazing	0.55	0.36	0.31	0.26	0.12
Regular triple glazing	0.50	0.35	0.31	0.27	0.11
Insulating low-E double glazing (12 mm air space)	0.44	0.34	0.30	0.26	0.11
Insulating low-E double glazing (6 mm air space)	0.43	0.33	0.30	0.26	0.11
Heat shielding low-E double glazing (12 mm air space)	0.29	0.23	0.20	0.18	0.07
Heat shielding low-E double glazing (6 mm air space)	0.30	0.23	0.21	0.18	0.08
Heat shielding double glazing (2 types of heat reflecting glazing, 6 mm air space)	0.27	0.21	0.19	0.18	0.07
Heat shielding double glazing (3 types of heat reflecting glazing, 6 mm air space)	0.19	0.16	0.15	0.13	0.06
Heat shielding double glazing (Heat absorbing glazing, 6 mm air space)	0.40	0.29	0.25	0.22	0.09
2 types of heat reflecting single glazing	0.34	0.27	0.24	0.22	0.08
3 types of heat reflecting single glazing	0.24	0.21	0.20	0.18	0.07
Heat absorbing single glazing	0.47	0.33	0.28	0.25	0.11

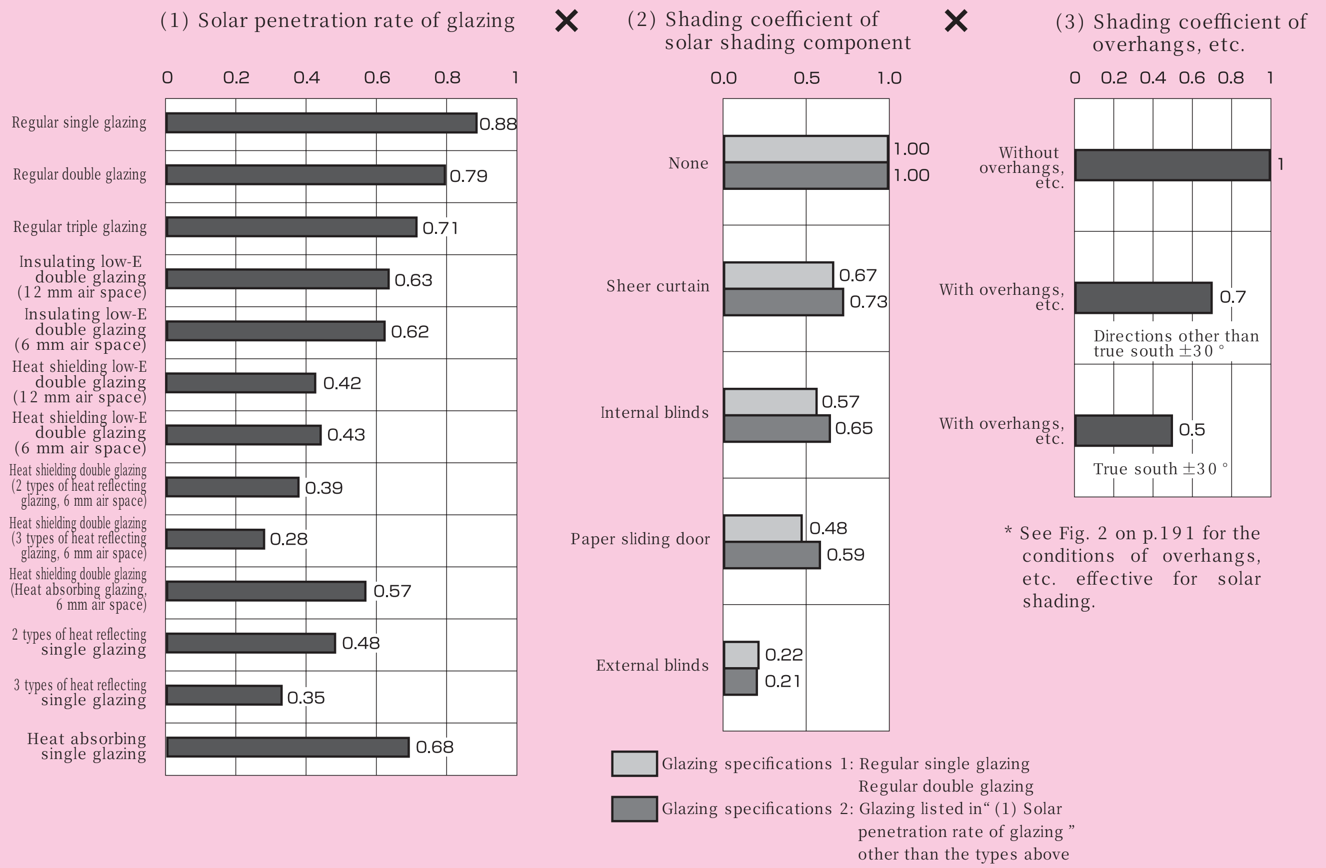
(3) With overhangs, etc. / Directions of true south ±30°

Glazing specifications	Solar shading component type				
	None	Sheer curtain	Internal blinds	Paper sliding door	External blinds
Regular single glazing	0.44	0.28	0.23	0.19	0.09
Regular double glazing	0.39	0.26	0.22	0.19	0.09
Regular triple glazing	0.36	0.25	0.22	0.19	0.08
Insulating low-E double glazing (12 mm air space)	0.32	0.24	0.22	0.19	0.08
Insulating low-E double glazing (6 mm air space)	0.31	0.24	0.22	0.19	0.08
Heat shielding low-E double glazing (12 mm air space)	0.21	0.16	0.14	0.13	0.05
Heat shielding low-E double glazing (6 mm air space)	0.21	0.17	0.15	0.13	0.06
Heat shielding double glazing (2 types of heat reflecting glazing, 6 mm air space)	0.20	0.15	0.14	0.13	0.05
Heat shielding double glazing (3 types of heat reflecting glazing, 6 mm air space)	0.14	0.11	0.10	0.10	0.04
Heat shielding double glazing (Heat absorbing glazing, 6 mm air space)	0.29	0.20	0.18	0.16	0.07
2 types of heat reflecting single glazing	0.24	0.19	0.17	0.15	0.06
3 types of heat reflecting single glazing	0.17	0.15	0.14	0.13	0.05
Heat absorbing single glazing	0.34	0.24	0.20	0.18	0.08

Comment ● Simple calculation method for solar penetration rate of opening

The solar penetration rate of each opening of housing can be calculated, if (1) glazing type, (2) solar shading component and (3) overhangs, etc. (their directions) are determined, based on the formula (1) × (2) × (3) shown below. However, as for the comprehensive solar penetration rate of an opening, more detailed calculation may be necessary, strictly speaking, as slightly complicated mechanisms such as the interaction between glazing and solar shading components are involved.

Fig.
Simple calculation data on solar penetration rate of opening



* See Fig. 2 on p.191 for the conditions of overhangs, etc. effective for solar shading.

* With regard to the type of glazing not listed above, use the numerical values provided by manufacturers.

* With regard to solar shading components not listed above, use the numerical values provided by manufacturers.

Comment ● Solar penetration rate measurement results

Recently, the measurement of an opening's comprehensive solar penetration rate has become possible thanks to the use of artificial sunshine. Fig a shows part of the measurement results (case of metal frame with thermal break).

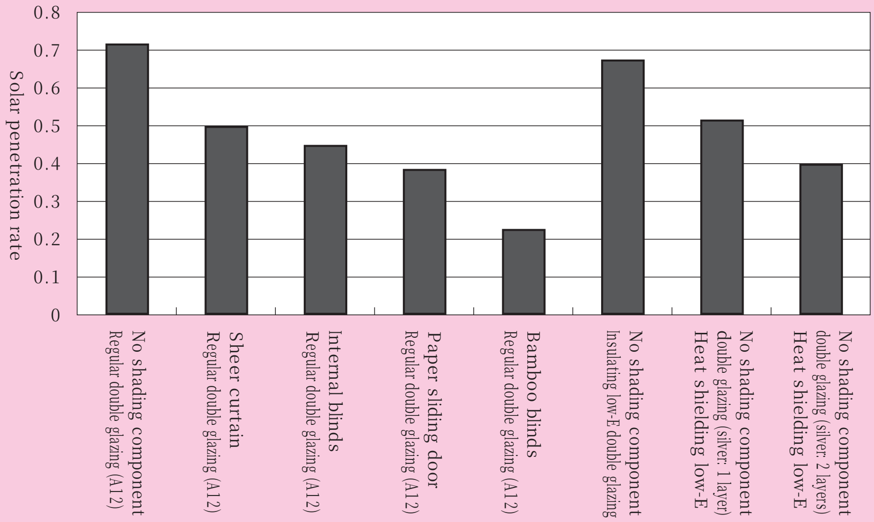


Fig a　Measurement results of solar penetration rate of opening

Fig b　Solar shading components used for measurement

3) Handling roofs, exterior walls, etc.

- As for non-transparent areas of roofs and exterior walls, if insulation described in "4.1 Insulated Building Envelope Planning for Zone V" is applied, solar penetration rates are much lower compared to transparent areas. Therefore, they are not handled as elements related to the achievement of target levels. However, since the size of roofs and exterior walls is large and their influence on cooling load is not small, their handling methods are explained in "4.3.4 Solar shading methods".

4.3.3 Steps for Examining Solar Shading Technology and Setting Target Levels

1. Steps for examining solar shading technology

Step 1 Confirming the site condition / Setting target levels

- Confirm solar radiation which buildings receive according to the site condition.
- Examine opening layout planning that takes solar radiation into account while considering conditions such as views. Then, set target levels for solar shading schemes.

▼

Step 2: Examining solar shading methods for openings – Method 1

1) Selecting windows effective in solar shading
2) Solar shading for openings using solar shading components
3) Solar shading for openings using overhangs, etc.

▼

Step 3: Examining solar shading methods for openings – Method 2

1) Using roofing with high solar reflectance
2) Solar shading through attic ventilation (in the case of ceiling insulation)
3) Solar shading through roof ventilation control (in the case of roof insulation)

▼

Step 4: Examining solar shading methods for exterior walls – Method 3

1) Using exterior wall materials with high solar reflectance
2) Solar shading through exterior wall ventilation control

▼

Step 5: Examining solar shading methods for others – Method 4

1) Prevention of reflected heat
2) Solar shading with garden trees

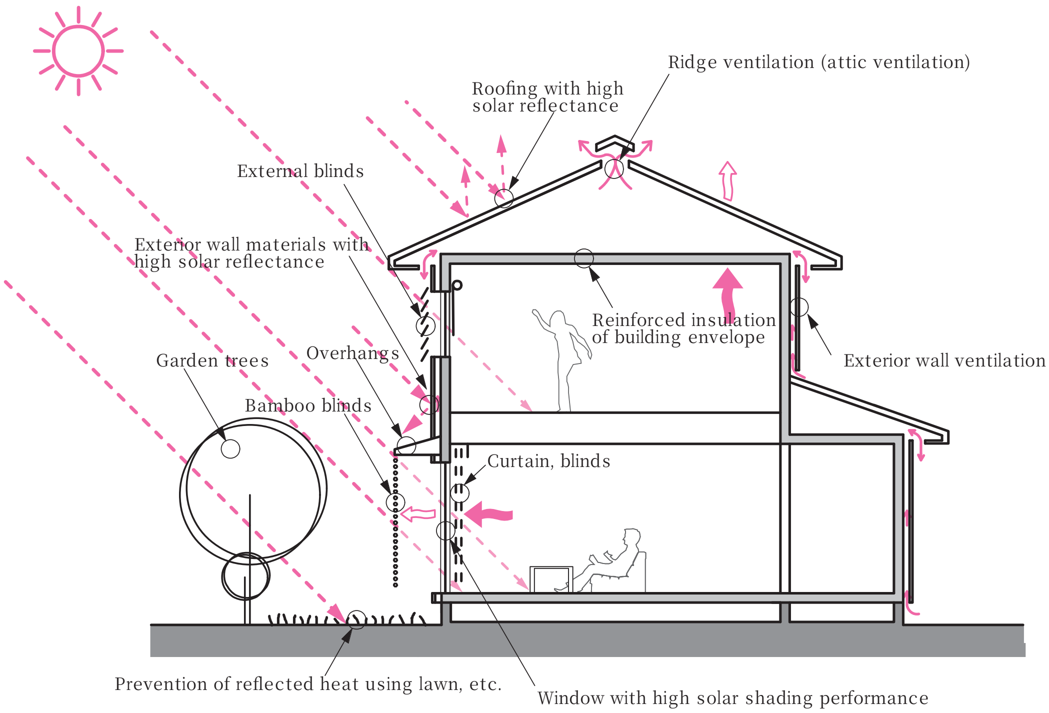


Fig. 3 Overview image of solar shading methods

2. Confirming surrounding conditions of building and setting target levels

By confirming the surrounding conditions of the building and planning layout of openings to take solar radiation into account, set the target levels of solar shading for openings.

1) Confirmation of surrounding conditions of building

- The necessity of solar shading varies depending on the level of solar shading which a building receives in summer and in-between seasons. Therefore, it is necessary to confirm the surrounding conditions of the building and predict the level of solar radiation which the building receives.
- Solar radiation level may be lower in the case of sites where hours of having shade are long due to surrounding buildings or the case of small sites where space between neighboring buildings is small such as small sites in cities. In these cases, the necessity for solar shading schemes is thought to be lower.

2) Layout planning for openings which takes solar radiation into account

- In order to achieve as much solar shading as possible in summer and receive more solar radiation in winter, it is important that the direction of openings is southerly.
- If openings have to face east and west when taking into consideration views or their relationship with roads and neighboring houses, it is essential to use solar shading components.
- When openings are created facing the southerly direction (true south ±30°), great solar shading effects through overhangs, etc. can be expected (See Fig. (3) of Comment on p.193).

4.3.4. Solar shading methods

Method 1: Solar shading methods for openings

- When solar shading schemes are not implemented for openings, temperature inside a building will rise in summer and in-between seasons, leading to a loss of comfort as well as a significant increase in cooling energy.
- Fig. 4 shows the comparison of window surface temperature between a window with external blinds and a window with internal blinds. When solar shading is done inside the building, such as with internal blinds, it is clear that the window surface receiving solar radiation increases in temperature like a large panel heater.
- Solar shading methods for openings can be divided into types shown in Table 4, and it is necessary to select an appropriate method according to conditions.

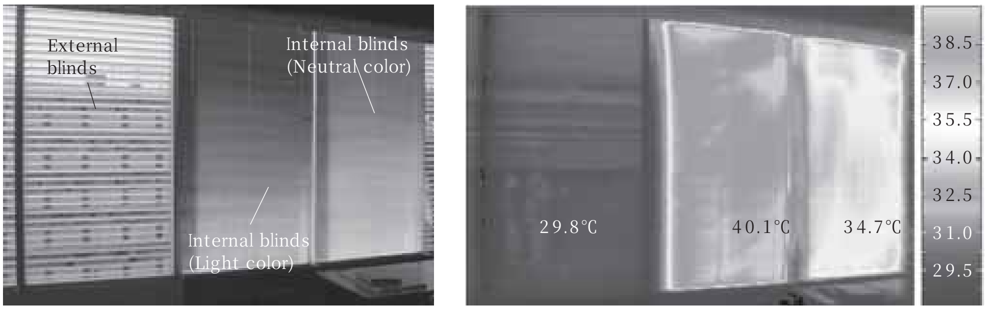


Fig. 4 Comparison of window surface temperature with the use of blinds

■ The colored version of Fig. 4 is shown in Appendix 2 on p.391.

Table 4 Solar shading methods for openings and effects

Solar shading methods for openings		Outline	Effect
1) Selecting windows effective in solar shading		Solar shading method through the use of sashes and glass with high heat shielding performance	Medium
2) Solar shading for openings using solar shading components	External solar shading components	Solar shading method using accessories attached to the outside of openings, such as external blinds, which offers promising effects for all directions	Great
	Internal solar shading components	Solar shading method using accessories attached to the inside of openings, such as curtains and blinds	Small
3) Solar shading for openings using overhangs, etc.		Method using overhangs, which blocks off solar radiation entering through openings. The solar shading effect varies depending on the direction of overhangs and the measurement of their projection.	Great when attached to the south side

1. Selecting windows effective in solar shading

- This is a solar shading method using windows themselves, and its solar shading effect varies depending on the solar reflectance and heat transmission coefficient of glazing and frame.
- Openings are the components that can be a weak point in terms of insulation performance. It is necessary to select proper windows by considering insulated building envelope planning in addition to the perspective of solar shading.
- Windows with proper specifications should be selected according to the type of glazing as well as the materials and size of frame.

■Conditions for inside and outside boundaries
Temperature: Outside – 30°C
Inside – 25°C
Solar radiation rate: 500 W/m²
Surface heat transfer coefficient:
Outside – 23W/m²·K
Inside – 9W/m²·K

■The colored version of Fig. 5 is shown in Appendix 2 on p.391.

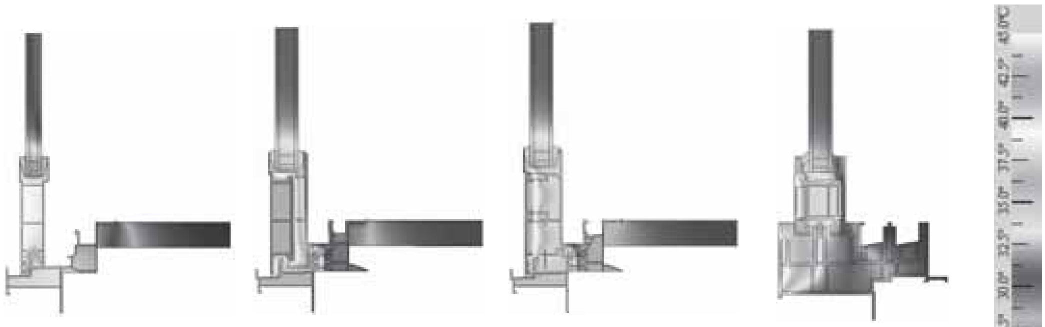


Fig. 5　Cross-sectional temperature distribution diagram of window frame (summer)

1)　Glazing types and solar shading effects

・In general, there are single glazing, double glazing, insulating low-E double glazing, heat shielding low-E double glazing, double glazing with built-in blinds and other types of glazing (Fig. 6, Fig. 7). Their characteristics are listed in Table 5.

Fig. 6
Heat shielding low-E double glazing

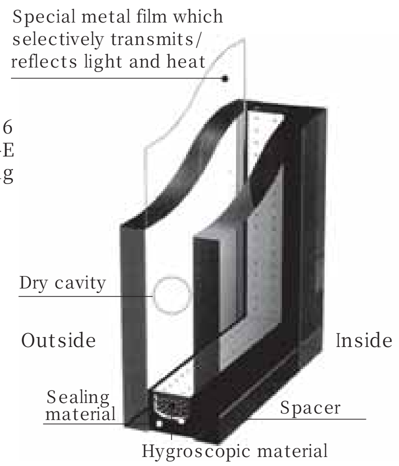


Fig. 7
Double glazing with built-in blinds

Table 5　Glazing types and characteristics

Glazing type	Characteristics	Effect
Single glazing	The most common transparent, flat pane glazing which transmits most solar radiation	Small
Regular double glazing	This glazing has enhanced insulation performance by sealing dry air into the space between two panes of glazing but transmits most solar radiation	Small
Insulating low-E double glazing	The glazing on the inner pane of this double glazing is coated with special metal low-E film which offers superior insulation performance and moisturizing effects, providing a solar shading effect to some extent	Small - medium
Heat shielding low-E double glazing	The glazing on the outer pane of this double glazing is coated with special metal low-E film which offers superior heat shielding and insulation performance, providing a solar shading effect	Medium
Double glazing with built-in blinds	Built-in blinds are in the cavity of this double glazing. In addition to a superior insulation effect, it provides the effect of controlling light by closing and opening the blinds, being effective in solar shading.	Medium - Great

2)　Frame types and solar shading effects

・In general, there are sashes made of metal, metal with thermal break, metal and resin combined, resin, wood, and wood covered with metal or resin. Their characteristics are listed in Table 6.

Table 6　Frame types and characteristics

Frame type	Characteristics	Effect
Metal (aluminum)	Thermal conductivity is great, so this frame conducts absorbed solar heat into the room	Small
Metal with thermal break	Aluminum component with great thermal conductivity that is thermally separated into inner and outer panes by using resin materials so that heat cannot be conducted easily	Medium
Metal and resin (wood) combined	So that heat cannot be conducted easily, this frame uses highly durable aluminum for the outer pane and resin and wood, which make it difficult for heat to be conducted, for the inner pane	Medium
Resin, wood	Thermal conductivity is low, so this frame makes it most difficult for absorbed solar heat to be conducted into the room	Great

2.　Solar shading for openings using solar shading components

- This method is designed to block solar radiation which tries to enter the building through openings by setting components effective in solar shading, such as blinds, louvers and screens, on the outside or inside of windows (Fig. 8).
- By using mobile solar shading components, it is possible to make adjustments, such as removing them, according to changes of season, time and weather as well as life-related demands such as views and ventilation.
- It is important to select components with appropriate specifications and mechanisms while taking cross ventilation utilization, daylight utilization and housing design into consideration.
- Solar shading components are divided into external and internal components. When internal solar shading components are used, most of the heat passing through the windows and hitting the surface of the solar shading components radiates into the room. Therefore, they are not as effective as external solar shading components (Fig. 9).

* From a standpoint of daylight utilization, solar shading components are considered as devices with a sun control function. With regard to this, refer to p.074 and p.075.

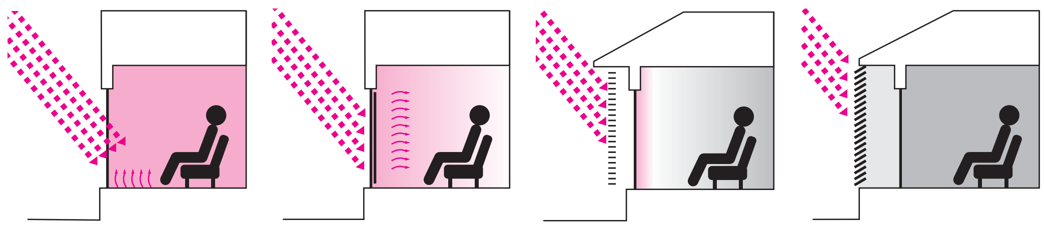


Fig. 8　Difference in effect depending on the existence and location of solar shading components for openings

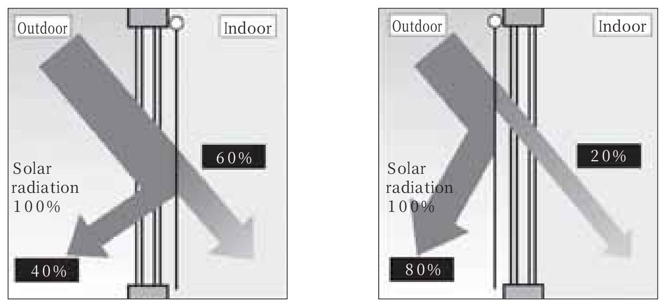


Fig. 9 Effect based on location of solar shading components (image)

1)　External solar shading component planning

- External solar shading components include blinds, louvers, awnings, bamboo blinds and screens.
- It is necessary to select external solar shading components which are user-friendly and do not easily cause flapping or noise due to wind. Moreover, it is necessary to set them up at a safe, trouble-free place by taking into consideration the wind direction and velocity of the region.
- Table 7 shows the characteristics of each component (Fig. 10-14).

Table 7　Types and characteristics of external solar shading components

External solar shading component	Characteristics	Effect
Screen	This component helps regulate solar radiation and visibility from outside, but is vulnerable to wind	Medium - Great
Bamboo blinds	Reasonable but inferior to other shading components in terms of storage and durability	Medium - Great
Awning	Offers a good view as it does not face an opening directly	Medium - Great
Blind shutters	Highly functional component with the functions of blinds and shutters	Great
Blinds	Offers highly flexible regulation of solar radiation and visibility from outside, but is vulnerable to wind	Great
Louver	Fixed type without any vertical movement although its slats rotate	Great

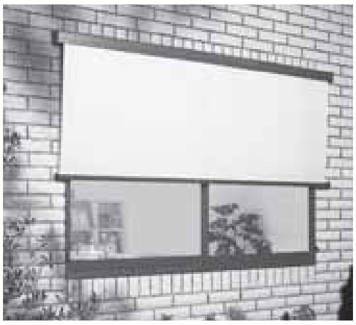


Fig. 10　Screen

Fig. 11　Bamboo blinds

Fig. 12　Awning

Fig. 13　Blind shutters

Fig. 14　Louver

Note
A considerable amount of solar radiation enters a room through skylights set up on the roof even if it faces the north. Since there are few accessories for skylights which are effective in blocking solar radiation, it is important to keep this in mind.

2)　Internal solar shading component planning

- Internal solar shading components include blinds, paper sliding doors, roller blinds and sheer curtains.
- Table 8 shows the characteristics of each component (Fig. 15, Fig. 16).

Table 8　Types and characteristics of internal solar shading components

Internal solar shading component	Characteristics	Effect
Sheer curtains	Helps regulate solar radiation and visibility from outside, but the solar shading effect varies depending on the color as well as how coarse the texture is	Small
Roller blinds	Helps regulate solar radiation and visibility from outside, but the solar shading effect varies depending on the color	Small - Medium
Paper sliding doors	Helps regulate solar radiation and visibility from outside, but the solar shading effect varies depending on the color	Medium
Blinds	Enables highly flexible regulation of solar radiation and visibility from outside, but the solar shading effect varies depending on the color	Medium

Fig. 15
Paper sliding doors

Fig. 16　Wooden blinds

3. Solar shading for openings using overhangs, etc.

- This method is designed to block off solar radiation, which enters a building through openings, by using eaves attached to roofs and lean-to roofs as well as small overhangs, etc (Fig. 17). The solar shading effect in summer varies depending on the direction and the projection of overhangs, etc. Proper planning according to the direction is important.
- As for the east face and west face which receive solar radiation during hours when the solar altitude is low, not much of a solar shading effect through horizontal overhangs, etc. can be expected. On the other hand, as for openings on the south face, we can fully expect an effect from overhangs since the solar altitude is high (Fig. 18).

Fig. 17 Examples of solar shading using overhangs, etc.

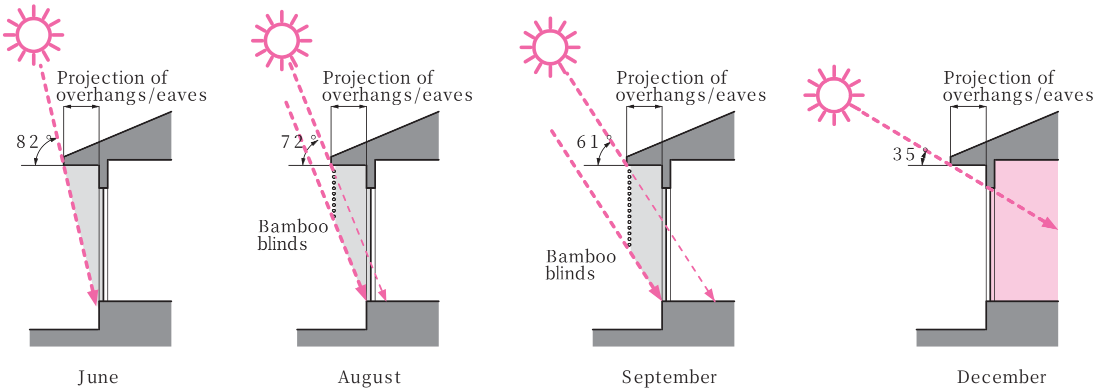


Fig. 18 Image of effects of overhangs, etc. (south)

Note
By setting up overhangs, etc., solar shading effects for not only openings but also exterior walls can be expected. In addition, in winter, overhangs, etc. do not cause a significant loss in solar heat gain because the solar altitude is high.

Key point

Method of planning overhangs, etc. which take directions into consideration

- With regard to openings facing south, it is thought that setting up overhangs with projection measuring one third or more in length of the vertical interval between the bottom of the window and the bottom of overhangs, etc. is effective in solar shading.
- With regard to openings facing east and west, solar shading using only overhangs, etc. is not so effective compared to the south. Therefore, combined use of other methods is thought to be effective, such as setting up solar shading components (Fig.).

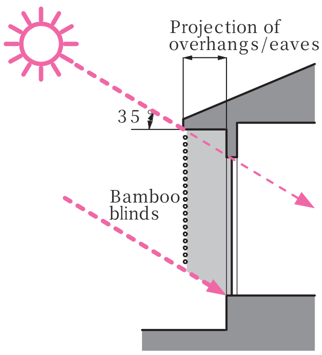


Fig.
Image of effect of overhangs, etc

Method 2: Solar shading method for roof

- Since roofs receive solar radiation for long periods, it is important to implement solar shading schemes in addition to insulation. It is necessary to implement measures which control the inflow of heat into the room through the roof as well as the inflow of heat and heat radiation through the ceiling.

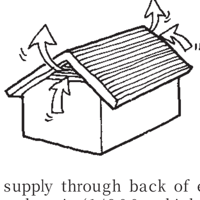
1. Using roofing with high solar reflectance

- Solar shading effects can be enhanced by increasing the solar reflectance of the roof.
- The solar reflectance or absorption rate of a building material varies greatly depending on the color. In general, a material with a light color, rather than a dark color, or with luster, such as polished tiles, offers a higher solar reflectance, controlling temperature increase. Solar shading effects can be enhanced by using light-colored building materials for the outer surface of the building, such as roofing and exterior wall materials.
- When light-colored building materials cannot be used (for reasons of design or in order to avoid causing solar-radiation-related troubles to neighbors), there is a method using heat shielding paint, a method described in Method 3 (solar shading methods for exterior walls).

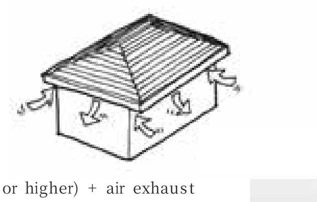
2. Solar shading through attic ventilation (in the case of ceiling insulation)

- In a house for which ceiling insulation is used, ensuring a large amount of attic ventilation is thought to be very effective in enhancing the solar shading effect of the roof.
- It is advisable for attic ventilation to be implemented five times or more per hour.
- See Fig. 19 to discuss attic ventilation methods and attic ventilation rate and make sure that air vent size is sufficient. However, the ratios of air vent size indicated in Fig. are the guidelines originally suggested for preventing condensation, and they indicate the minimum values. For solar shading, it is important to ensure a much larger air vent size. Fig. 20 shows an example of a house which puts emphasis on attic ventilation. The wall surface under the eave has many louvers.
- As for houses where double ceiling is not created for the second floor and the attic is exposed, heat exhaust through attic ventilation cannot be expected. Therefore, solar shading performance of the roof should be improved.

①Air supply and exhaust through attic (1/300 or higher)

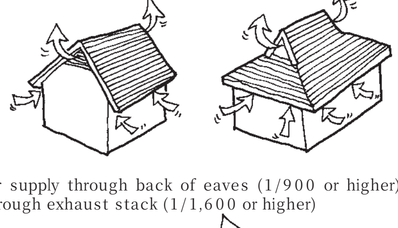


②Air supply and exhaust through back of eaves (1/250 or higher)



* Values in brackets show ratio of air vent size compared to ceiling size.

③Air supply through back of eaves (1/900 or higher) + air exhaust through attic (1/900 or higher)



④Air supply through back of eaves (1/900 or higher) + air exhaust through exhaust stack (1/1,600 or higher)

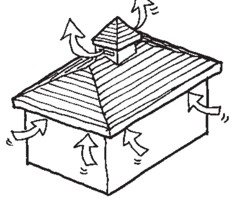


Fig. 19 Method of installing attic air vents

Fig. 20 Example of house which puts emphasis on attic ventilation

3. Solar shading through roof ventilation control (in the case of roof insulation)

- The temperature of the roof rises due to solar radiation, radiating heat into the building. In particular, it is very effective to install ventilated cavity for houses with roof insulation in order to control the amount of heat radiated from the roof to the inside of the building (Fig. 21).
- The size of a ventilated cavity should be as large as possible, and it is advisable to ensure at least 30 mm.
- Components for ventilating the ridge should be installed on the top of the roof.
- Attention is required when positioning furring strips in order to ensure a certain amount of ventilation.
- The opening of ventilated cavity should be as large as possible while the prevention of rain water infiltration is taken into consideration.

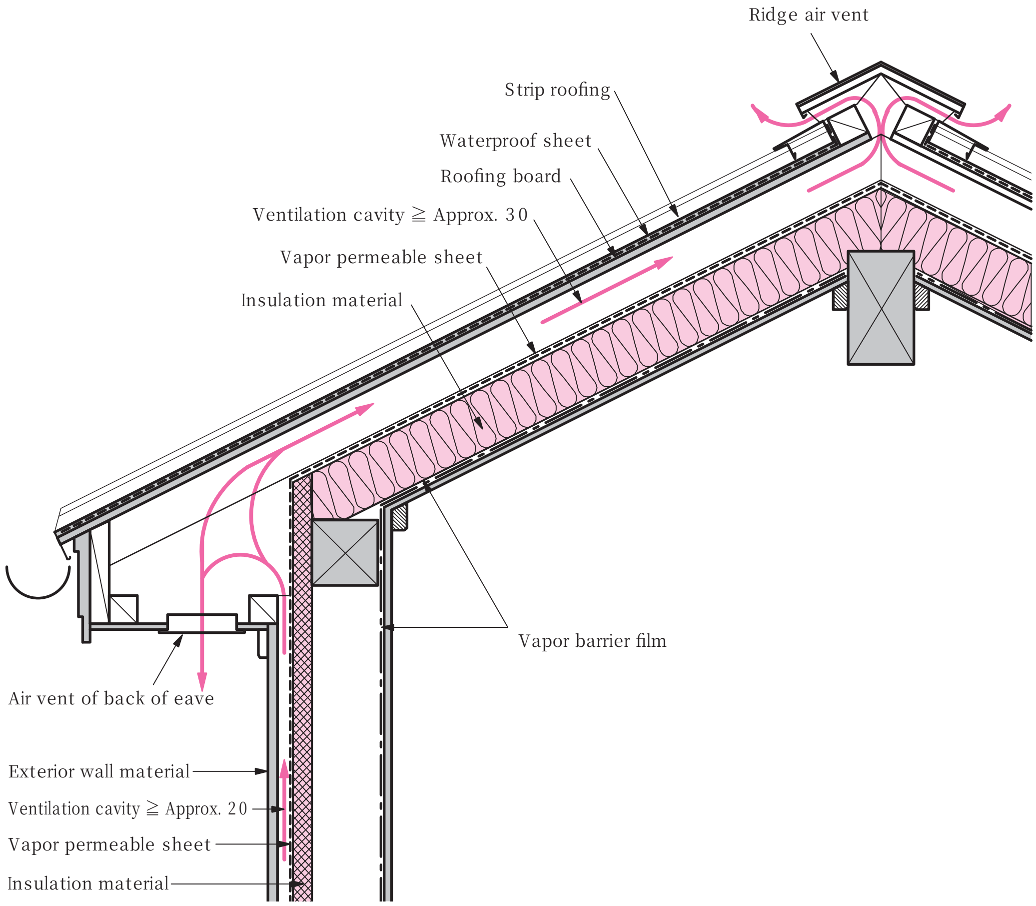


Fig. 21 Roof ventilation (in the case of roof insulation)

Method 3: Solar shading method for exterior walls

- The foundation of solar shading schemes for exterior walls, as is the case for the roof, is to increase insulation performance. Try to improve the insulation performance of exterior walls by referring to "4.1 Insulated Building Envelope Planning for Zone V", and at the same time, consider schemes for controlling the inflow of solar heat absorbed on the exterior wall surface into the inside of the building.

1. Using exterior wall materials with high solar reflectance

- The quantity of heat received varies depending on the color (solar reflectance) of exterior wall materials. It is desirable to use a color that is as close to white as possible for exterior wall materials.
- A heat shielding paint provides an enhanced reflectance in near-infrared regions, so this paint has a high solar reflectance accordingly (Fig. 22). Since a darker color provides a higher solar reflectance than a lighter one, this paint is used for enhancing the solar reflectance when a dark color is selected.

Note
Recently, the term "insulation paint" is used sometimes. In general, it refers to a paint which effectively controls the amount of solar radiation absorption by increasing the reflectance of the surface. It should be called "heat shielding paint". It is different from materials effective in increasing heat resistance such as normal insulation materials.

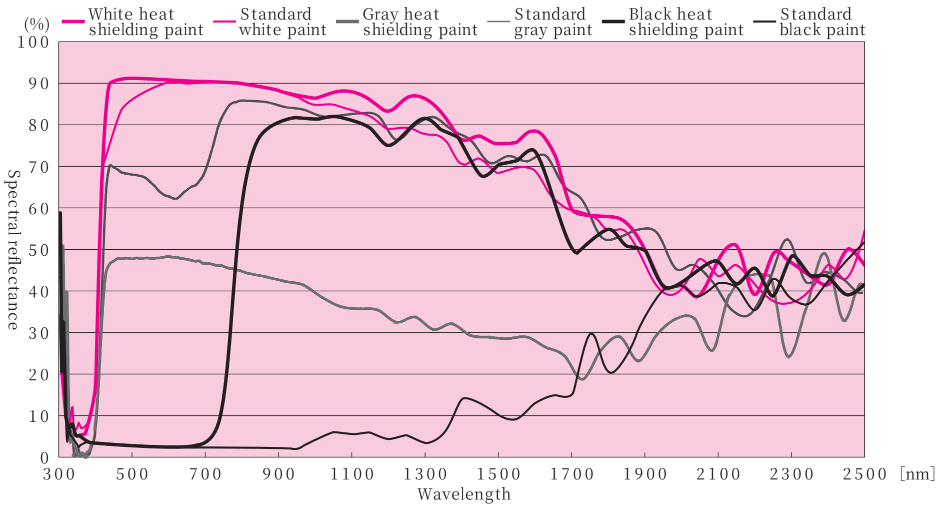


Fig. 22 Results of reflectance measurements using heat shielding paints

2. Solar shading through exterior wall ventilation control

- The temperature of exterior walls rises by receiving solar radiation, radiating heat into the inside of the building. In the case of a method using exterior wall material, it is effective to incorporate a ventilation cavity in order to control the quantity of heat radiated into the building through the exterior wall material (Fig. 23). A ventilation cavity is also effective in preventing rain water infiltration as well as releasing moisture accumulated inside the wall.
- It is desirable to ensure that the size of ventilation cavity is approximately 20 mm.
- The opening of a ventilated cavity should be as large as possible.
- Attention is required when positioning furring strips in order to ensure ventilation cavity.

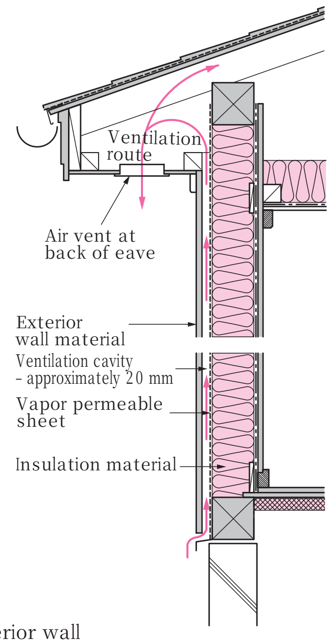


Fig. 23 Ventilation control of exterior wall

Method 4: Other solar shading methods

1. Prevention of reflected heat

- It is possible for the inside of the building to receive heat through openings due to heat reflected from the surface of the earth, porch, balcony, and surrounding buildings' roofs and walls.
- In order to reduce heat which the inside of the building receives as much as possible, it is necessary to consider the materials and finish of surfaces reflecting heat.

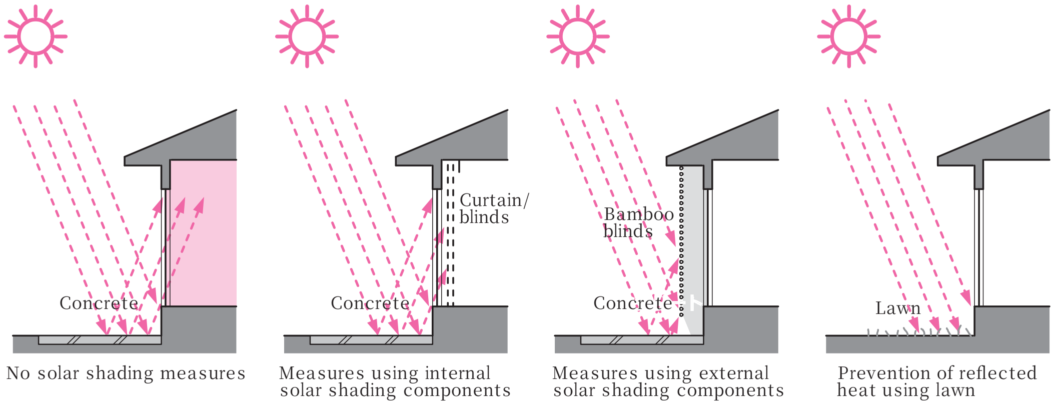


Fig. 24 Image of prevention of reflected heat

2. Solar shading with garden trees

- In a house with a garden, trees around the house can be expected to play an effective role in solar shading (Fig. 25).
- Deciduous trees block solar radiation in summer but do not block the sunlight much in winter because leaves fall. Therefore, they can be used for improving the comfort of the inside of the house (Fig. 26).

Fig. 25 Example of residential area where garden trees and green walls are used for solar shading

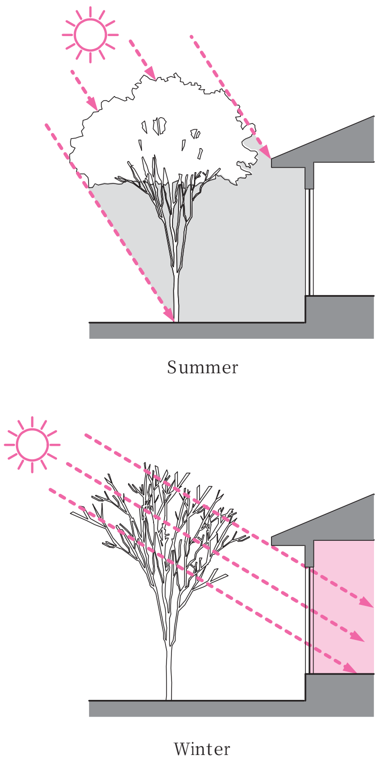


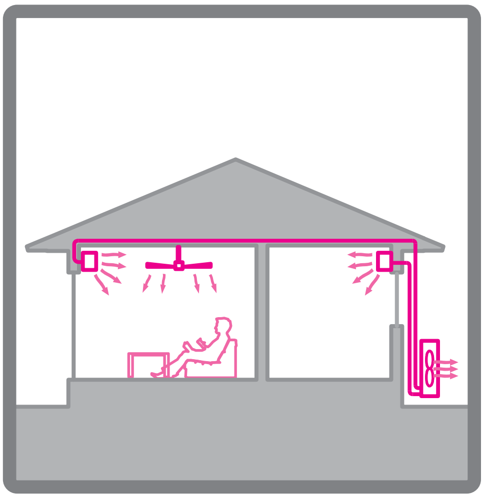
Fig. 26 Solar shading with garden trees

Now equipment has become so important that it is essential to our life. We need to select energy efficient devices and systems in order to use them with the minimum possible energy consumption. Additionally, exercising ingenuity in equipment planning that best suits the lifestyles of occupants and building performance can further enhance the use of equipment technology, contributing to increased comfort.

5

Chapter 5 : Energy-efficient Equipment Technology

5.1 Cooling System Planning for Zone VI



Cooling accounts for an important segment of energy consumption of a household located in a hot humid region (Zone VI). Applying energy-efficient technologies when planning a cooling system is therefore worthwhile.

Planning and designing a cooling system based on the concept of energy efficiency requires that we select a high-efficiency air conditioner with appropriate cooling capacity and consider installing an electric fan or ceiling fan.

5.1.1 Purpose and Key Points of Cooling System Planning

- **It is not uncommon in a typical home nowadays to experience difficulty in maintaining a cool temperature only with solar shading or cross ventilation during the height of summer. Cooling systems are therefore becoming an important method to provide protection from heat.**
- **The indoor thermal environment created by a cooling system and the system's energy consumption vary depending on factors such as weather conditions, the solar shading performance of the building, the amount of internal heat generation, and the use of the cooling system, electric and ceiling fans by the occupants. The use of wind also influences the reduction of cooling energy consumption.**
- **When selecting a cooling system, consideration should be given to systems possessing high energy consumption efficiency with appropriate cooling capacity based on the solar shading performance of the building as well as the size of the room.**
- **Electric and ceiling fans help reduce the cooling energy consumption by making it possible to set a slightly higher cooling temperature and creating an indoor airflow to reduce the use of cooling systems.**

5.1.2 Energy Conservation Target Levels for Cooling System Planning

1. Definition of target levels

- **This document sets targets for individual cooling with an air conditioner.**
- **Energy conservation target levels for cooling systems are divided into Level 1 to Level 4 as seen below. These levels indicate the reduction rate of the energy consumption of a cooling system.**

Level 0	:	Cooling energy reduction rate	None
Level 1	:	Cooling energy reduction rate	Approx. 10%
Level 2	:	Cooling energy reduction rate	Approx. 20%
Level 3	:	Cooling energy reduction rate	Approx. 25%
Level 4	:	Cooling energy reduction rate	Approx. 35%

- **In 2000, the typical cooling energy consumption was 10.3 GJ (approximately 16% of total energy consumption; see Section 6.1 on p.339).**
- **Any target level can be achieved by adopting the cooling system planning methods.**

2. How to achieve target levels

- **This document provides the following two methods as cooling system planning methods that can achieve energy saving effects.**

Method 1	:	Installing high-efficiency air conditioners
Method 2	:	Using electric and ceiling fans

- **Method 1 makes use of a device (air conditioner) with a high COP (energy consumption efficiency). Method 2 uses electric or ceiling fans making it possible to shorten the time the air conditioner is in use and raise the set temperature of the air conditioner. Any target level for cooling system planning can be achieved by combining these two methods (Table 1).**
- **The cooling energy reduction effect of using both an air conditioner and electric and ceiling fans depends on the amount of "reduction in power consumed by the air conditioner" and "increase in power consumed by the electric and ceiling fans". The cooling energy reduction rate shown on Table 1 using Method 2 is based on the calculation that assumes that the set cooling temperature was raised by 1ºC (See Method 2, Section 1. Using electric fans on p.214).**

Table 1 Target levels for cooling system planning and how to achieve them

Target level	Energy saving effect (Cooling energy reduction rate)	Method used	
		Method 1	Method 2
Level 0	0	Approx. COP3	Not used
Level 1	Approx. 10%	Approx. COP4	Not used
Level 2	Approx. 20%	Approx. COP3	Used
		Approx. COP5	Not used
Level 3	Approx. 25%	Approx. COP4	Used
Level 4	Approx. 35%	Approx. COP5	Used

* To calculate the cooling energy reduction rate shown in the table above, it was assumed that the models were selected based on the conventional and typical guidelines for selecting the air conditioner's cooling capacity.

- **Detailed explanation on these methods will be provided in the Section 5.1.4 Energy Saving Methods in Cooling System Planning.**

※The energy saving effect is calculated using estimate values obtained from methods such as validation experiments and theoretical calculations based on a family of four.

Glossary: COP
COP stands for Coefficient of Performance, which is an energy consumption efficiency, the number of which indicates how many times more output (capacity) can be obtained by the input of 1. Larger numbers therefore represent better efficiency.
COP = Capacity (kW) / Power Consumption (kW)
Although Annual Performance Factor (APF) or annual energy consumption efficiency has been displayed in product brochures in recent years, this document uses cooling COP to evaluate energy performance.

5.1.3 Steps for Considering Cooling System Planning and Factors for Selecting Cooling System

1. Steps for considering cooling system planning

Step 1 Considering factors for selecting cooling system

1) The solar shading performance of the building envelope
→See Section 4.2 Solar Shading Methods for Zone VI on p.164
2) Controlling the internal heat generation
→See Section 5.5 Lighting System Planning on p.288, and Section 5.6 Adopting High-efficiency Consumer Electronics on p.310
3) Adopt the most appropriate model according to the space.

▼

Step 2 Considering installation of high-efficiency air conditioners (Method 1)

1) Select a high-efficiency device with appropriate cooling capacity
2) Consider the energy-efficiency planning and design
3) Consider when the device is in operation

▼

Step 3 Considering use of electric and ceiling fans (Method 2)

1) Consider the use of electric fans
2) Consider the use of ceiling fans

2. Factors for selecting cooling system

When selecting a cooling system and determining the target level, consideration has to be given to the solar shading performance of the house, the household composition, the number of hours when occupants are at home, and the balance between the level of comfort the occupants desire and the cost.

1) The relationship between the cooling system and the solar shading performance of a building envelope

- **Solar-shading measures using the building envelope controls the flow of solar heat coming into the room during the summer months and the in-between seasons. It is therefore considered fundamental to providing protection from heat in hot humid regions and helps significantly to reduce cooling energy consumption. To customize the cooling system plan appropriately, it is thus important to examine the level of the solar shading measures first and consider cooling devices that offer appropriate capacity accordingly. This document uses the M value (a summer solar gain coefficient that takes into account factors such as the effect of adjacent buildings) for solar shading measures. See Section 4.2 Solar Shading Methods for Zone VI for its definition.**

2) Controlling internal heat generation

- **Controlling the heat generated by consumer electronics, lighting devices, cooking, etc., helps considerably to control the cooling energy consumption and to reduce room temperature. A typical power consumption of a family of four with common consumer electronics and lighting devices is 9.76 kWh/day on average (or 292.8 kWh/month). By room, the living and dining room consumes 5.18 kWh/day, the master bedroom 0.36 kWh/day, children's room (two kids in one room) 1.37 kWh/day, and other rooms 2.85 kWh/day. Using these numbers as a guideline, refer to "5.5 Lighting System Planning" and "5.6 Utilizing High-efficiency Consumer Electronics" when considering ways to control internal heat generation so as to examine the issue from the point of view of controlling the cooling energy consumption as well.**

3) Adopting most appropriate method according to space

- **In addition to the conventional wall-mounted air conditioner indoor units, there are a variety of other models. Some models such as those that are buried completely into the wall or ceiling do not protrude and may be more suitable for aesthetic reasons that need to be taken into account.**
- **In a room with a high or vaulted ceiling, using an air circulator such as a ceiling fan may be an effective way to eliminate warm air that tends to pool around the ceiling.**

5.1.4 Energy Saving Methods in Cooling System Planning

Method 1 : Installing high-efficiency air conditioners

- **Ordinarily, when cooling with air conditioners, every room in the house including the living and dining room would have an air conditioner each, which is used intermittently and as the need arises.**

1. Selecting high-efficiency device with appropriate cooling capacity

- **Select an air conditioner that offers the appropriate COP according to the target level. Table 2 shows the maximum cooling capacity of devices deemed appropriate for the room size based on the target level for solar shading (See Section 4.2.2 Energy Conservation Target Levels for Solar Shading Schemes on p.167).**
- **Using devices in which capacity exceeds requirements results in reduced energy consumption efficiency. This applies to air conditioners as well as other devices.**
- **Generally, an air conditioner's maximum capacity would be greater when heating than cooling. However, in Zones VI and V, the need for cooling exceeds the need for heating. The maximum cooling capacity is therefore the only target that should be used as a guideline when selecting the device.**

Table 2 Maximum cooling capacity as guideline for selecting air conditioner (Unit: kW)

Level of solar shading method	M value Summer solar gain coefficient that factors in the effect of adjacent buildings		6 *tatami* mats (10 m²)	8 *tatami* mats (13 m²)	10 *tatami* mats (16 m²)	14 *tatami* mats (22 m²)
	Insulation or vented cavity	Solar reflection				
Level 0	Exceeds 0.135	Exceeds 0.150	3.7	4.9	6.1	8.6
Level 1	0.135	0.150	3.1	4.1	5.1	7.1
Level 2	0.10	0.125	2.6	3.4	4.3	6.0
Level 3	0.08	0.115	2.1	2.8	3.5	5.3
Level 4	0.065~0.04	0.105~0.092	1.9~1.6	2.6~2.1	3.2~2.7	4.9~4.0

- **It is well known that COP can vary depending on operating conditions such as the load factor (the ratio of output when actually operating and when measuring COP) and the outside air temperature. Fig. 1 shows the relationship based on the measurement results between the load factor, the outside air temperature and COP. COP is highest at around half of the maximum load factor (when the air conditioner's output is at its maximum). When the load factor falls below that point, COP is shown to decrease. Furthermore, the lower the outside air temperature, the higher the COP when cooling. Generally speaking an air conditioner operates at its highest output immediately after starting and operates at a low output otherwise which decreases the COP.**

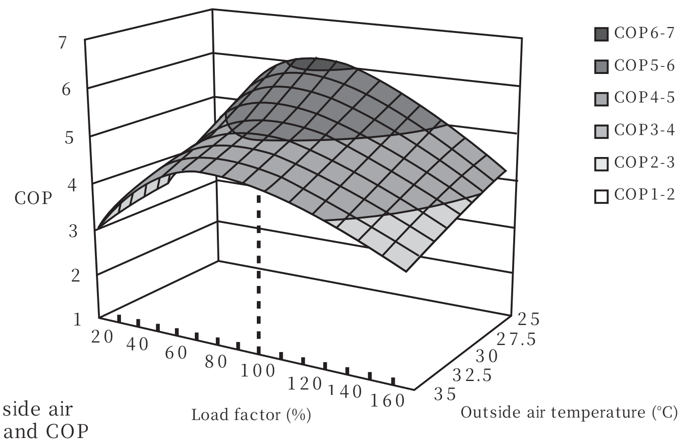


Fig. 1 Relationship between outside air temperature, load factor, and COP

Glossary: "Output" of a cooling system
This refers to the amount of heat that a cooling system removes from the indoor space per hour. Units are measured in kW.

- When an air conditioner has been in operation for many hours, the cooling load can become extremely low in the room, resulting in an intermittent operation. COP of an intermittent operation falls even lower than shown in Fig. 1. It is therefore not desirable to operate an air conditioner under low load and intermittent operation conditions from the perspective of taking advantage of the air conditioner's energy-saving performance (high efficiency). If an air conditioner is adopted with a capacity that far exceeds the room's cooling load, the time required to reach a set room temperature is shortened; however, the amount of the time the air conditioner is operating at an inefficient low output increases. Fig. 2 shows test results for the effect that operating with a load factor of less than 50% has on average COP throughout the cooling period (seasonal COP). Using the same device, the lower the ratio of low-output operation, the better the seasonal COP.

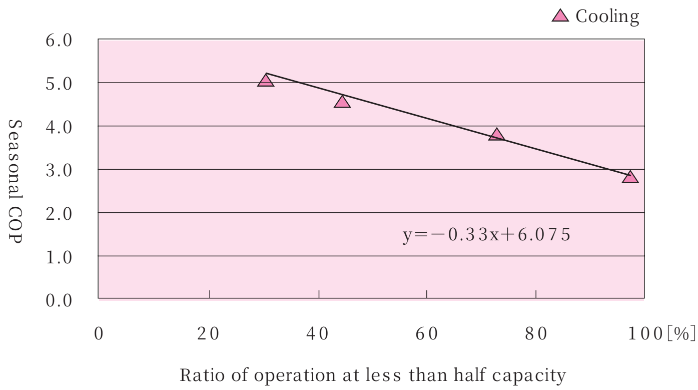


Fig. 2
Effect of ratio of low-load operation on seasonal COP

2. Considerations for energy conservation planning and designing

- If the outdoor unit is exposed to a direct sunlight, it can reach a high temperature, which in turn causes the COP to worsen when cooling. It is therefore desirable to place the outdoor unit in the shade; however, if it is not possible to do so, an awning may be installed. As the awning must not block the ventilation of the outdoor unit, its shape and the position should be carefully considered.
- If the roof or the outside wall is heated by sunlight, not only does it cause the increase of the cooling load, it also increases thermal sensation, thereby causing discomfort. The discomfort can be alleviated by implementing solar shading measures in the envelope.
- Careful attention needs to be paid during construction to avoid flooding through piping sleeves during typhoons or strong wind and rain. Furthermore, in regions adjacent to the sea, possible salt damage needs to be taken into account. Commercially available outdoor units with salt-damage protection may be used.

3. Considerations during operation

- Raising the set temperature of the air conditioner by 1°C will cut energy consumption by more than 15% (Fig. 3).

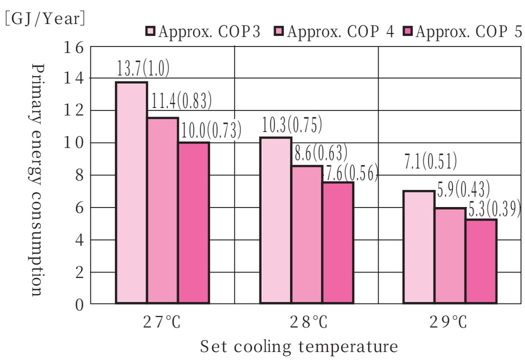


Fig. 3
Cooling energy consumption according to different air conditioner performance and set cooling temperature

- Using cross ventilation can limit the increase in room temperature by eliminating the indoor heat and releasing it outdoors. It also stimulates air circulation, which makes one feel cooler.
- A clogged filter reduces the amount of airflow from the air conditioner, which ultimately leads to a lower COP. It is therefore essential to frequently clean the filter to keep the operation efficient. Some commercially available models now come equipped with a self-cleaning function.

Key Point

The importance of selecting air conditioner appropriate for load

- **Fig. a Comparison of efficiency between conventional and energy-efficient air conditioners shows the relationship between the outside air temperature (the cooling load varies depending on the outside air temperature) and the COP of a conventional air conditioner (COP≈3) and an energy-efficient air conditioner (COP≈6) measured during the summer months using actual units placed in a living room. This figure confirms the energy saving effect of an energy-efficient device.**
- **Fig. b Comparison of efficiency between living room and bedroom shows the efficiency of devices with approximately the same COP when one is placed in a living room while the other in a bedroom during the summer months. Although the COPs of both devices are almost identical, it is apparent that the efficiency of the air conditioner placed in the bedroom is lower. It can be presumed that this is caused by the bedroom being located on the north side of the house, thereby creating a comparatively cool (smaller load) environment.**
- **Fig. c Distribution of load factor shows the amount of output when in operation compared to the device's maximum output (100%) during the summer months. It is shown that, during these months, the air conditioner in the living room operated at approximately half the maximum output while the one in the bedroom was operating merely at 5-20%. In other words, when the capacity of the device far exceeds the load of the room, it can lead to inefficient operation that does not take full advantage of the fact the device itself is efficient. The capacity of the device to be selected therefore needs to be determined with the help of Table 2 and other tools.**

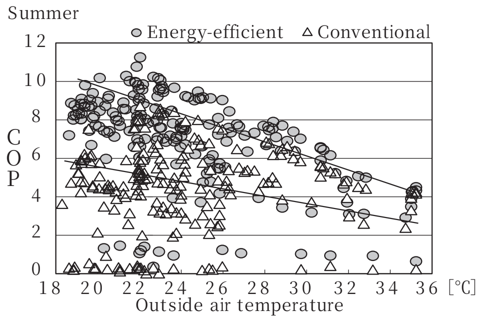


Fig. a Comparison of efficiency between conventional and energy-efficient air conditioners

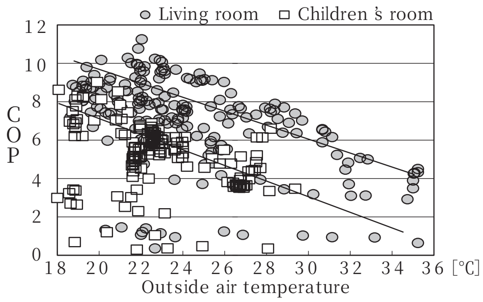


Fig. b Comparison of efficiency between living room and children's room

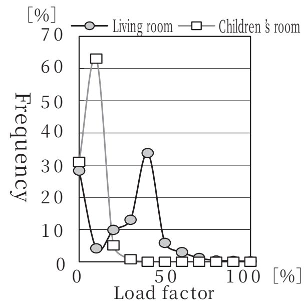


Fig. c Frequency distribution of load factor

Comment ● Air conditioner's dehumidification function

We are recently seeing many air conditioners with a dehumidification function that employs a method called reheat dehumidification. The traditional dehumidification method had a shortcoming whereby it excessively decreased the room temperature. The reheat dehumidification method, on the other hand, dehumidifies the air by cooling it then reheats it before releasing it back into the room, which alleviates the discomfort of the dehumidification process. However, it should be noted that the reheat dehumidification operation requires more energy than the conventional dehumidification operation as well as a regular cooling operation.

Method 2 : Using electric and ceiling fans

- **Using electric and ceiling fans allows us to set a higher cooling temperature for the air conditioner. Fans also contribute to minimizing the hours required for cooling. It can be expected that setting a higher cooling temperature will result in less consumption of cooling energy.**

1. Using electric fans

- **Electric fans can be useful in limiting the use of cooling as they lower thermal sensation due to a breeze. Occupants can turn on a fan temporarily at a higher setting (high or medium) after returning from work or taking a bath.**
- **It is still difficult to quantitatively evaluate the cooling sensation created by the airflow of an electric fan. However, even though cooling systems have become commonplace, the energy saving effect of frequently used electric fans cannot be overlooked. The amount of heat removed from the body surface by the airflow varies depending on factors such as the speed of the airflow, the cycle (oscillation cycle, etc.) and the evaporation of sweat.**
- **Table 3 shows the measured results of the power consumption and the wind speed using two models of electric fans. Model 2 is shown to consume less power yet provides a higher wind speed, which means it is more efficient.**

Table 3 Measured results of power consumption and wind speed of electric fans

		Model 1			Model 2		
Rated power consumption (W; 50/60 Hz)		52/53			40/43		
Wind speed setting		Low	Medium	High	Low	Medium	High
Power consumption (W; 50 Hz)	W/ oscillation	40	46	56	24	31	50
	W/O oscillation	37	44	54	23	31	49
Wind speed W/O oscillation (Average value at the top speed; m/s)	At 2 m	1	1.1	1.2	1.2	1.4	2
	At 3 m	0.6	0.7	0.8	1	1.2	1.4
Full oscillation cycle (s)		21.8	18.9	16.4	25.7	20.0	15.3

- **From our estimates, it was shown that 1°C in reduction of thermal sensation can be expected when the electric fan is placed at a distance of 2 to 3 m (when used for a long period of time at a low wind speed setting with oscillation). As we can expect to lower the thermal sensation by 1°C and can set the cooling temperature of the air conditioner 1°C higher, using an electric fan along with an air conditioner can be said to have a cooling energy saving effect. On the other hand, if the cooling temperature of the air conditioner remains unchanged when used in conjunction with an electric fan, the energy consumption simply increases for the amount used by the electric fan.**

2. Using ceiling fans

- **Ceiling fans (Fig. 4) can send airflow to a wider area than electric fans and can have a more general effect in reducing thermal sensation within a room. If the ceiling offers a good height such as a vaulted ceiling where warm air tends to pool, a ceiling fan can limit the increase of the temperature on the ceiling surface by circulating the air as well as reduce the thermal sensation within the area. (However, if the cause of the warm air pooling at the ceiling is weak insulation or solar shading in the roof or attic, using a ceiling fan may increase the cooling energy consumption.)**
- **Ceiling fans consume approximately the same amount of energy as electric fans but cover a wider area with airflow, which means that they can have a more general effect in the room to reduce the thermal sensation. (When an experiment was conducted with a ceiling fan with a ceiling height of 4.9 m, the wind speed obtained was 0.3 m/s at medium setting and 0.1 to 0.2 m/s at low setting within the area. The wind created at medium setting appears to be sufficient to be felt by occupants.)**
- **Although ceiling fans can be difficult to install unless the ceiling height is relatively high, more and more products now combine the fan and the lighting to facilitate installation. In terms of safety and other factors, a ceiling height of 2.5 m seems to be the minimum requirement. (The distance between the ceiling surface and the lowest point of the fan can be as small as 20 cm or so depending on the product.)**
- **We are increasingly seeing fans with simple, modern designs in addition to the conventional classic design, which gives consumers a wide range of selection design-wise.**

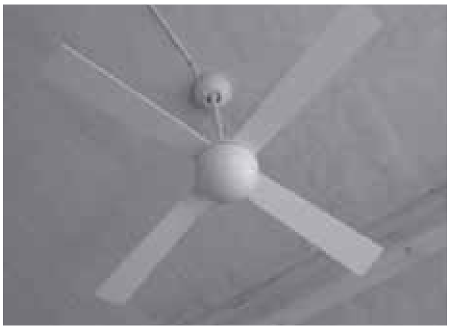


Fig. 4 Example of ceiling fan

5.1.5 Selecting Auxiliary Heater

- **There exist many choices in auxiliary heaters used during the winter months including *kotatsu* (a small quilt-covered table with an electric heater affixed underneath), electric panel heaters, electric space heaters, electric carpets, ceramic heaters, and halogen heaters. Using these devices may consume more power than heat pump air conditioners used for the same period of time.**
- **Burning an open flame or heating with an unvented heater that releases exhaust into the room reduces the indoor air quality as fuel is burned indoors. Care is therefore required such as avoiding using such heaters for a long period of time and airing the room frequently when in use.**

Comment ● Power consumption of auxiliary heaters

The figure compares the power consumption of an energy-efficient heat pump air conditioner, an electric carpet and a *kotatsu* all placed in a living room (floor area: 24 m²). The heat pump air conditioner may consume a significant amount of power immediately after start-up; however, when the temperature stabilizes, it is shown to consume not much more than the electric carpet or the *kotatsu* at a low setting. Furthermore, from the point of view of energy efficiency, the low setting is recommended for both the *kotatsu* and the electric carpet. The electric carpet and the *kotatsu* may seem energy efficient, as they are localized heaters; however, if left on for a long period of time, they consume more energy than other heaters that heat the entire room.

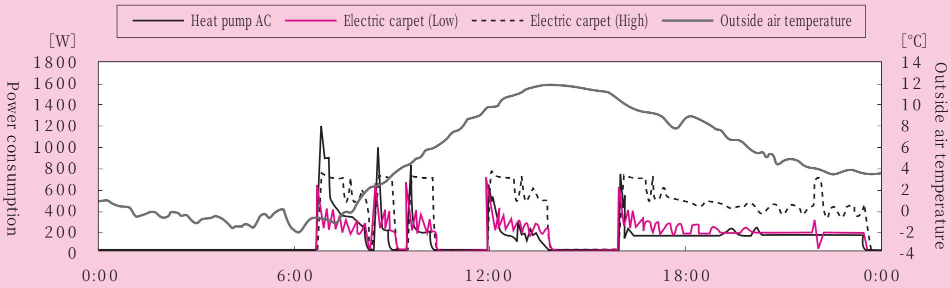


Fig. a Energy consumption comparison between heat pump air conditioner and electric carpet

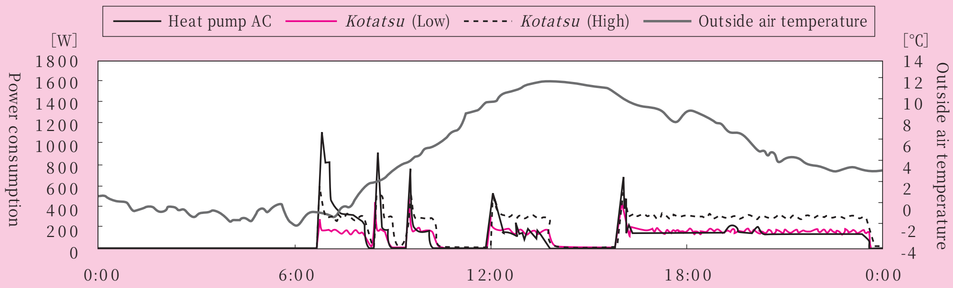


Fig. b Energy consumption comparison between heat pump air conditioner and *kotatsu*

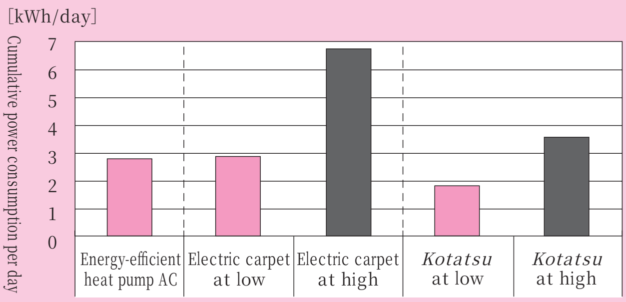


Fig. c Comparison of daily power consumption

■Conditions

Building and location: Multi-family residential building in Tsukuba City, Ibaraki Prefecture

Heat pump AC: Energy-efficient 2.2 kW model (COP≈6)

Electric carpet: For use for 3-*tatami*-mat area (Area: 5 m²; Rated power consumption: high = 700 W, low = 350 W)

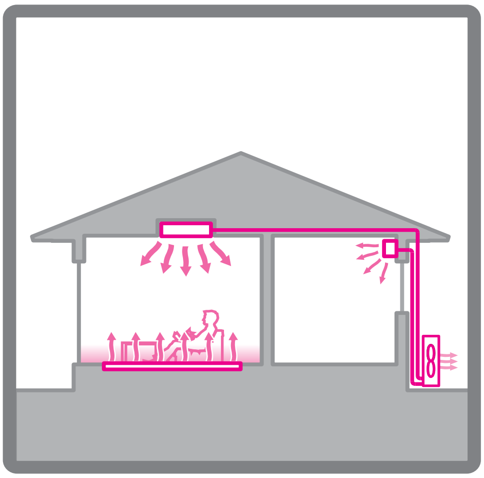
Kotatsu: Square-shaped (Each side measures 75 cm: rated power consumption: 600 W)

The power consumption patterns for the electric carpet and the *kotatsu* were estimated based on the power consumption measured in the artificial climate chamber (outside temperature = 5°C, indoor temperature = 15°C).

5

Chapter 5 Energy-efficient Equipment Technology (Elemental Technology Application Method 3)

5.2 Heating and Cooling System Planning for Zone V



Heating and cooling energy consumption accounts for 15 – 40% of total energy consumption of a household located in a hot humid region (Zone V). Applying energy-efficient technologies when planning a heating and cooling system is therefore worthwhile.

Planning and designing a heating and cooling system based on the concept of energy efficiency requires basic knowledge for selecting and installing appropriate system and devices.

5.2.1 Purpose and Key Points of Heating and Cooling System Planning

- Since it is common in modern houses to experience difficulty in maintaining a comfortable indoor environment only with insulated building envelopes, solar shading or solar heat gain, it requires heating and cooling systems. Energy consumption of heating and cooling systems is significant, making energy saving design in heating and cooling systems important.
- Many different types of heating and cooling system are available for detached houses. When operation methods are categorized according to the area to be heated or cooled, they can be divided into a system in which heating and cooling is controlled room by room, i.e. the partial system, and a system in which heating and cooling is controlled by the whole building, i.e. the whole-building system. There are a range of heating and cooling devices belonging to either of these two categories. Moreover, new devices are being developed frequently.
- According to the classification by the duration of heating and cooling, a system in which heating and cooling is operated while occupants are in each room, i.e. the partial intermittent system, is generally used when heating and cooling is controlled room by room. Meanwhile, when heating and cooling is controlled by the whole building, a system in which heating and cooling is operated 24 hours regardless of occupants being in each room or not, i.e. the whole-building continuous system is used (Table 1).
- The indoor thermal environment created by a heating and cooling system and the system's energy consumption vary depending on factors such as weather conditions, insulation performance of building envelopes, solar shading performance of openings, and the use of the system by occupants (e.g. household composition, number of hours when occupants are at home, operation methods). The utilization of natural energy such as wind and solar heat also influences the reduction of heating and cooling energy consumption.
- Although it is not easy to systematically organize the energy saving design methods for heating and cooling systems, it is important to select a system according to the equipment characteristics and make an energy saving design for the system.

Table 1 Classification of heating and cooling system by operation method

Classification by area to be heated or cooled	Heating and cooling controlled room by room	Partial system
	Heating and cooling controlled by whole building	Whole-building system
Classification by duration of heating and cooling	Heating and cooling operated only when occupants are in each room (heating and cooling not operated when occupants are asleep)	Intermittent system
	Heating and cooling operated 24 hours regardless of occupants being at home or not	Continuous system

Remark Duration of heating and cooling can be roughly categorized as shown above, but various other operation methods are possible, such as turning off heating when sleeping at night or setting heating temperature low while using a continuous system. Any combination of two of the above-mentioned operation methods is also feasible, for example, using a continuous system in living and other major rooms while adopting an intermittent system in bedrooms in which heating and cooling is operated when the occupants are there.

5.2.2 Energy Conservation Target Levels for Heating and Cooling System Planning

1. Types of heating and cooling system discussed in this document

- This document provides information on the following four types of heating and cooling system, both partial intermittent and whole-building continuous systems, which are generally used in homes in hot humid regions (Zone V):
  1) Type 1: Heating and cooling air conditioner
  2) Type 2: Gas or oil hot water heating
  3) Type 3: Forced flue (FF) heating
  4) Type 4: Duct central heating and cooling
- Types 1, 2 and 3 are applicable to the partial intermittent system while Type 4 is applicable to the whole-building continuous system.
- Heating and cooling air conditioner (Type 1) and duct central heating and cooling (Type 4) can be used for heating in winter as well as cooling in summer. However, gas and oil hot water heating (Type 2) and FF heating (Type 3) can be used only for heating in winter.
- In this document, gas and oil hot water heating is expected to adopt a partial intermittent system in which floor heating is used for heating the living and dining room only, instead of a whole-building heating system in which heat radiation panels are installed in each habitable room as seen in cold regions. Therefore, a heat pump air conditioner is anticipated to be used in habitable rooms other than the living room, dining room and kitchen.
- Duct central heating and cooling is assumed to adopt a system in which a heat pump is used as a heat source and heating and cooling is performed with electricity.

2. Definition of target levels

- Energy saving methods and effects vary depending on which type of heating and cooling system is used.
- The partial intermittent system (Type 1: heating and cooling air conditioner) and whole-building continuous system (Type 4: duct central heating and cooling) have energy conservation target levels as shown in the table below.
- Of the partial intermittent systems, energy saving effects of hot water heating (Type 2) and FF heating (Type 3) are explained in the next section.

Energy conservation target levels for partial intermittent system (Type 1: heat pump air conditioner)

Level 0	:	Heating energy reduction rate	None
Level 1	:	Heating energy reduction rate	Approx. 5%
Level 2⁻	:	Heating energy reduction rate	Approx. 10%
Level 2	:	Heating energy reduction rate	Approx. 15%
Level 3⁻	:	Heating energy reduction rate	Approx. 20%
Level 3	:	Heating energy reduction rate	Approx. 25%
Level 4	:	Heating energy reduction rate	Approx. 30%

Energy conservation target levels for partial intermittent system (Type 1: air conditioner)

Level 0	:	Cooling energy reduction rate	None
Level 1	:	Cooling energy reduction rate	Approx. 5%
Level 2⁻	:	Cooling energy reduction rate	Approx. 10%
Level 2	:	Cooling energy reduction rate	Approx. 15%
Level 3⁻	:	Cooling energy reduction rate	Approx. 20%
Level 3	:	Cooling energy reduction rate	Approx. 25%
Level 4⁻	:	Cooling energy reduction rate	Approx. 30%
Level 4	:	Cooling energy reduction rate	Approx. 35%

Energy conservation target levels for whole-building continuous heating system (Type 4: duct central heating)

Level 0	:	Heating energy reduction rate	None
Level 1	:	Heating energy reduction rate	Approx. 20%
Level 2	:	Heating energy reduction rate	Approx. 45%

Energy conservation target levels for whole-building continuous cooling system (Type 4: duct central cooling)

Level 0	:	Cooling energy reduction rate	None
Level 1	:	Cooling energy reduction rate	Approx. 25%
Level 2	:	Cooling energy reduction rate	Approx. 40%

- In 2000, the typical heating and cooling energy consumption when adopting a partial intermittent system was 5.0 GJ and 5.7 GJ, respectively (approximately 7% and 8% of total energy consumption; see Section 6.1 on p.339).
- In 2000, the typical heating and cooling energy consumption when adopting a whole-building continuous system was 13.4 GJ and 27.0 GJ, respectively (approximately 13% and 27% of total energy consumption; see Section 6.1 on p.339).

3. How to achieve target levels

1) Prerequisites for verifying energy saving effects

①Partial intermittent heating and cooling system

- Details and effectiveness of energy saving methods vary depending on the heating system. This document presents the methods that can achieve energy conservation target levels by heating system type.
- Generally, an appropriate capacity of heat source equipment is determined by factors such as the house performance, area of heated room, and duration of heating. If the device capacity selected is much larger than the appropriate capacity, energy saving effects described in this document may not be expected. The higher the radiator capacity of hot water heating (Type 2; heating area in case of floor heating), the greater its performance, which may result in energy saving. Because of this, it is necessary to differentiate the capacity of radiator and that of heat source equipment. See Section 5.2.4 Energy Saving Methods in Heating and Cooling System Planning on p.230 for how to select device capacity.
- Since the heating energy consumption of bedrooms, children's rooms and other habitable rooms is very low compared to that of the living room, dining room and kitchen, the effectiveness of introducing energy saving methods to other habitable rooms is relatively low. This is why this document does not estimate the effectiveness of introducing energy saving methods to other habitable rooms. Therefore, if an appropriate capacity of air conditioner is chosen for the living room, dining room and kitchen, great energy saving effects can be expected.
- This document is written assuming that other habitable rooms are used before and after dinner and before sleeping during the weekdays. However, if other habitable rooms are used for extended periods of time because of being occupied by seniors or other people, energy saving effects become relatively higher, thus it is very effective to introduce high-efficiency air conditioners.
- Energy saving effects shown in this document are calculated with a room temperature set at 28°C in summer and 20°C in winter.

②Whole-building continuous heating and cooling system

- Regarding duct central heating and cooling, an appropriate capacity of heat source equipment is generally determined by factors such as the house performance, area of heated room, and duration of heating. If the device capacity selected is much larger than the appropriate capacity, energy saving effects described in this document may not be expected.
- Energy saving effects shown in this document are calculated with a room temperature set at 28°C in summer and 20°C in winter.

2) Target levels for heating and cooling air conditioner and how to achieve them (Type 1)

①Heat pump air conditioner

- This document provides the following methods as system planning methods for heat pump air conditioners that can achieve energy saving effects:

Method 1	:	Adopting high-efficiency air conditioners
Method 2	:	Setting appropriate device capacity

- Method 1 makes use of a device (air conditioner) with a high rated heating efficiency, which is influenced by the rated heating efficiency of air conditioners installed in the living room, dining room and kitchen.
- Method 2 selects an air conditioner with an appropriate capacity according to the insulation performance of the house. Since manufacturers' selection criteria are based on obsolete information on average homes, it is likely to be more energy efficient to choose an air conditioner with a smaller capacity than the value provided in the catalogue for a modern house with good insulation performance. However, if the capacity is too low it is difficult to heat the house with the heat pump air conditioner alone and energy inefficient heaters may also end up being used. This does not save energy, thus careful attention is required when selecting the air conditioner capacity. For details, see Section 5.2.4 Energy Saving Methods in Heating and Cooling System Planning on p.231.

- Table 2 shows the correspondence between energy conservation target levels and methods for heat pump air conditioners. It subdivides the target levels based on the relationship between the methods and heating energy reduction rates.

Glossary: Rated efficiency
Rated efficiency is a value of heating and cooling capacity measured under rated conditions that is divided by power consumption at that time. It is expressed as energy consumption efficiency or COP in product catalogues.
As this value increases, less power consumption is required for heating and cooling, thus it is more energy efficient.
Rated conditions refer to test conditions for measuring energy saving performance of air conditioners specified by the Japanese Industrial Standards (JIS).

Table 2 Target levels for heat pump air conditioner (Type 1; partial intermittent system) and how to achieve them

Target level	Energy saving effect (Heating energy reduction rate)	Method used: Rated heating efficiency (air conditioner installed in living/dining room/kitchen)	
		Without Method 2	With Method 2
Level 0	0	Below 4.9	—
Level 1	Approx. 5%	4.9 or higher	—
Level 2⁻	Approx. 10%	—	Below 4.0
Level 2	Approx. 15%	—	4.0 or higher
Level 3⁻	Approx. 20%	—	4.5 or higher
Level 3	Approx. 25%	—	5.3 or higher
Level 4	Approx. 30%	—	6.2 or higher

* The device capacity of air conditioner (maximum heating capacity) in the case of "Without Method 2" is estimated as 7.51 kW for living/dining room and kitchen and 3.08 kW for other habitable rooms. In the case of "With Method 2", it is estimated as 3.08 kW for both living/dining room and kitchen and other habitable rooms. Rated heating efficiency for Level 0 is assumed as 3.8.

②Air conditioner

- This document presents the following methods as system planning methods for air conditioners that can achieve energy saving effects:

Method 1	:	Adopting high-efficiency air conditioners
Method 2	:	Setting appropriate device capacity
Method 3	:	Using electric or ceiling fans

- Method 1 makes use of a device (air conditioner) with a high rated cooling efficiency.
- Method 2 selects an air conditioner with an appropriate capacity according to the insulation performance of the house (Same as (1) heat pump air conditioner).
- Method 3 makes good use of an electric or ceiling fan when an air conditioner is required. Reducing the thermal sensation by generating airflow in the room allows you to set the air conditioner temperature higher in addition to shortening the duration of cooling devices.

・Energy saving effects of air conditioners vary between the living room, dining room and kitchen and other habitable rooms. Therefore, a sum of the energy saving effect of the living room, dining room and kitchen and other habitable rooms should be calculated according to the following equation:

Energy saving effects of air conditioner
= Energy saving effect of living room, dining room and kitchen + Energy saving effect of other habitable rooms

・Here, we present the correspondence between energy saving effects and methods using air conditioners in the living room, dining room and kitchen and other habitable rooms (Tables 3, 4). Energy conservation target levels for air conditioners are set in a combination of class for the living room, dining room and kitchen and class for other habitable rooms. Table 5 subdivides the target levels based on the relationship between a combination of classes and cooling energy reduction rate.

Table 3 Energy saving effect classes of air conditioner (Living/dining room/kitchen)

Class	Energy saving effect (Cooling energy reduction rate)	Method used (Rated cooling efficiency)			
		Without Method 3		With Method 3	
		Without Method 2	With Method 2	Without Method 2	With Method 2
Class 0	0	Below 3.5	—	Below 3.0	—
Class 1	Approx. 5%	3.5 or higher	—	3.0 or higher	—
Class 2	Approx. 10%	4.3 or higher	Below 3.7	3.7 or higher	Below 3.2
Class 3	Approx. 15%	5.6 or higher	3.7 or higher	4.9 or higher	3.2 or higher
Class 4	Approx. 20%	—	4.4 or higher	—	3.9 or higher
Class 5	Approx. 25%	—	5.3 or higher	—	4.9 or higher

Table 4 Energy saving effect classes of air conditioner (Other habitable rooms)

Class	Energy saving effect (Cooling energy reduction rate)	Method used (Rated cooling efficiency)			
		Without Method 3		With Method 3	
		Without Method 2	With Method 2	Without Method 2	With Method 2
Class 0	0	Below 3.8	Below 3.7	Below 3.3	Below 3.2
Class 1	Approx. 5%	3.8 or higher	Below 3.7	3.3 or higher	3.2 or higher
Class 2	Approx. 10%	5.1 or higher	Below 4.9	5.0 or higher	4.8 or higher

Table 5 Target levels for air conditioner (Type 1; partial intermittent system) and how to achieve them

Target level	Energy saving effect (Cooling energy reduction rate)	Living/dining room/kitchen class applied		
		When other habitable room class is 0	When other habitable room class is 1	When other habitable room class is 2
Level 0	0	Class 0	—	—
Level 1	Approx. 5%	Cass 1	Class 0	—
Level 2⁻	Approx. 10%	Cass 2	Cass 1	Class 0
Level 2	Approx. 15%	Cass 3	Cass 2	Cass 1
Level 3⁻	Approx. 20%	Class 4	Cass 3	Cass 2
Level 3	Approx. 25%	Class 5	Class 4	Cass 3
Level 4⁻	Approx. 30%	—	Class 5	Class 4
Level 4	Approx. 35%	—	—	Class 5

3) Target levels for gas and oil hot water heating and how to achieve them (Type 2)

- This document provides the following methods as system planning methods for gas and oil hot water heating that can achieve energy saving effects:

Method 1	:	Adopting high-efficiency heat source equipment
Method 2	:	Lowering supply water temperature of heat source equipment
Method 3	:	Underfloor and piping insulation and shortening piping length
Method 4	:	Adopting floor heating and increasing rate of floor heating area

- Method 1 adopts high-efficiency heat source equipment, i.e. heat source equipment with high energy consumption efficiency (heating output divided by fuel consumption).
- Method 2 involves a device that functions to lower the supply water temperature of heat source equipment.
- Method 3 aims to reduce heat loss by reinforcing the insulation under the floor heating panels on the first floor and insulating hot water piping as well as shortening the piping length.
- Method 4 makes use of floor heating and increases the rate of floor heating area. Floor heating can increase comfort and decrease heating temperature. An increased rate of floor heating area enhances the amount of heat radiation and improves heat source efficiency.

- Table 6 provides the correspondence between energy conservation target levels and methods for gas and oil hot water heating.
- The energy saving evaluation shown in Table 6 is based on air conditioners (see Table 2 on p.219 for standard conditions), and energy consumption is estimated to increase by 15% compared to the standard even when Methods 1 to 4 are adopted. However, radiant heating such as floor heating and panel heating which is also hot water heating, is generally highly recognized for comfort. For that reason, if we are to comprehensively evaluate these hot water heating devices there is no reason for restraining from using them. Having said that, it is recommended to control energy consumption by keeping in mind the characteristics presented in Table 6 and adopting Methods 1 to 4 or to reduce overall energy consumption by adopting other elemental technologies (e.g. energy saving technology related to domestic hot water system).
- Characteristics of the thermal environment created by radiant heating, floor heating in particular, and its energy efficiency are still not completely known and further research and development efforts are required.

Table 6 Target levels for gas and oil hot water heating (Type 2; living/dining room/kitchen) and how to achieve them

Target level	Energy saving effect (Heating energy reduction rate)	Method used	
		Gas heat source	Oil heat source
Level −4	Approx. 65% increase	—	Method(s) not adopted
Level −3	Approx. 40% increase	Method(s) not adopted	All methods adopted
Level −2	Approx. 15% increase	All methods adopted	—

* The calculation is based on a heat source equipment efficiency of 78%, 60 °C hot water supply, sleeve tube piping, and floor heating panels in which 85% of total energy used for floor heating is released in the room as heat. Method 1 is calculated with 83% efficiency of high-efficiency heat source equipment and 60 °C hot water supply. Latent heat recovery gas heat source equipment is used as a low-temperature model for Method 2, which is calculated at 86% efficiency with 40 °C and 60 °C hot water supply. For Method 3, the calculation is based on insulated piping and floor heating panels in which 90% of total energy used for floor heating is released in the room as heat. For piping length, it is assumed that piping is laid from where the heat source equipment is installed near the panels (east of the living/dining room and kitchen). Method 4 is calculated assuming that heating load is reduced by 10%.

4) Target levels for forced flue (FF) heating and how to achieve them (Type 3)

- This document does not specify the system planning methods for FF heating which are expected to provide energy saving effects. The energy conservation target level for a device with average capacity is shown in Table 7.
- This target level is set based on the energy consumption of heat pump air conditioners at Level 0, and energy consumption tends to increase compared to heat pump air conditioners.

Table 7 Target levels for FF heating (Type 3; living/dining room/kitchen)

Target level	Energy saving effect (Heating energy reduction rate)	Method used
Level −1	Approx. 5% increase	Not specified

* The value above is calculated based on the FF heating system for living/dining room and kitchen with a maximum capacity of 4.77 kW, rated efficiency of 86.1%, and rated power consumption of 48W.

Comment ● Use of electric heaters in other habitable rooms

Bedrooms, children's rooms and other habitable rooms are sometimes heated by electric heaters. Electric heaters are not intended to heat the entire room alone but are often used as portable heating units. Although it depends on the situation, using heat pump air conditioners in the living room, dining room and kitchen and electric heaters in all other habitable rooms increases heating energy consumption by approximately 40% compared to level 0 (standard level of heat pump air conditioners).

Converting electric energy directly into heat energy without heat pump technology is the least efficient, and the use of electric heaters should be avoided as much as possible (See Section 5.2.5 Selecting Auxiliary Heater on p.243 for details).

Comment ● Use of unvented heaters

Heaters are divided into two types—unvented and vented—according to the way it burns kerosene, processed natural gas and other fuels. Heaters take the air into the inside to burn the fuel to generate heat. Unvented heaters release the combustion gas generated during this process into the room while vented heaters directly release it outside.

When an unvented heater is used, indoor air pollutants, including nitrogen dioxide and carbon dioxide, which may cause health hazards to the occupants (toxicity of carbon dioxide becomes an issue when the concentration exceeds 3,500 ppm), are emitted depending on the fuel composition. Because of this, a large amount of ventilation is required, but it is hardly performed in reality since it is difficult to achieve this level of ventilation. As a result, unvented heater can be a source of indoor air pollutants.

For your reference, the amount of ventilation required per unit heat generation (1 kW) is approximately 90 m3/h for regular processed natural gas and approximately 185 m3/h for kerosene (source: Materials on Symposium about HASS102-1995 Ventilation Standard, The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan).

Moreover, a large amount of vapor generated from fuel combustion is a major cause of condensation, which tends to soil the interior finish and promote mold growth. Unvented heaters should be avoided from this perspective as well.

5) Target levels for duct central heating and cooling and how to achieve them (Type 4; whole-building continuous system)

- This document presents the following methods as system planning methods for duct central heating and cooling that can achieve energy saving effects:

Method 1	:	Adopting high-efficiency central heating and cooling system (at least 4.0 of rated cooling efficiency)
Method 2	:	Adopting model with room-by-room temperature control function

- Tables 8 and 9 show the correspondence between energy conservation target levels and methods for duct central heating and duct central cooling, respectively.

Table 8 Target levels for duct central heating and how to achieve them (Type 4)

Target level	Energy saving effect (Heating energy reduction rate)	Method used
Level 0	0	No method adopted
Level 1	Approx. 20%	Method 1
Level 2	Approx. 45%	Method 1 + Method 2

* A central heating system with a rated heating capacity of 8 kW and rated consumption of 2.54 kW (equivalent of COP3) is used. Method 1 estimates a high-efficiency central heating and cooling system of the similar capacity with an energy consumption efficiency close to COP4. The temperature control function of Method 2 is calculated with heating temperature at 16 °C when the occupants are either not in the room or are sleeping.

Table 9 Target levels for duct central cooling and how to achieve them (Type 4)

Target level	Energy saving effect (Cooling energy reduction rate)	Method used
Level 0	0	No method adopted
Level 1	Approx. 25%	Method 1
Level 2	Approx. 40%	Method 1 + Method 2

* A central cooling system with a rated cooling capacity of 7.1 kW and rated consumption of 2.36 kW (approx. COP3.1) is used. Method 1 estimates a high-efficiency central heating and cooling system of the similar capacity with an energy consumption efficiency close to COP4. The temperature control function of Method 2 is calculated with cooling temperature at 30 °C when the occupants are either not in the room or are sleeping.

5.2.3 Steps for Considering Heating and Cooling System Planning

1. Steps for considering heating and cooling system planning

Step 1 Checking prerequisites

- Weather conditions
- Insulation performance of building envelopes
  → See Section 4.1 Insulated Building Envelope Planning for Zone V on p.124
- Ventilation system types and other factors
  → See Section 5.3 Ventilation System Planning on p.244
- Household composition

▼

Step 2 Considering how to operate (duration and place) heating and cooling system

- Duration of heating and cooling
  …Intermittent or continuous system
- Place of heating and cooling
  …Partial system (heating only the room being occupied)
  Whole building system (heating the entire house)

▼

Step 3 Considering types of heating and cooling system

- Select types of heating and cooling system
  Type 1: Heating and cooling air conditioner
  Type 2: Gas or oil hot water heating
  Type 3: Forced flue (FF) heating
  Type 4: Duct central heating and cooling
- Consider the use of auxiliary heaters (avoid as much as possible or limit to short-term use)
- Consider the use of natural wind and auxiliary cooling (electric and ceiling fans)

▼

Step 4 Examining energy saving methods for heating and cooling system planning

1) Examine energy saving methods
(Select appropriate heating and cooling capacity and high-efficiency equipment)
2) Consider the energy efficiency planning and design
3) Consider the operating system
(See Section 5.2.4 Energy Saving Methods in Heating and Cooling System Planning on p.230)

▼

Step 5 Consider methods for utilizing auxiliary heaters

(See Section 5.2.5 Selecting Auxiliary Heater on p.243)

2. Checking prerequisites (Step 1)

When selecting the type of cooling and heating system and determining the target level, consideration has to be given to the insulation specifications of the house, household composition, number of hours when occupants are at home, and the balance between the level of comfort the occupants desire and the cost.

1) Relationship with insulation performance of building envelope

- The insulation specifications of the house form the foundation of heating and cooling system planning. It is necessary to select the insulation level specifications appropriate for the weather conditions and consider the type of heating and cooling system by taking into account the relationship between the insulation level and the heating and cooling system. For the details of this relationship, see Section 4.1 Insulated Building Envelope Planning for Zone V.

2) Relationship with ventilation planning

- Selecting the type of heating and cooling system is closely related to 5.3 Ventilation System Planning. Since regular ventilation planning cannot address pollutants generated from conventional unvented heaters, the effects on occupant health and risk of condensation should be considered first when using this type of heater.

3) Relationship with household composition and number of hours when occupants are at home

- Regarding the household composition and number of hours when occupants are at home, a different type of heating and cooling system should be selected depending on, for example, whether it is a single-person household occupied for short periods of time, or a household with people working from home or seniors which is occupied for long periods of time.
- If the house is occupied for short periods of time, as in a single-person household, partial intermittent heating and cooling is sufficient. The use of continuous heating and cooling system will result in wasteful energy consumption when occupants are not home.
- If the house is occupied for long periods of time, as in a household with people working from home or seniors, it is recommended to use either continuous heating and cooling which improves the indoor environment or whole-building heating and cooling which aims for barrier-free design features regarding the thermal environment with little temperature difference throughout the house.

3. Considering how to operate (duration and place) heating and cooling system (Step 2)

1) Duration of heating and cooling

- Duration of heating and cooling is roughly classified by an intermittent and continuous system.
- With the intermittent system, heating and cooling is operated only when occupants are in each room. The system is generally turned off when occupants are asleep.
- With the continuous system, heating and cooling is operated 24 hours a day even when occupants are not at home. The system is turned off, however, when occupants are away when travelling for a long period of time. The system may be turned off only when occupants are asleep or the heating and cooling temperature setting may be changed to a less energy consuming level.
- Even though the intermittent system consumes less energy than the continuous system, a better indoor environment is maintained by the continuous system. For example, with the intermittent system, since the rooms are cold in winter when occupants wake up or come home in the evening, it somewhat takes time for the room to reach an appropriate temperature after the heating is turned on. Generally, as the wall surface temperature is closer to the air temperature with the continuous system than with the intermittent system, even when the air temperature is the same, the continuous system makes you feel more comfortable because of the radiant heat from the walls.

2) Place of heating and cooling

- Regarding the rooms to be heated and cooled, a whole-building system heats and cools the entire house including hallways while a partial system heats and cools only the rooms that are being occupied.
- From the energy consumption perspective, the heating and cooling area is smaller with the partial system and energy consumption is also less. Fig. 1 on the next page shows the heating load when the whole-building continuous system and the partial intermittent system are used with a set temperature of 18°C and 20°C, respectively. This figure indicates that the whole-building continuous operation has a higher heating load (heat required to maintain the rooms' temperature) than the partial intermittent operation by approximately 1.5 to 2.0 times. However, when the insulation level increases, the heating load of both systems tends to become closer. When examining the whole-building continuous operation of heating and cooling system, it is necessary to first consider increasing the insulation and solar shading performance.

- On the other hand, the partial intermittent system causes a temperature difference between the heated or cooled room and the unheated or uncooled room. This system provides inferior comfort particularly in winter when hallways and washing rooms become extremely colder compared to the living room or kitchen.
- In actual houses, it is possible to create an intermediate system between the whole-building system and the partial system by increasing the insulation performance and using ingenuity in creating ventilation paths and room plans to heat and cool the living room and kitchen, which allows the hallways and washing rooms to be moderately heated and cooled as well. Design ingenuity creates a possibility of overcoming the disadvantages of both systems in terms of running costs and comfort.
- The insulation performance of the entire house needs to be increased so that the thermal environment of unheated space including hallways, stairs, washing rooms and toilets is not significantly different from that of heated rooms. Table 10 shows the temperature differences between heated rooms (living and dining rooms) and unheated rooms (washing room, first floor toilet and bedrooms) of a house during the heating period (January and February). The greater the insulation level, the higher the room temperature and the lower the temperature difference of the unheated rooms.

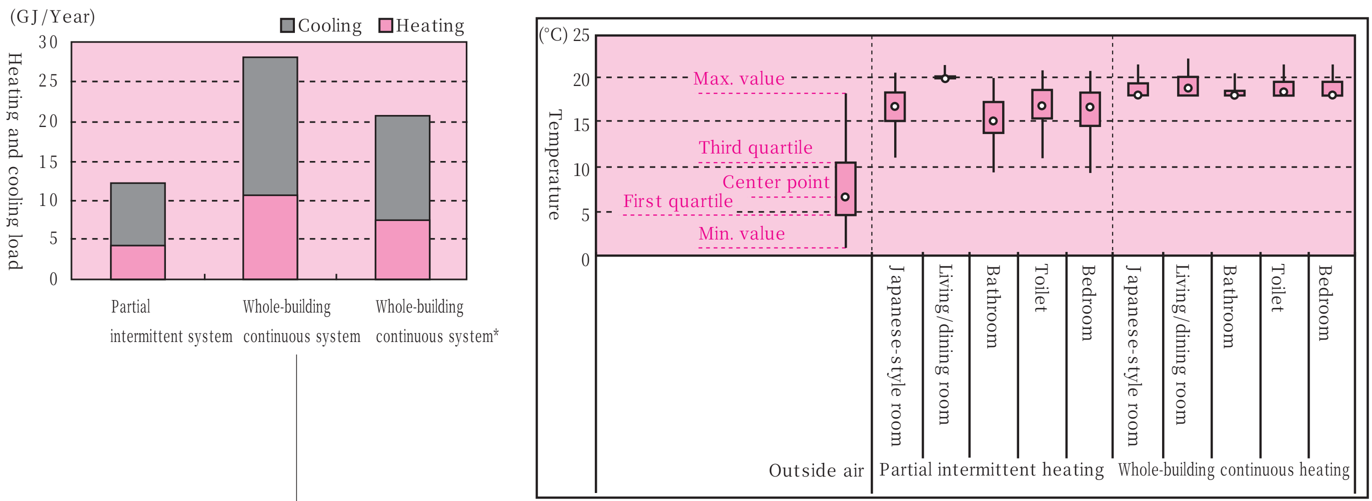


Fig. 1 Energy consumption and indoor temperature differences of partial intermittent operation and whole-building continuous operation

* Shows results when a model with room-by-room temperature control function is used.

Note: The heating and cooling load and room temperature have been calculated with insulation level as equivalent to the 1999 energy conservation standard (Level 3).

- In particular, as the bathroom, washing room and changing room is likely to be poorly insulated, it is necessary to ensure that insulation is properly installed while paying attention to the assembly process of prefabricated bath unit.

Table 10 Temperature differences of heated and unheated rooms by insulation level(Unit:°C)

Insulation level	Heated room	Unheated room			Temperature difference (average)
	Living/dining rooms	Bathroom	First floor toilet	Bedroom	
Level 0	20.0	11.7	12.9	12.1	7.8
Level 1	20.0	13.6	14.8	14.3	5.8
Level 2	20.0	14.9	16.3	15.9	4.3
Level 3	20.1	15.5	16.8	16.3	3.9
Level 4	20.3	15.9	17.5	17.1	3.5

* Insulation level in the above table is from Table 1 of Section 4.1 Insulated Building Envelope Planning for Zone V on p.128.

■ Conditions

- Heating operation type: Partial intermittent heating
- Comparison time/room: Average temperature at 22:00
- Comparison period: January and February

・Operation methods of heating systems can be categorized into four types depending on the combination. Their general advantages and disadvantages are summarized in Table 11 below.

Table 11　Advantages and disadvantages of heating systems by operation method

Classification by place	Classification by duration	
	Continuous system	Intermittent system
Whole-building system	<Whole-building continuous heating> ・Energy consumption is high. ・Wall surface temperature is close to air temperature so good indoor environment can be maintained.	<Whole-building intermittent heating> ・Rooms are cold when occupants wake up or come home in the evening.
Partial system	<Partial continuous heating> ・Wall surface temperature is close to air temperature so good indoor environment can be maintained. ・There are temperature differences between heated and unheated rooms.	<Partial intermittent heating> ・Energy consumption is low. ・Rooms are cold when occupants wake up or come home in the evening. ・There are temperature differences between heated and unheated rooms.

Key Point

Differences in indoor environment between continuous heating and intermittent heating

- The figure below compares the air temperature and wall surface temperature of the living room, dining room and kitchen at 6:00 on a weekday. The temperature is set at 20°C for partial intermittent heating and 18°C for whole-building continuous heating, with partial intermittent heating being 2°C higher .
- Even though the room air temperature is 2°C higher with partial intermittent heating than whole-building continuous heating, the wall surface temperature is lower.
- MRT stands for Mean Radiant Temperature, which is an average surface temperature with the size of wall area considered, and is 1°C higher for whole-building continuous heating than partial intermittent heating. This is because walls and floors cool down during the night and are not warmed enough immediately after the heater is turned on when using the partial intermittent heating system. On the other hand, the whole-building continuous heating system also heats the house during the night and walls and floors are sufficiently warmed.
- The heat transfer of human body is influenced by heat radiation from walls in addition to the surrounding air. Therefore, the room air temperature as well as wall surface temperature affects people's comfort. Operative temperature (OT) is a mean value of air temperature and wall surface temperature, which is one of the indicators of comfort. Although the temperature is set 2°C lower for whole-building continuous heating than partial intermittent heating, both heating systems provide the same level of comfort, as far as assessing in terms of OT.

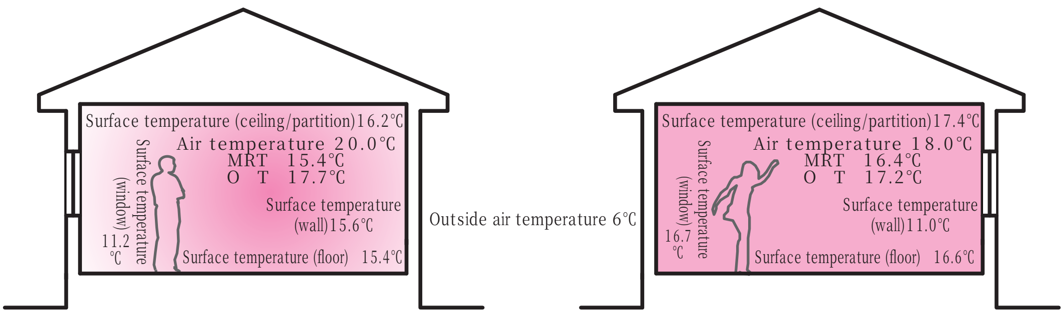


Fig.　Air temperature and wall surface temperature in living room, dining room and kitchen

4. Considering types of heating and cooling system (Step 3)

1) Characteristics of each system

①Heating and cooling air conditioner, gas hot water heating and forced flue (FF) heating (common characteristics of Types 1 to 3)

- A partial intermittent heating and cooling system that uses an individual heating and cooling device to heat and cool the living, dining and bedrooms separately. The advantage of this system is that the heating and cooling device is installed and operated as needed, but consideration should be made so that the temperature difference with hallways, stairs, washing rooms and toilets, and other unheated or uncooled spaces should not be significant.

②Heating and cooling air conditioner (Type 1)

- This efficient device produces heat using heat pump technology. One of the characteristics peculiar to heat pump is that its efficiency varies depending on the load factor, and it is important to select an appropriate device capacity.
- Since it circulates the indoor air for heating and cooling, occupants are likely to feel the airflow, which can cause a chill, particularly during heating. It is necessary to increase the insulation performance and due consideration must be given to the installation position and air outlet direction.

③Gas hot water heating (Type 2)

- This system circulates hot water warmed by gas heat source equipment and heats the room using a radiator, fan convector and floor heating.
- A fan convector is a heating system (convection heating) that warms the room with warm air in the same way as a heat pump air conditioner. Therefore, similar to a heat pump air conditioner, it requires due consideration of the installation position and air outlet position.
- A radiator and floor heating is a heating system (radiant heating) that warms the room mainly using radiant heat. Since radiant heating does not stir the room air, not only occupants do not feel the airflow but also the temperature distribution in the room is small, achieving a high level of comfort.
- A radiator and floor heating is controlled so that the surface temperature does not reach too high in order to prevent the risk of burns. Because of this, if the panel area is small it may result in lack of heat radiation, thus a sufficient panel area needs to be designed.

④FF heating (Type 3)

- This type of device has the highest heating capacity compared to other types used for partial intermittent system, thus the time to reach the set temperature after the operation is started is the shortest.
- Similar to a heat pump air conditioner, it is a convection heating system and tends to have a significant vertical temperature gradient. Additionally, as it causes airflow due consideration must be given to the installation position and air outlet direction.

⑤Duct central heating and cooling (Type 4)

- This whole-building continuous heating and cooling system carries cool or warm air to each room through a duct using a heat pump heat source installed for the entire house or on each floor. Combined with a ventilation system, it heats, cools and ventilates the entire house.
- Unlike the partial heating and cooling, it heats and cools the entire building and maintains an almost uniform thermal environment throughout the house. This enables a high level of comfort without temperature differences between the heated rooms and hallways and other unheated areas, but the energy consumption increases.
- This is a convection heating and cooling system, similar to a heating and cooling air conditioner. Therefore, it requires due consideration for the installation position and air outlet direction.

2) Balance of comfort and cost

- Considering economic efficiency, both initial and running costs are generally lowest when using a partial intermittent system such as a heat pump air conditioner and FF heating system.
- The whole-building continuous system provides greater comfort while the partial intermittent system achieves higher energy efficiency.

• Since incentive programs may be available for energy-efficient heating and cooling systems, architects need to fully understand these programs from the homeowners' perspective.

3) Adopting system that is suitable for characteristics of indoor space

• Since the vertical temperature gradient in the room with a high ceiling or vaulted ceiling tends to become significant, floor heating is appropriate for keeping feet warm. It is also a good idea to stir the indoor air using ceiling fans or other devices in order to decrease the vertical temperature gradient.

• For a house comprised of large space with few partitions (open space layout), a duct central heating and cooling system which warms the entire house is suitable.

Key Point

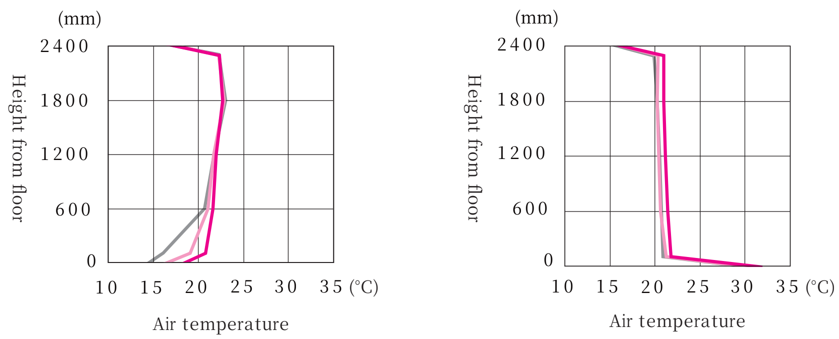
Indoor temperature distribution differences between heat pump air conditioners and floor heating

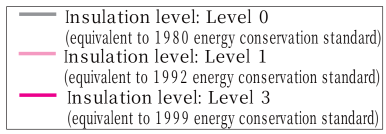
• Heat pump air conditioners and other convection heating systems send warm air, and the warm air rises to the ceiling while the cold air descends from the windows or enters from the unheated space flows around the floor, which tends to cause a significant vertical temperature gradient in the room. On the other hand, as floor heating warms the indoor air in addition to receiving radiant heat from the floor, it maintains low air temperature to create a comfortable indoor environment with a low vertical temperature gradient.

• Fig. a shows vertical temperature distributions when the heating systems are used. Since occupants often sit on the floor or chair, the temperature at 0 to 1,200 mm from the floor is important. When a heat pump air conditioner is used, particularly if the insulation performance of the house is low, the temperature decreases as it nears the floor. To solve this problem, some special considerations are required such as increasing the insulation performance, preventing drafts by extending curtains to the floor and lowering air outlet direction. Meanwhile, floor heating hardly produces a vertical temperature distribution and creates a warm space including the floor surface.

• Fig. b shows horizontal temperature distributions when the heating systems are used. You can see the temperature is higher near the air outlet of air conditioner. It may be necessary to adjust the wind direction of air outlet so that the heated air does not directly hit the occupants.

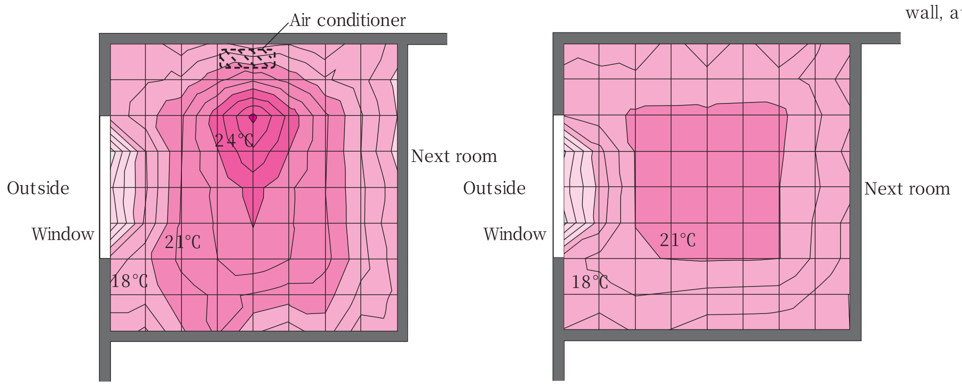
Glossary: Draft
Discomfort caused by the cold local airflow in the room. It is also referred to as "cold draft".





■Conditions
• Test room: 8 tatami mat (3.64 x 3.64 m), two sets of continuous walls adjoining the outside and next room
• Outside: Outside air temperature 2±1.5°C
• Next room: room temperature 11.5°C, crawl space: 7°C, ceiling crawl space: 11.5°C
• Air conditioner: rated heating capacity 3.2 kW, 30°, set temperature 22°C
• Floor heating: rate of floor heating area 83% (floor heating area 11 m²), set temperature 22°C (remote controller position: near indoor wall, at 1,200 mm high)

Fig. a Vertical temperature distributions during heating (room center) (Left: heat pump air conditioner; right: floor heating)



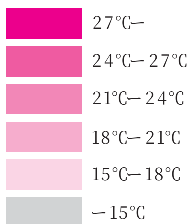


Fig. b Horizontal temperature distributions during heating (height: 1,200 mm) (Left: heat pump AC, right: floor heating)

5.2.4 Energy Saving Methods in Heating and Cooling System Planning

Type 1 Heating and cooling air conditioners

- Generally, a heating and cooling air conditioner is installed individually in every room in the house including the living, dining and bedrooms and is operated as needed, as a partial intermittent heating and cooling system.

1. Energy saving methods (Type 1)

Method 1: Adopting high-efficiency air conditioners

- Energy conservation target levels for heating and cooling air conditioners can be achieved by adopting a heating and cooling device with high energy consumption efficiency (COP).
- COP is an indicator of operation efficiency of air conditioners. COP is a value indicating the heating and cooling capacity divided by power consumption and is known to fluctuate depending on various operating conditions.

Key Point

Air conditioner efficiency

- Fig. a shows the relationship between the outside air temperature, load factor (ratio of heating and cooling capacity to rated capacity), and COP. For example, the higher the outside air temperature, the greater the COP during heating. Moreover, COP becomes the highest at the capacity, near approximately half of the maximum load factor (maximum capacity). The greater the heating and cooling load belonging to this range, the higher the annual operation efficiency.
- The air conditioner capacity increases the lower the outside air temperature when cooling, and the higher the air temperature when heating. For example, when the outside air temperature of 7°C is set as the standard temperature for heating, the capacity increases approximately 10% at 12°C whereas it decreases approximately 10% at 2°C.

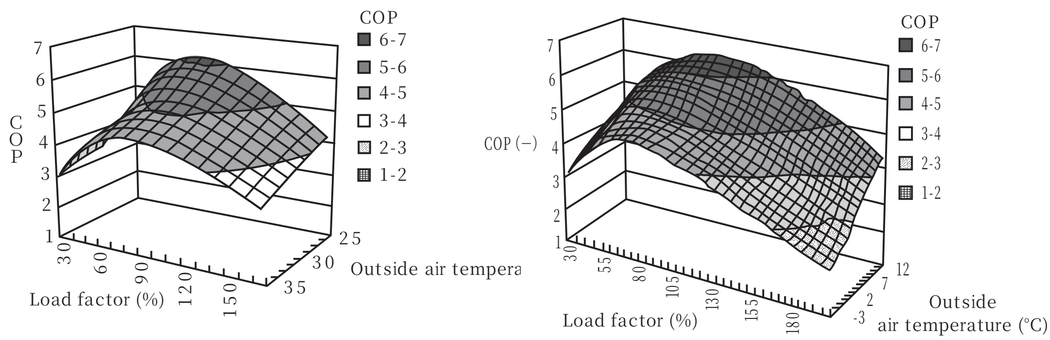


Fig. a Relationship between outside air temperature, load factor and COP (left: cooling, right: heating)

- As the indoor relative humidity changes during cooling, so is the air conditioner capacity and COP. Fig. b shows the result of comparing the indoor humidity (dry bulb: 27°C, wet bulb: 19°C, relative humidity: approximately 47%), which is specified as the COP measuring condition by the Japanese Industrial Standards (JIS), with COP under high humidity conditions. For example, when the relative humidity is 55 – 60%, the device capacity and COP increase 10 – 15%.

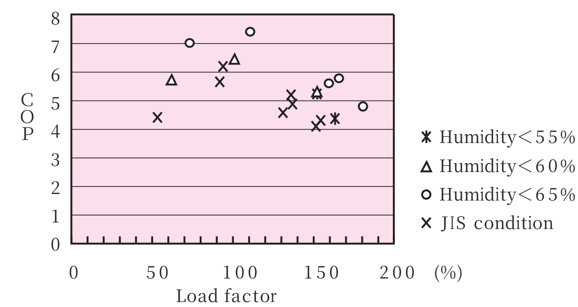


Fig. b
Influence of indoor relative humidity on COP

Method 2: Setting appropriate device capacity

- Generally, the operation load of air conditioners is high immediately after heating or cooling has started although it is low other times and COP declines as shown in the figure of Key Point on p.230. The indoor heating load becomes extremely low particularly when an air conditioner is operated for extended periods of time, and the air conditioner may go into intermittent operation. Since COP further decreases during intermittent operation, it is not desirable to continuously operate an air conditioner under a low load and intermittent state from an energy saving perspective.
- If the air conditioner you selected has an excessive capacity compared to the heating and cooling load of the room, the time for reaching a certain room temperature is shortened and the level of comfort increases. However this also increases the ratio of inefficient, low load operation.
- Since the maximum air conditioner capacity is higher than the rated capacity indicated as a typical device capacity in the catalogue, it is necessary to select a model with appropriate maximum capacity compared to the maximum heating load of the room. The appropriate maximum capacity varies depending on the room temperature rise time as mentioned above, i.e. the time that has been set to reach a comfortable room temperature after the air conditioner starts operation. Fig. 2 shows the result of investigating the effect of the ratio of operating an air conditioner at or below the intermediate capacity (half of the rated capacity), i.e. low load operation, on COP for both heating and cooling periods. Even when using the same model, seasonal COP increases as the ratio of low load operation decreases.

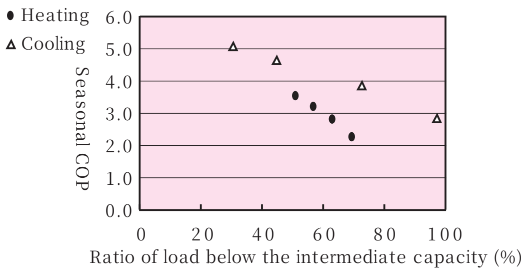


Fig. 2
Effect of rate of low load operation on COP

- It is important to set an appropriate capacity when installing an air conditioner. When the air conditioner is also used for heating, heating load is generally higher than cooling load, thus selection of a heating capacity suitable for the heating load is required. If the air conditioner capacity is insufficient, you will encounter such problems as the room never being heated or not being quickly heated. On the other hand, if the capacity is excessive, the room can be sufficiently heated or cooled but the air conditioner is operated intermittently during the season with low heating and cooling load, which is inefficient and results in increased energy consumption. Larger air conditioner capacity does not mean better; rather it is important to select an air conditioner that has the appropriate capacity by taking into account the size and usage of the room.
- Select a heating and cooling device that provides the appropriate output and as high COP as possible according to the target level. Table 12 shows, for reference purposes, the heating and cooling capacity of devices deemed appropriate for the room size based on the target level for insulated building envelope planning (see Section 4.1.2 on p.128).
- What is important here is to select a 'device that provides the appropriate output according to the load of the room', not a 'device that provides the output exceeding the load of the room'. Regardless of whether it is a heating and cooling device, the use of any device which produces more than the required output will reduce the energy consumption efficiency.

Table 12 Capacity as guideline for selecting heater (required maximum heating capacity) (Unit: kW)

Insulation level			6 tatami mats ($10\ m^2$)	8 tatami mats ($13\ m^2$)	10 tatami mats ($16\ m^2$)	14 tatami mats ($22\ m^2$)
Level 0	1980 energy conservation standard		2.7	3.6	4.5	6.3
Level 1	1992 energy conservation standard	(Medium airtight)	2.2	2.9	3.6	5.0
		(Airtight)	2.3	3.0	3.7	5.2
Level 2	Intermediate of 1992 and 1999 energy conservation standards	Reinforced ceiling and opening insulation	1.8	2.4	3.0	4.2
		Mud-plastered wall	1.8	2.4	2.9	4.1
Level 3	1999 energy conservation standard	Evenly distributed insulation	1.8	2.4	3.0	4.2
		Reinforced ceiling and opening insulation	1.8	2.3	2.9	4.1
		Reinforced opening insulation	1.7	2.2	2.7	3.8
		Mud-plastered wall	1.8	2.3	2.9	4.0

Note: The shaded figures indicate that a model with a device capacity (rated cooling capacity) of 2.2 kW meets the maximum heating capacity indicated in the table.
Please select a model with a device capacity (rated cooling capacity) of 2.8 kW for other figures.

Key Point

The importance of selecting air conditioners appropriate for load

- Fig. a Comparison of efficiency between conventional and energy-efficient air conditioners shows the relationship between the outside air temperature and the energy efficiency of a conventional air conditioner (rated COP≈2.7) and an energy-efficient air conditioner (rated COP≈5.8) measured using actual units placed in a living room. This figure confirms the energy saving effect of an energy-efficient device.
- Fig. b Comparison of efficiency between living room and children's room shows the efficiency of devices with identical COP when one is placed in a living room while the other in a children's room. Although the COPs of both devices are almost identical, it is apparent that the efficiency of the air conditioner placed in the children's room is lower. It can be presumed that this is caused by the children's room being small, thereby requiring small heating load.
- Fig. c Frequency distribution of load factor shows the amount of output when in operation compared to the device's maximum output. It is shown that, during summer months, the air conditioner in the living room operated at approximately 40% of the maximum output while the one in the children's room was operating merely at 10%. In other words, when the capacity of the device far exceeds the load of the room, it can lead to inefficient operation that does not take full advantage of the fact the device itself is efficient. The adequate capacity of the device to be selected therefore needs to be determined with the help of Table 12 (p.231) and other tools.

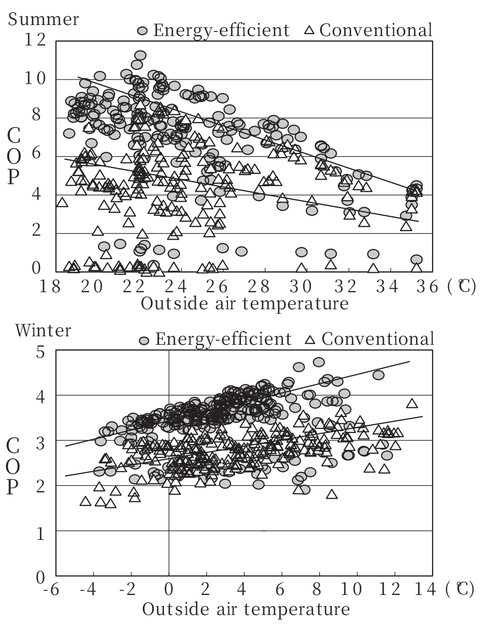


Fig. a Comparison of efficiency between conventional and energy-efficient air conditioners

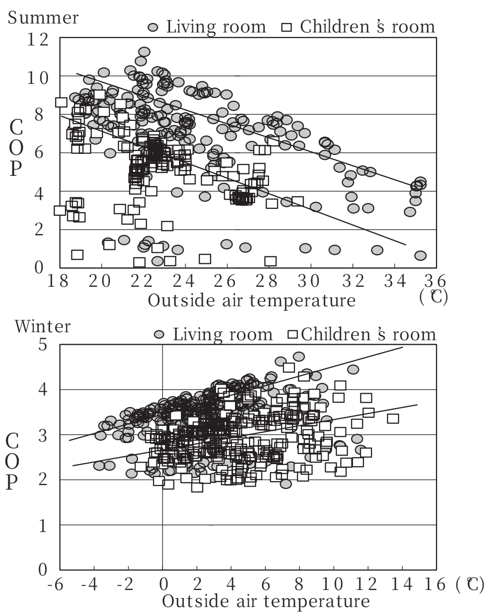


Fig. b Comparison of efficiency between living room and children's room

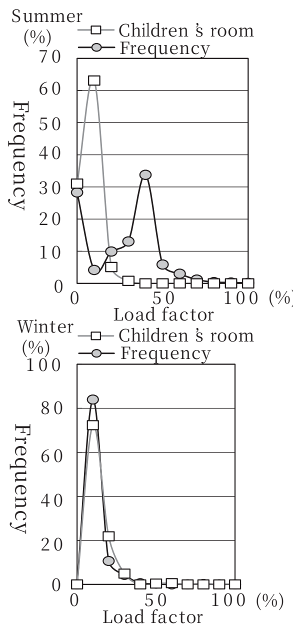


Fig. c Frequency distribution of load factor

Comment ● Air conditioner's dehumidification function

We are recently seeing many air conditioners with a dehumidification function that employs a method called reheat dehumidification. The traditional dehumidification method had a shortcoming whereby it excessively decreased the room temperature. The reheat dehumidification method, on the other hand, dehumidifies the air by cooling it then reheats it before releasing it back into the room, which alleviates the discomfort of the dehumidification process. However, it should be noted that the reheat dehumidification operation requires more energy than the conventional dehumidification operation as well as a regular cooling operation.

Method 3: Using electric and ceiling fans (cooling only)

- Using electric and ceiling fans allows us to set a higher cooling temperature for the air conditioner. Fans also contribute to minimizing the hours required for cooling. It can be expected that setting a higher cooling temperature will result in less consumption of cooling energy.

1) Using electric fans

- Electric fans can be useful in limiting the use of cooling as they lower thermal sensation due to a breeze. Occupants can turn on a fan temporarily at a higher setting (high or medium) after returning from work or taking a bath.
- It is still difficult to quantitatively evaluate the cooling sensation created by the airflow of an electric fan. However, even though cooling systems have become commonplace, the energy saving effect of frequently used electric fans cannot be overlooked. The amount of heat removed from the body surface by the airflow varies depending on factors such as the speed of the airflow, the cycle (oscillation cycle, etc.) and the evaporation of sweat.
- Table 13 shows the measured results of the power consumption and the wind speed using two models of electric fans. Model 2 is shown to consume less power yet provides a higher wind speed, which means it is more efficient.

Table 13　Measured results of power consumption and wind speed of electric fans

		Model 1			Model 2		
Rated power consumption (W; 50/60 Hz)		52/53			40/43		
Wind speed setting		Low	Medium	High	Low	Medium	High
Power consumption (W; 50 Hz)	W/ oscillation	40	46	56	24	31	50
	W/O oscillation	37	44	54	23	31	49
Wind speed W/O oscillation (Average value at the top speed; m/s)	At 2 m	1	1.1	1.2	1.2	1.4	2
	At 3 m	0.6	0.7	0.8	1	1.2	1.4
Full oscillation cycle (s)		21.8	18.9	16.4	25.7	20.0	15.3

- From our estimates, it was shown that 1°C in reduction of thermal sensation can be expected when the electric fan is placed at a distance of 2 to 3 m (when used for a long period of time at a low wind speed setting with oscillation). As we can expect to lower the thermal sensation by 1°C and can set the cooling temperature of the air conditioner 1°C higher, using an electric fan along with an air conditioner can be said to have a cooling energy saving effect. On the other hand, if the cooling temperature of the air conditioner remains unchanged when used in conjunction with an electric fan, the energy consumption simply increases for the amount used by the electric fan.

2) Using ceiling fans

- Ceiling fans (Fig. 3) can send airflow to a wider area than electric fans and can have a more general effect in reducing thermal sensation. If the ceiling offers a good height such as a vaulted ceiling where warm air tends to pool, a ceiling fan can limit the increase of the temperature on the ceiling surface by circulating the air as well as reduce the thermal sensation within the area. (However, if the cause of the warm air pooling at the ceiling is weak insulation or solar shading in the roof or attic, using a ceiling fan may increase the cooling energy consumption.)
- Ceiling fans consume approximately the same amount of energy as electric fans but cover a wider area with airflow, which means that they can have a more general effect in the room to reduce the thermal sensation. (When an experiment was conducted with a ceiling fan with a ceiling height of 4.9 m, the wind speed obtained was 0.3 m/s at medium setting and 0.1 to 0.2 m/s at low setting within the area. The wind created at medium setting appears to be sufficient to be felt by occupants.)
- Although ceiling fans can be difficult to install unless the ceiling height is relatively high, more and more products now combine the fan and the lighting to facilitate installation. In terms of safety and other factors, a ceiling height of 2.5 m seems to be the minimum requirement. (The distance between the ceiling surface and the lowest point of the fan can be as small as 20 cm or so depending on the product.)
- We are increasingly seeing fans with simple, modern designs in addition to the conventional classic design, which gives consumers a wide range of selection design-wise.

Fig. 3　Example of ceiling fan

2. Considerations for energy efficiency planning and design (Type 1)

- It is important to install an air conditioner with good energy consumption efficiency (COP) for cooling the house in summer. It is also vital to reduce the cooling load by utilizing wind as well as ceiling fans (See Section 3.1 Use and control of wind).
- When building a house, it is desirable to install sleeves which accommodate air conditioner piping during the construction stage as much as possible. Since carelessly drilling a hole in the wall after the house is completed can impair the insulation performance or air tightness, it should be discussed with the homebuilder prior to the construction. Fig. 4 is an example of insulation being drilled with a hole saw after the house was built.
- If the space around the outdoor unit is insufficient, the heat exchanged air stagnates, causing a reduced heating and cooling capacity and decreased COP. Therefore, it is desirable to install an outdoor unit in as large an area as possible. However, if this results in increased distance from the indoor unit, again the COP deteriorates.

Fig.4
Example of insulation being drilled with hole saw

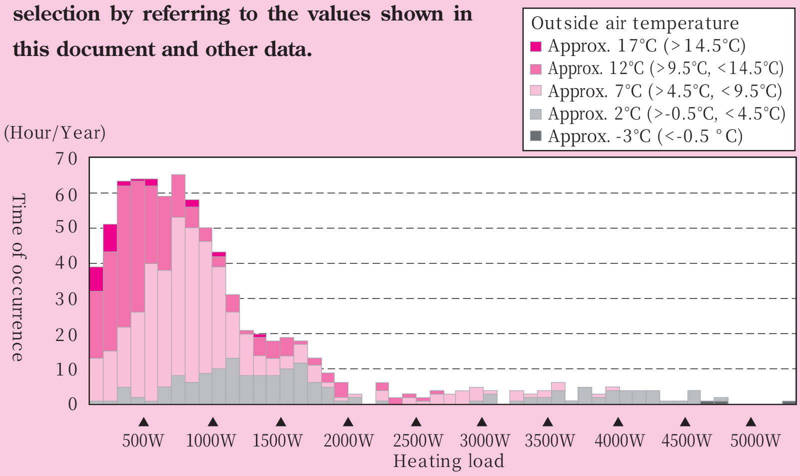
3. Considerations for operation systems (Type 1)

- When heating the living room at the time the occupants wake up in winter, it takes time for the room to reach the set temperature, regardless of type of heater. Because of this, an electric carpet, electric heater or kotatsu (a small quilt-covered table with an electric heater affixed underneath) is also used as soon as the heat pump air conditioner is turned on. Nevertheless, the heat pump technology of air conditioner efficiently generates heat, providing a few times higher heat generation efficiency than an electric carpet, electric heater or kotatsu. Even if the air conditioner is turned on with a timer to heat the room 30 minutes to an hour before the occupant uses the room, energy consumption increase is not very significant.
- The COP of the device tends to increase as the set temperature increases for cooling and decreases for heating. Since setting the room temperature higher during cooling and lower during heating not only decreases the heating and cooling load but also increases COP, energy saving effects can be expected. However, if the device installed has an excessive capacity, the ratio of low load operation increases and COP may deteriorate.
- There is often a difference between the set temperature of the remote control and the actual temperature of the living area. This is mainly because the air conditioner is often controlled based on the temperature around the air inlet of the indoor unit and there is a temperature difference between the living area and the air inlet temperature due to the indoor vertical temperature gradient, in addition to the control characteristics of the device. Regarding a comfortable indoor condition and how to set the remote control for it, occupants need to ingeniously operate the air conditioner for example, placing a desktop thermometer in the room for checking the appropriate temperature.
- Air conditioners can cause a chill particularly when the airflow directly hits the body during heating. Careful consideration is required regarding the installation position and air outlet direction of the indoor unit.

Comment ● APF indication

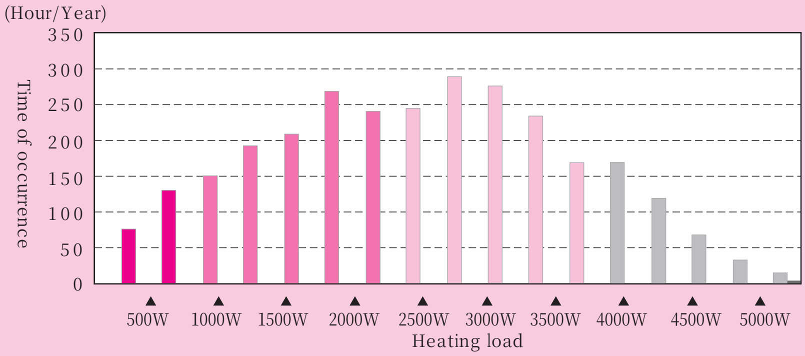
Annual performance factor (APF) will replace COP as an index that indicates the efficiency of air conditioners. While COP represents the air conditioner efficiency under a certain load (rated condition), APF indicates an annual energy efficiency of heating and cooling a building in Tokyo with an air conditioner. Therefore, this index also considers the efficiency for factors other than rated conditions—for example, changes in the efficiency due to the influences of outside air temperature and level of heating and cooling load—and is intended to indicate efficiency that is closer to the reality.

However, the heating load distribution is influenced by factors such as the weather, insulation performance, operation method and operation type, and varies from house to house. Because of this, the actual annual energy efficiency of using an air conditioner and the APF value are not the same. The figure on the right compares the value estimated by APF and the calculated value of an actual house regarding the heating and cooling load distribution in relation to the outside air temperature. Of course, the load distribution of the calculated value also changes according to the building insulation performance. Therefore, APF should also be treated as a guideline for indicating the device performance, just like COP. You can use COP and APF alone especially for relatively comparing the performance of air conditioners. However, to compare the energy saving effects of different heating systems, how much energy is actually consumed is the key and it is necessary to make any selection by referring to the values shown in this document and other data.



(a) Heating load distribution in living/dining room/kitchen used in this document

* Calculation is based on the insulation level of 1999 energy conservation standard (Level 3).



(b) Heating load estimated for APF

* Calculation is based on rated cooling capacity of 5 kW.

Fig. Heating and cooling load distribution in relation to outside air temperature

Type 2 Gas and oil hot water heating

- Generally, in the case of hot water heating, a radiator is installed individually in every room in the house including the living, dining and bedrooms and is operated as needed, as a partial intermittent heating system.
- Floor heating is a heating method that retains a high level of indoor comfort as it effectively reduces discomfort caused by cold draft (see Glossary on p.229) from the windows and easily maintains a uniform indoor thermal environment. A panel radiator also has the similar effect, but the location of panels needs to be deliberately examined, such as below the waist-level window.
- Compared to forced flue (FF) heating, hot water heating tends to have higher initial and running costs. Nevertheless, this heating method maintains a high level of indoor comfort if a radiator or floor heating is used.
- To reduce energy consumption, attention must be paid to the appropriate piping insulation, appropriate floor insulation (only if floor heating is used), and use of high-efficiency heat source equipment. Lowering the supply water temperature generally decreases the radiation heat loss from the heat source equipment and pipes. It is advisable to consider using the heat source equipment with selectable temperature setting and securing the radiator area that sufficiently heats even at low temperatures.

1. Energy saving methods

Method 1: Adopting high-efficiency heat source equipment

- The efficiency of heat source equipment is expressed with energy consumption efficiency, which is obtained by dividing the heating output of the heat source equipment with fuel consumption (heat quantity). The higher this value, the lower the fuel consumption the equipment requires to produce hot water of the same temperature and quantity. Please select the heat source equipment with as high energy consumption efficiency as possible.
- In addition to an ordinary gas water heater, a latent heat recovery gas water heater is also a heat source of hot water heating. An oil water heater and heat pump heat source can also be used in addition to a gas water heater, and high-efficiency heat source equipment is anticipated to increase the energy saving effect of floor heating.

Key Point

Efficiency of heat source equipment

- The figure below shows an output efficiency of heat source equipment. It is clear that the smaller the output the lower the efficiency. The heat source equipment efficiency declines significantly in the output range of approximately below 2,000 W that occurs when a heat source equipment burner is turned on or off. Generally, heat source equipment with a large capacity has a high lower limit of continuous combustion output of a burner and is often turned on and off. The use of heat source equipment with an excessively large capacity should be avoided.
- (A) in the figure represents the efficiency of gas heat source equipment when the prompt heating mode is used. This operation mode quickly heats the room immediately after the floor heating is started by supplying hot water at a higher temperature (e.g. 75°C) than normal. Although this operation mode instantly heats the room and provides comfort, the efficiency deteriorates as shown in the figure. If the room is already warm, it is recommended to turn off this mode with a remote control. For example, when operating floor heating after getting up in the morning, if the insulation performance of the house is high, it reduces the coldness of the room (temperature increases) thus the duration for using this operation mode can be shortened.
- (B) in the figure represents the heat source equipment efficiency when the supply water temperature is set low. The lower the hot water temperature, the better the heat source equipment efficiency. Especially when using latent heat recovery heat source equipment, more latent heat is recovered if the hot water temperature is low and it is important to choose a device that can control low temperature water. However, if the supply water temperature is low, the heat radiation from floor heating decreases. It is advisable to reduce the heating load by increasing the insulation performance of the house when using this type of heat source equipment.

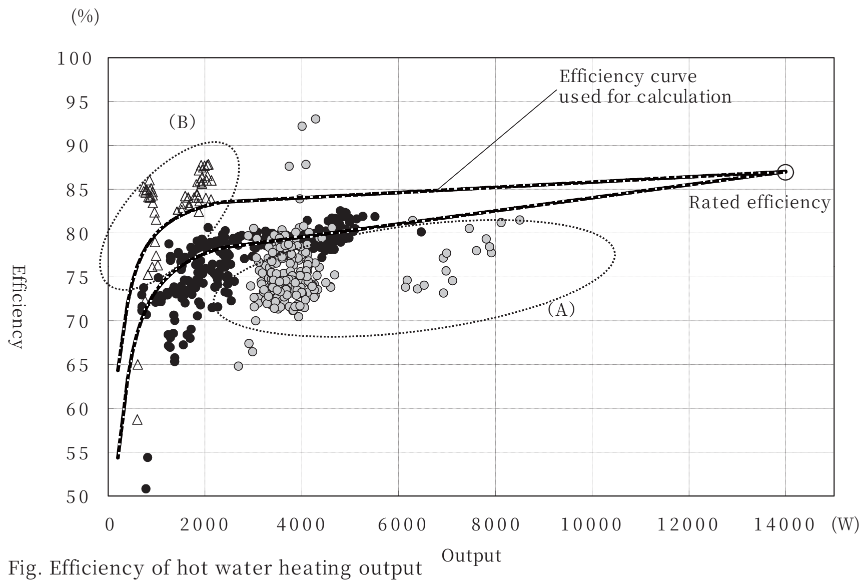


Fig. Efficiency of hot water heating output

Method 2: Lowering supply water temperature of heat source equipment

- If the supply water temperature is lowered, heat loss from piping and other elements decreases while the efficiency of heat source equipment generally increases. On the other hand, when comparing radiators in the same room size, the lowered hot water temperature decreases the heating capacity, which may lead to an insufficient heating capacity during severe winter months. In order to lower the hot water temperature for energy conservation, it is necessary to fully insulate the building to reduce the heating load as well as increasing the area of heat radiation panels (including floor heating panels).

Method 3: Underfloor and piping insulation and shortening piping length

- It is important to use thick insulation underneath the floor and properly install hot water piping insulation in order to prevent heat loss in the crawl space and other unheated spaces.
- A considerable amount of heat is estimated to be lost from the circulation pipes between the heat source equipment and the floor panels. Therefore, it is necessary to sufficiently perform thermal insulation of piping and shorten piping length. For thermal insulation, bare tubes covered with 10-mm thick expanded polyethylene should be used for piping or insulation should be installed around the piping so that it ensures the same level of insulation performance (linear thermal transmittance of not more than 0.15W/m·K).
- Underneath the floor heating also requires a sufficient level of insulation. Insulation materials with a thermal resistance of at least 1.6 m2K/W (60-mm thick 32K glass wool board or 75-mm thick 16K glass wool board) should be used.

Method 4: Adopting floor heating and increasing rate of floor heating area

- Any floor heating system that is designed to heat the entire room (e.g. one providing at least 70% of floor heating area against the total heating area) can lower the room temperature while maintaining the same level of comfort as other heating systems. However, this does not apply to any floor heating system with a small heating area, such as that intended for heating occupants' feet in the kitchen.

Key Point

Designing appropriate panel radiating area

- The amount of heat radiation from convectors, radiators and floor heating is determined by the radiating area and temperature of supplied hot water. It is important to design the radiating area so that a sufficient heating capacity is ensured during the coldest days of the year when the heating load is high. Since the temperature of supplied hot water is limited, it is necessary to secure a sufficient radiating area. When calculating a radiating area, the supply water temperature is set at a certain level, 60°C for example. If the installation space is permitted, it is recommended to use a large radiator. This is because a large radiator radiates more heat at the same supply water temperature than a small radiator and can easily maintain room temperature even during the coldest days of the year when the heating load is high. Moreover, when comparing these radiators in terms of the same amount of radiation, a large radiator can reduce the supply water temperature or shorten the time in which water is supplied, and thus decreased heat loss from piping and increased efficiency of heat source equipment are expected. However, this will decrease heat radiation from floor heating. It is advisable to reduce the heating load by increasing the insulation performance of the house when using a large radiator.

5

Chapter 5 Energy-efficient Equipment Technology (Elemental Technology Application Method 3)

Key Point

Heat loss by heat source equipment and underfloor and piping insulation

- We will present four examples of energy consumption of hot water floor heating by means of different heat source equipment, with or without piping insulation, and with different thicknesses of insulation under the floor heating panels.
- Fig. a is a case in which energy saving methods were not applied.
- Fig. b shows a case of increased heating area and shortened piping length in addition to Method 3 which adopts both piping insulation and underfloor insulation. Compared with Fig. a, energy consumption decreases by approximately 9%.
- Fig. c is the same as Fig. b except for adopting high-efficiency heat source equipment (Method 1).
- Fig. d is the same as Fig. c except selecting a latent heat recovery device that can reduce the supply water temperature (40°C) and adopting Method 2. Lowering the supplied hot water temperature increases the heat source equipment efficiency and further decreases energy consumption by approximately 11%.

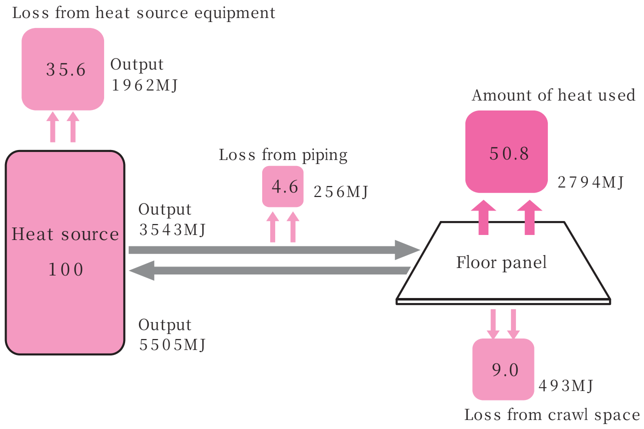


Fig. a Conventional heat source equipment + poor underfloor insulation, without piping insulation (Case 1)

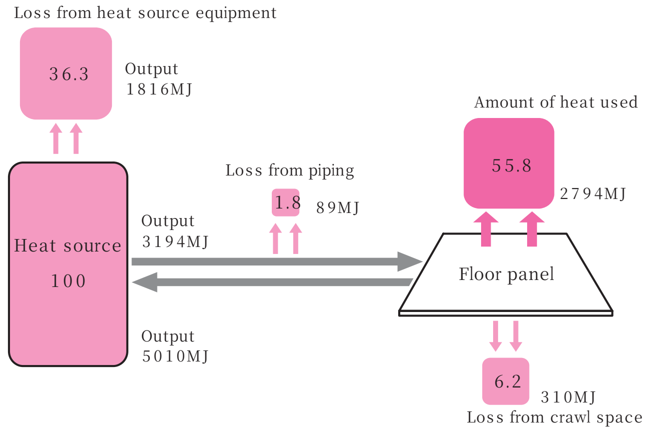


Fig. b Conventional heat source equipment + high underfloor insulation, with piping insulation (Case 2)

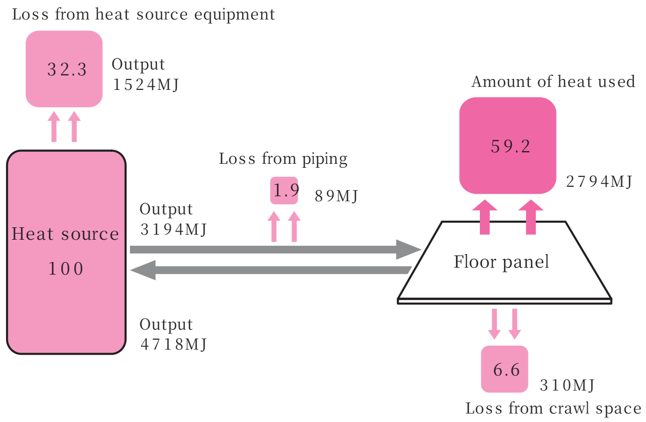


Fig. c High-efficiency heat source equipment + high underfloor insulation, with piping insulation (Case 3)

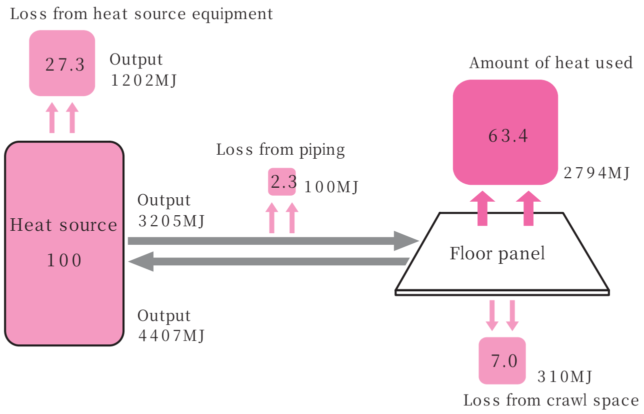


Fig. d High-efficiency heat source equipment (low supply water temperature) + high underfloor insulation, with

■Calculation conditions
- Floor heating location: first floor living/dining room (floor area: 21.5 m²) and kitchen (floor area: 8.3 m²) of detached house
- Rate of floor heating area: (1) standard 70% (floor heating area: 20.9 m²), (2) high 75% (floor heating area: 22.4 m²)
- Piping length: (1) standard 29.6 m, (2) short 15.5 m
- Heat source equipment (rated efficiency): (1) conventional 78.0%, (2) high-efficiency 83.0%, (3) latent heat recovery 86.0%
- Underfloor insulation: (1) low level (thermal resistance: 1.0 m²K/W, 50-mm thick 16 K glass wool), (2) high level (thermal resistance: 1.6 m²K/W, 60-mm thick 32 K glass wool)

* (1) uses standard rate of floor heating area and (2) uses high rate of floor heating area.
- Piping insulation: (1) without piping insulation (heat loss coefficient: 0.21 W/mK), (2) with piping insulation (heat loss coefficient: 0.15 W/mK)

* (1) uses standard piping length and (2) uses half piping length.
- Supply water temperature: 60°C (standard), 40°C (in case of low supply water temperature)

3. Considerations for energy efficiency planning and design (Type 2)

- As mentioned in Method 2, increasing the temperature of supplied hot water will increase the heat source equipment efficiency. This also decreases the heat loss from piping. Therefore, decreasing the temperature of hot water to be supplied as much as possible is effective for saving energy. However, lowering the hot water temperature decreases the amount of heat radiation, which is likely to result in a lack of heating capacity. It is necessary to increase the insulation level to reduce the heating load and secure a large panel radiating area so that the supply water temperature can be reduced.
- It is effective to shorten the piping length on top of insulating the piping in order to reduce the heat loss from the hot water piping. Another good idea is to install heat source equipment near the room that is most frequently heated (e.g. living room).
- If the same heat source is shared between the domestic hot water system and the heating system, it is important to pay attention to the piping plan and install a device that minimizes the piping length. On the other hand, if another heat source equipment is used for the heating system, installing it on the balcony in front of the living room, in which the heating system is used most frequently, can shorten the piping length.

3. Considerations for operation systems (Type 2)

- As it takes time to heat the floor when using a floor heating system, it is effective to set the timer so that the system starts running 30 minutes before the occupants use the room, such as when they wake up in the morning or come home in the evening. Meanwhile once the floor is heated it stays warm even if the system is stopped, it is effective to stop the system earlier before going to bed or going out.

Comment ● Heat pump hot water floor heating and electric floor heating

Recently, it is becoming popular to use the same heat pump technology used for air conditioners in the heat source equipment for hot water heating. Similar to air conditioners, this heat source equipment is energy efficient because it generates three to four times more heat than the consumed power.

On the other hand, heat source equipment that uses an electric heater is also becoming prevalent. This heat source directly converts the power consumed by an electric heater into heat energy and can only generate the same amount of heat as the consumed power. In the case of electric floor heating, it is possible to reduce the running cost using late-night power, but this is not energy efficient when evaluating the primary energy consumption from an energy saving perspective. If an electric floor heating system is installed, it is recommended to replace the heat source equipment with gas or other type of energy when renewing the heat source equipment, or switch to heat pump heat source equipment that is more efficient than an electric heater.

Type 3　Forced flue (FF) heating

- Generally, FF heating is installed individually in every room in the house including the living, dining and bedrooms and is operated as needed, as a partial intermittent heating system.

1.　Energy saving methods (Type 3)

- Although this document does not suggest any specific energy saving method for this heating system (See p.222), when choosing FF heating, select the device that has as high a combustion efficiency as possible.
- In addition, as FF heating heats the furnace first when it is ignited, selecting a device that consumes less power during ignition is also critical.

2.　Considerations for energy efficiency planning and design (Type 3)

- If the device selected has an excessive capacity compared to the heating load, it goes on and off repeatedly. Generally, the combustion efficiency is low during ignition or consumes a lot of power as it heats the combustion area. Because of this, it is important to prevent the device from going on and off repeatedly (i.e. intermittent operation) as much as possible. It is also vital to select a device with appropriate capacity according to the heating load (see Table 12 on p.231) by taking into account the location and insulation performance of the house.
- It is effective to install the device near the windows in order to achieve a uniform temperature distribution in the room and prevent cold drafts particularly from windows. Since this requires a flue duct to be installed, the device should be placed near the outside-facing wall.
- Please avoid placing the flue duct of the heater where the air becomes stagnant as it might cause the duct to reabsorb the combustion gas, which results in imperfect combustion.

3.　Considerations for operation systems (Type 3)

- Lowering the set temperature of FF heating will provide energy saving effects in the same way as other heaters.
- Similar to heat pump air conditioners and hot water heating, this is a convection heating system which circulates the indoor air. Occupants are likely to feel the airflow, which can cause a chill, particularly during heating.

Type 4　Duct central heating and cooling

- Central heating and cooling is a whole-building continuous heating and cooling system which carries cool or warm air to each room through a duct using a heat pump heat source installed for the entire house or on each floor. Combined with a ventilation system, it heats, cools and ventilates the entire house (Fig. 5).
- As this system achieves a uniform thermal environment throughout the house and barrier-free design features regarding the thermal environment, it dramatically enhances the comfort but energy consumption tends to increase compared to the partial intermittent heating and cooling system.
- When using the central heating and cooling system, it is desirable to apply at least Level 3 for insulated building envelope planning (see Section 4.1.2 on p.128) and at least Level 2 for solar shading methods (see Section 4.3.2 on p.190). The greater the insulation level, the higher the energy saving effects.

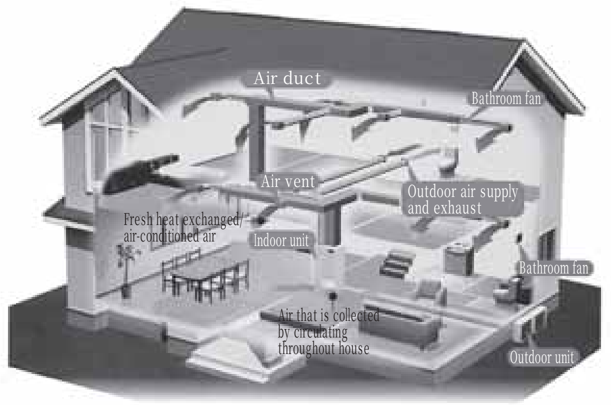


Fig. 5　Example of central heating and cooling

1.　Energy saving methods (Type 4)

Method 1:　Adopting high-efficiency equipment

- Since this system uses a heat pump in the same way as a heating and cooling air conditioner, the first thing of importance is to adopt a heating and cooling device which has high energy consumption efficiency (COP) in order to increase energy efficiency. A rated cooling efficiency of at least 4.0 is required.

Method 2:　Adopting model with room-by-room temperature control function

- When the device has a room-by-room temperature control function, you can reduce the heating and cooling load by setting the heating and cooling temperatures of a guest room or other rooms which are not usually used closer to the outside air temperature than other habitable rooms (used for extended periods of time).

2.　Considerations for energy efficiency planning and design (Type 4)

- An intermittent heating and cooling system receives a high load immediately after it is turned on, while this does not occur to a continuous heating and cooling system. That is why you can use a continuous system that has a relatively smaller capacity in terms of the total processing ability than that of an intermittent heating and cooling device.
- Although a duct should always be insulated in order to supply the required heat, the insulation should be more thoroughly installed, particularly when the duct is placed outside the insulated areas. The duct should be insulated at least at the same level as the insulated areas.

- Since the air is constantly sent from the fan, it is important to reduce as much pressure loss as possible by keeping the duct as short as possible with little curves (See Section 5.3.4 Energy Saving Methods in Ventilation System Planning on p.249).
- In order to retain the heat generated by the outdoor unit as much as possible, it is vital to thoroughly insulate refrigerant pipes as well as keeping these pipes as short as possible. It is desirable to use a plan that allows the outdoor unit to be installed as close as possible to the main unit.
- When the outdoor unit receives solar radiation, it works advantageously for heating while disadvantageously for cooling. Therefore, when installing the outdoor unit in a place that is prone to solar radiation, the use of overhangs to protect from solar radiation in summer and receive solar radiation in winter will increase the equipment efficiency.
- If the filter for outdoor air or circulating air is clogged, the equipment performance significantly declines. It is necessary to install the main unit in a place where the filter can be easily cleaned (e.g. on the floor).
- Since the central heating and cooling system sends the air into each room, it also serves as a duct ventilation system. However, it may result in excess or deficiency compared to the required amount of ventilation. If there is deficiency, the use of local ventilation system or other measures is required.
- The whole-building continuous heating and cooling system inevitably requires higher energy consumption than the partial intermittent heating and cooling system. It is necessary to highly insulate the envelope and reduce air leakage (target air tightness of envelope: specific leakage area of house C = 3 cm2/m2) in order to reduce as much energy consumption as possible.
- In order to reduce the cooling load, it is important to give consideration to the position and size of windows and use solar shading components.

3. Considerations for operation systems (Type 4)

- It is important to reduce the air conditioning load in rooms that are not occupied by lowering the set room temperature for heating (raising it for cooling) and controlling the air flow.
- Frequent cleaning and replacing of the air conditioning or heat exchanger filter leads to the reduction of energy consumption. It is important to encourage the occupants to frequently clean and replace filters.
- Careful attention is required not to raise the room temperature too high in winter, as it not only increases energy consumption but also causes overdrying.
- One of the advantages of the central heating and cooling system is that it is basically a whole-building air-conditioning system and the temperature variation is small between the rooms. However, as temperature variations do not affect rooms that are infrequently used, from the energy efficiency perspective, it is desirable to set the temperature of such rooms closer to the outside air temperature, or to use a control system that can turn off the equipment.

5.2.5 Selecting Auxiliary Heater

- There exist many choices in auxiliary heaters used during the winter months including kotatsu (a small quilt-covered table with an electric heater affixed underneath), electric panel heaters, electric space heaters, electric carpets, ceramic heaters, and halogen heaters. Using these devices may consume more power than heat pump air conditioners used for the same period of time.
- Burning an open flame or heating with an unvented heater that releases exhaust into the room reduces the indoor air quality as fuel is burned indoors. Care is therefore required such as avoiding using such heaters for a long period of time and airing the room frequently when in use.

Comment ● Power consumption of auxiliary heaters

The figure compares the power consumption of an energy-efficient heat pump air conditioner, an electric carpet and a kotatsu all placed in a living room (floor area: 24 m2). The heat pump air conditioner may consume a significant amount of power immediately after start-up; however, when the temperature stabilizes, it is shown to consume not much more than the electric carpet or the kotatsu at a low setting. Furthermore, from the point of view of energy efficiency, the low setting is recommended for both the kotatsu and the electric carpet. The electric carpet and the kotatsu may seem energy efficient, as they are localized heaters; however, if left on for a long period of time, they consume more energy than other heaters that heat the entire room.

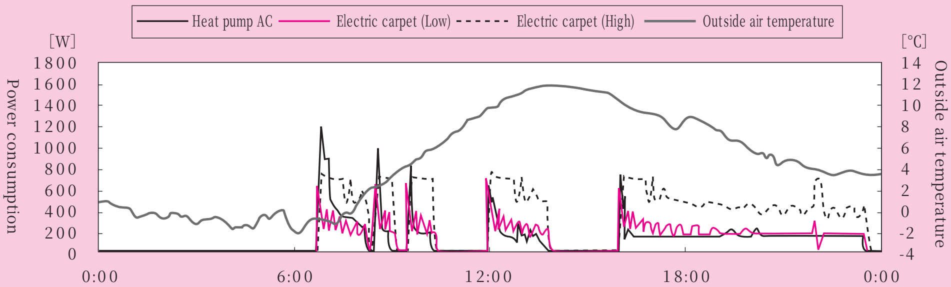


Fig. a Energy consumption comparison between heat pump air conditioner and electric carpet

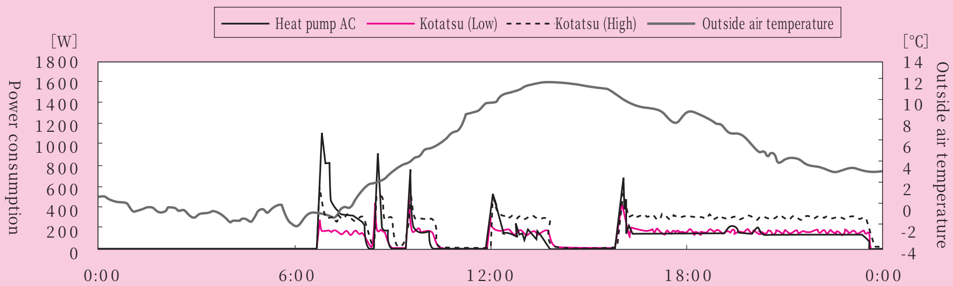


Fig. b Energy consumption comparison between heat pump air conditioner and kotatsu

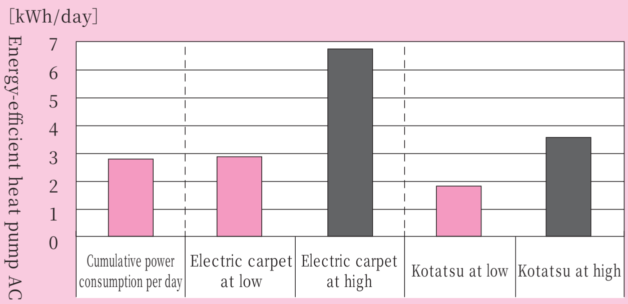


Fig. c Comparison of daily power consumption

■Conditions

Building and location: Multi-family residential building in Tsukuba City, Ibaraki Prefecture

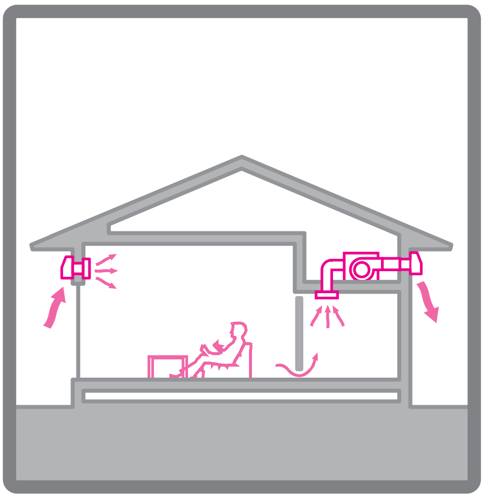
Heat pump AC: Energy-efficient 2.2 kW model (COP≈6)

Electric carpet: For use for 3-tatami-mat area (Area: 5 m^2; Rated power consumption: high = 700 W, low = 350 W)

Kotatsu: Square-shaped (Each side measures 75 cm: rated power consumption: 600 W)

The power consumption patterns for the electric carpet and the kotatsu were estimated based on the power consumption measured in the artificial climate chamber (outside temperature = 5°C, indoor temperature = 15°C).

5.3 Ventilation System Planning



Since the Building Standard Law of Japan was revised in 2003, it became mandatory for virtually all houses to have a mechanical ventilation system as a measure against "sick house" syndrome. Along with placing a limit on the amount that can be used of building materials that release chemicals such as formaldehyde, the Law also requires that a room must have at least 0.5 air changes per hour (ACH) of effective ventilation per hour throughout the year.

It is therefore important, from the point of view of energy-efficient technologies for ventilation systems, to come up with ways to save energy on mechanical ventilation.

5.3.1 Purpose and Key Points of Ventilation System Planning

- The purpose of a ventilation system planning is to ensure that there is at least 0.5 ACH of ventilation required by the Building Standard Law with all openings (windows) closed and to maintain a safe and comfortable indoor air environment in a house.
- The purpose of installing a local ventilation system is to eliminate vapor and odor in moisture-prone rooms such as toilets, bathrooms and kitchens in order to maintain the sanitary levels of the indoor space. However, its ventilation capacity is far greater than the above-mentioned continuous ventilation. Appropriate planning, such as setting up an interlocking air supply opening or installing a timer, is therefore necessary.
- There exist two types of ventilation system: the duct ventilation system and the through-the-wall ventilation system. To save energy using these systems, there is a need for raising the awareness of occupants and plans that focus on supporting maintenance over the years, including the reduction of pressure loss from ducts or outside hoods as well as the selection of high efficiency fans.

5.3.2 Energy Conservation Target Levels for Ventilation System Planning

1. Definition of target levels

- This document provides information on two types of ventilation system: Duct ventilation system (balanced, supply-only and exhaust-only); and Through-the-wall ventilation system (balanced, supply-only and exhaust-only).
  As methods and effects of energy conservation differ from one type to the other, energy conservation target levels are determined as follows for each type.

Method 1: Duct ventilation system (balanced, supply-only and exhaust-only)

Level 0	:	Ventilation energy reduction	None
Level 1	:	Ventilation energy reduction rate	Approx. 30%
Level 2	:	Ventilation energy reduction rate	Approx. 50%

- The typical ventilation energy consumption in both Zone VI and V by a duct ventilation system (when performing partial intermittent heating and cooling) was 3.1 GJ (or approximately 5% of the entire energy consumption) in 2000 (See Section 6.1 on p.339).

Method 2: Through-the-wall ventilation system (balanced, supply-only and exhaust-only)

Level 0	:	Ventilation energy reduction	None
Level 1	:	Ventilation energy reduction	Approx. 20%

- The typical ventilation energy consumption in Zone VI and V by a through-the-wall ventilation system (when performing partial intermittent heating and cooling) was 2.8 GJ and 1.0 GJ respectively in 2000.

2. How to achieve target levels

- The following provides methods to adopt for each type of ventilation system to achieve the targets levels for ventilation system planning. (Table 1, Table 2)

Table 1 Type 1 Target levels for duct ventilation and how to achieve them

Target Level	Energy-saving effect (Ventilation energy reduction rate)	Method to adopt
Level 0	0	–
Level 1	Approx. 30%	Method 1: Reducing pressure loss of duct, etc.
Level 2	Approx. 50%	Method 1: Reducing pressure loss of duct, etc. Method 2: Installing high-efficiency device

Table 2 Type 2 Target levels for through-the-wall ventilation and how to achieve them

Target Level	Energy-saving effect (Ventilation energy reduction rate)	Method to adopt
Level 0	0	–
Level 1	Approx. 20%	Method 1: Making appropriate connection between the fan and the outside air terminal

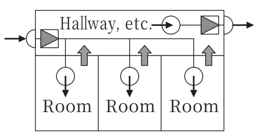
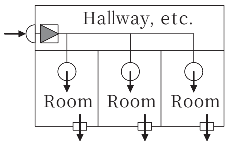
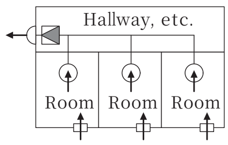
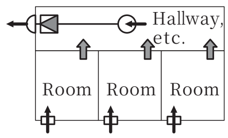
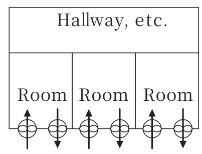
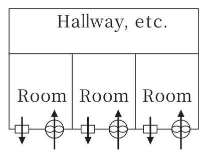
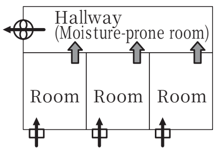
- Exhaust-only ventilation type also can serve as local ventilation in rooms such as a bathroom where vapor and odor need to be eliminated by operating the fan for an extended period. Installing this type of ventilation reduces the need to perform local ventilation and overall ventilation and, in consequence, reduces the energy consumption. The overall system also can be made simpler. However, it should be noted that the disadvantage of exhaust-only ventilation system is that opening windows in some rooms decreases the air supply to others.
- In reinforced concrete houses frequently seen in Zone VI, supply-only ventilation type becomes a more attractive option as it supplies air directly into each room without having to address the issue of interstitial condensation in walls. With balanced ventilation, as with supply-only ventilation, direct air supply into each room is ensured; however, the energy-saving advantage of installing a heat exchange type is virtually nonexistent in Zone VI.
- Detailed explanations on each method will be provided in "5.3.4 Energy Saving Methods in Ventilation System Planning".

5.3.3 Steps for Considering Ventilation System Planning

1. Types of ventilation systems

Common types of ventilation systems are listed below in Table 3. Although exhaust-only ventilation is predominantly used in hot humid regions, an overview of common ventilation systems for houses is described here. Understanding all the advantages and points of caution of these systems is essential when selecting an appropriate ventilation system based on the lifestyle of the occupants as well as the floor plan.

Table 3 Common ventilation systems

Types of ventilation system		Advantages	Points of caution	Remarks for planning
Duct balanced ventilation Mechanical air supply per room Centralized mechanical exhaust		• Ventilation can be ensured in each room • Low operating noise in rooms • Attractive interior design • If heat-exchange type, protection against cold drafts and reduction of air-conditioning load can be obtained (Zone V)	• Duct installation required for each room	• A fan unit with an appropriate capacity needs to be selected based on calculations • Determine the number of ducts and their length after examining the required ventilation airflow of each room • When setting up an exhaust path in moisture-prone rooms, ensure that it is possible beforehand with the specifications of the ventilation device
Duct supply-only ventilation Mechanical air supply per room		• Ventilation can be ensured in each room • Low operating noise in the room • An effective measure against "sick house" syndrome as it limits the airflow coming from the attic or inside the walls • Attractive interior design • No exhaust duct required	• Outside noise can enter through the exhaust opening of each room • Less attractive as many holes are made on exterior walls • Duct installation required for each room	• To take precautions against interstitial condensation in walls during the winter, a certain amount of effective opening area for exhaust is required (Zone V)
Duct exhaust-only ventilation Mechanical exhaust per room		• Ventilation can be ensured in each room • Low operating noise in the room • Attractive interior design • Privacy can be ensured, as it does not require door undercuts	• Outside noise can enter through the supply opening of each room • Less attractive as many holes are made on exterior walls • Requires measures against cold drafts at supply openings • Duct installation required for each room	• If door undercuts are set up, the fresh air supply to each room during the winter months decreases • If exhaust is required in moisture-prone rooms as well, use an airflow distribution design that can ensure the exhaust volume in the bathroom
Duct exhaust-only ventilation (combined with local ventilation) Centralized mechanical exhaust		• Low cost • Simple installation	• Outside noise can enter through the supply opening of each room • Less attractive as many holes are made on exterior walls • Requires measures against cold drafts at supply openings	• With a two-storey house that is not air tight, an air supply fan can be added in upstairs rooms in order to ensure ventilation (Zone V)
Through-the-wall balanced ventilation Mechanical air supply/exhaust per room		• Ventilation can be ensured in each room • Simple installation • Privacy can be ensured, as it does not require door undercuts • If using heat-exchange type with high ratio of fresh air to total supply air, protection against cold drafts and reduction of air-conditioning load can be obtained (Zone V)	• Operating noise may occur in rooms • Less attractive as the device is exposed • Less attractive as many holes are made on exterior walls • Requires measures against cold drafts at supply openings (Zone V)	• Address the ventilation in non-habitable rooms not used for extended periods of time , such as hallways and the entrance, by installing local continuous ventilation or other devices
Through-the-wall supply-only ventilation Mechanical air supply per room		• Ventilation can be ensured in each room • An effective measure against " sick house " syndrome as it limits the airflow coming from the attic or inside the walls • Simple installation • Privacy can be ensured, as it does not require door undercuts	• Outside noise can enter through the exhaust opening of each room • Less attractive as the device is exposed • Less attractive as many holes are made on exterior walls • Operating noise may occur in rooms • Requires measures against cold drafts at supply openings (Zone V)	• To take precautions against interstitial condensation in walls during the winter, a certain amount of effective exhaust opening area is required (Zone V)
Through-the-wall exhaust-only ventilation (combined with local ventilation)		• Cost is low as it is used in conjunction with local ventilation • Simple installation • Low operating noise in rooms	• Outside noise can enter through the supply opening of each room • Less attractive as many holes are made on exterior walls • Requires measures against cold drafts at supply openings (Zone V) • Is prone to clogging by dust that leads to reduced capacity	• With a two-storey house that is not air tight, an air supply fan can be added in upstairs rooms in order to ensure ventilation (Zone V)

Ventilation fan (Duct) Ventilation fan (Through-the-wall) Door, undercut, etc. Indoor air terminal for air supply or exhaust Outdoor air terminal for air supply or exhaust Air supply or exhaust opening

* Although the supply-only ventilation system (mechanical air supply) is not yet common, it was included in the table as a method to supply outside air in a stable fashion.

2. Steps for considering ventilation system planning

1) Duct ventilation system

- The duct ventilation system offers three major types: balanced, supply-only and exhaust-only. Furthermore, exhaust-only can also be combined with local ventilation with indoor air terminal devices in moisture-prone rooms such as toilets, bathrooms and kitchens. Select a system while closely considering the advantages and the points of caution.
- The placement planning of ventilation system components needs to take into account the need for regular maintenance.
- For the energy efficiency of a ventilation system, one needs to consider not only the performance of the main unit of the ventilation system and its placement, but also the placement of air terminal devices as well as their performance such as loss of pressure loss.
- Consider performing the airflow rate measurement as well as the airflow adjustment after completing the installation of a ventilation system.
- Houses, especially bungalow-style houses and reinforced concrete houses, in hot humid regions where the difference between the outdoor and indoor temperatures is relatively small throughout the year provide favorable conditions for the exhaust-only ventilation system combined with local ventilation.
- Similarly, zones such as Zone VI provide favorable conditions for the exhaust-only ventilation system combined with local ventilation when the house has an open floor plan which takes into account cross ventilation, or when openings between rooms are set up with particular care and ingenuity.

Glossary: Airflow adjustment
For the duct ventilation system, this refers to the change or adjustment made at the degree of opening at air terminal devices in order to maintain a balance in airflow between terminals at the end of branches .

Step 1 Considering ventilation system to be selected

1) Confirm the lifestyle of the occupants, the planning of the house, the air tightness of the house, and the method used for heating (Zone V) and cooling.
2) Consider types of ventilation system and ventilation paths.

▼

Step 2 Placement planning for ventilation system components

1) Consider the placement of outdoor and indoor air terminal devices while taking into account the regular cleaning.
2) Consider the placement of the main unit of the ventilation system while taking into account the regular cleaning.
3) Consider the placement of the duct while taking into account the structure of the house.
4) Reconfirm the ventilation paths.

▼

Step 3 Reconfirming ventilation system's capacity while being mindful of energy efficiency

1) Determine the design airflow rate
2) Consider ways to minimize pressure loss at ducts and perform pressure loss calculations.
3) Select energy-efficient fans while considering their power consumption.

▼

Step 4 Confirming items to be performed during or after installation

1) Confirm whether maintenance can be performed or not and make improvements.
2) Consider performing the airflow rate measurement.
3) Consider performing the airflow rate adjustment.

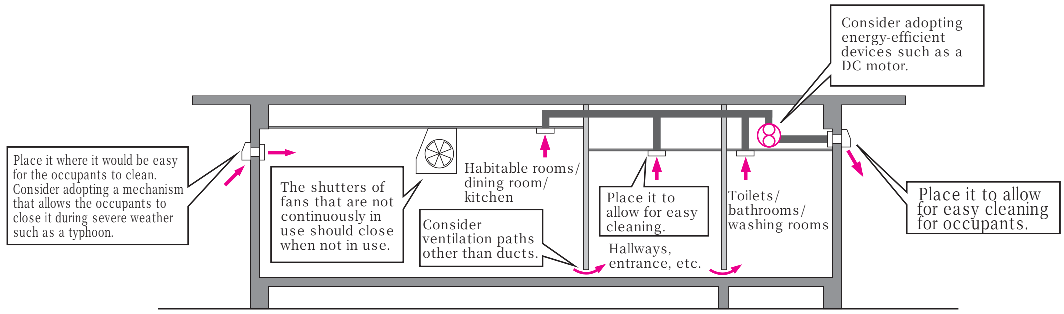


Fig. 1 Example of ventilation system planning (duct exhaust-only ventilation system)

2) Through-the-wall ventilation system

- The through-the-wall ventilation system is comprised of several fans installed in habitable rooms (used for extended periods of time) and moisture-prone rooms.
- There are two types of ventilation planning; one in which the ventilation path is devised for each room and the other where ventilation paths go from habitable rooms towards moisture-prone rooms. Select the system while closely considering the advantages and the points of caution.
- Generally speaking, the through-the-wall ventilation system can experience a significant decrease in air-flow due to accumulated dust on parts such as the grill, which is caused by the system's small pressure difference across the fan unit (the pressure required to feed air). The occupants need to be made aware of the need for regular cleaning.

Step 1 Considering ventilation system to be selected

1) Confirm the lifestyle of the occupants as well as the floor plan and air tightness of the house.
2) Consider types of ventilation system and ventilation paths.

▼

Step 2 Placement planning for ventilation system

1) Consider the use of local fans as part of the continuous overall ventilation.
2) Select the main unit and consider its placement while taking into account regular maintenance.

▼

Step 3 Verifying ventilation system ' s capacity while being mindful of energy efficiency

1) Determine the design airflow rate.
2) Consider ways to minimize pressure loss.
3) Select energy-efficient fans while taking into account the power consumption and pressure difference across the fan unit.

▼

Step 4 Confirming items to be performed during or after installation

1) Confirm whether maintenance can be performed or not and make improvements.
2) Consider performing the airflow rate measurement.
3) Consider performing the airflow rate adjustment.

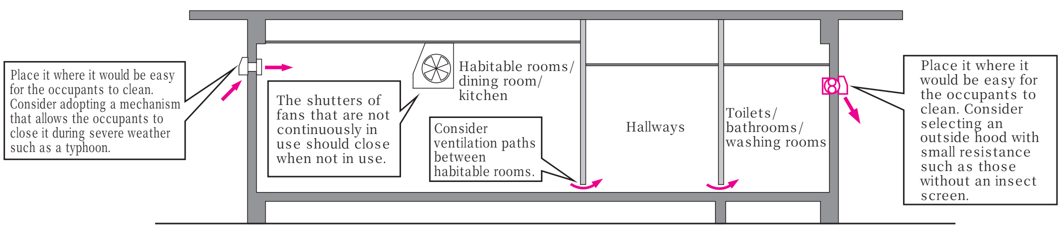


Fig. 2 Example of ventilation system planning (though-the-wall exhaust-only ventilation system)

5.3.4 Energy Saving Methods in Ventilation System Planning

Type 1 Duct Ventilation System (balanced, supply-only and exhaust-only)

Method 1: Minimizing pressure loss at ducts and other areas

When adopting the duct ventilation system, pay special attention to the placement of the ducts and their diameter in an effort to minimize the pressure loss, as the energy required to operate the ventilation will otherwise increase. The following section provides a detailed explanation of the method.

1) Widening the duct diameter

- Some prefer to use slimmer ducts putting too much emphasis on the ease of installation and saving space. It is best to avoid using them as much as possible as it is essential to select a duct diameter appropriate for the airflow. Although in a house it is common to use a diameter of 100 mm to 150 mm for a main duct and 50 mm for a branch duct, a diameter of at least 100 mm is required for both the main and the branch-end duct in order to minimize the pressure loss at ducts. Since the duct ventilation system requires the installation of an air terminal device in each room, it may be difficult to use ducts with a diameter (ø) of 100 mm depending on the envelope it is being employed in combination with. If so, use ducts with ø 75 mm or more whenever possible.

2) Minimizing the pressure loss with duct length and bends

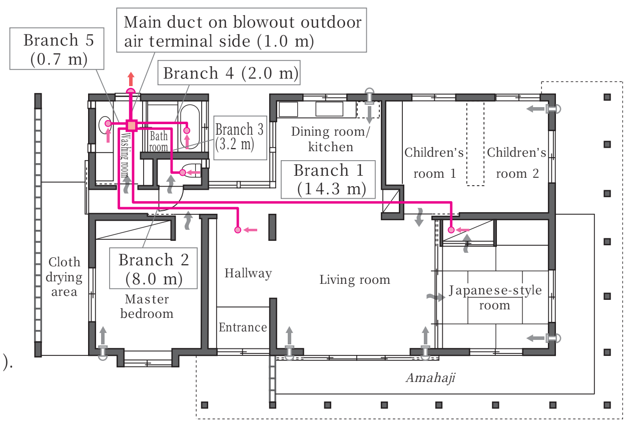
- You can also limit pressure loss by shortening the duct and reducing the number of bends. This also makes it possible to use smaller fan units.

Key Point

An example of energy-saving effect by widening duct diameter

1) House in Zone VI (reinforced concrete and bungalow)

- The figure below shows the calculation for estimating the energy-saving effect after changing the diameter of the duct in duct placement planning (using an AC motor).
- Plan A uses a main duct with ø 100 mm and an indoor-side branch duct with ø 50 mm while Plan B uses ø 150 mm and ø 100 mm, respectively.
- By widening the duct diameter, we can select the model (Model b) with less power consumption that produces the same airflow. In this case, the power consumption was reduced by approximately 40%.



Main duct ø 100 mm (Plan A) → ø 150 mm (Plan B)
Branch duct ø 50 mm (Plan A) → ø 100 mm (Plan B)
Dimensions in parentheses refer to the length of the duct.
An AC motor is used for the motor (See p.251).

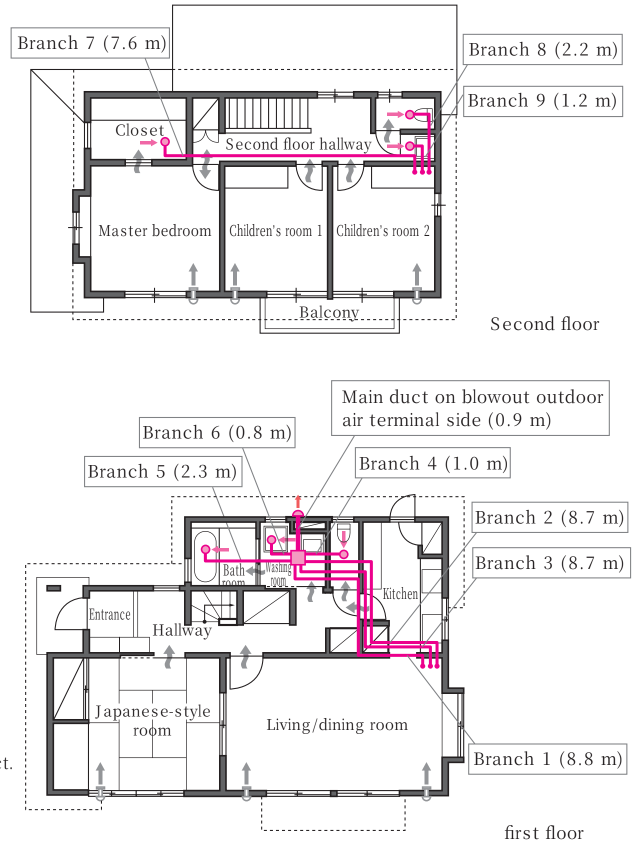
Fig. (1)-1 Bungalow model (AC motor)

Table (1)-1 Comparison of power consumption with different duct diameters (Zone VI)

	Duct placement		Fan unit model	Airflow	Pressure loss	Power consumption	Power consumption comparison	Specific fan power
	Main duct	Branch duct		(m^3/h)	(Pa)	(W)	(%)	($w/(m^3/h)$)
Plan A (VI)	100mm	50mm	Model a	160	149	36	100	0.23
Plan B (VI)	150mm	100mm	Model b	160	39	23	64 (36% reduction)	0.14

2) House in Zone V (Wooden, two-storey)

- The figure below shows the calculation for estimating the energy-saving effect after changing the diameter of the duct in the duct placement planning (using an AC motor).
- Plan A uses a main duct with ø 100 mm and an indoor-side branch duct with ø 50 mm while Plan B uses ø 150 mm and ø 100 mm, respectively.
- By widening the duct diameter, we can select the model (Model b) with lower power consumption that produces the same airflow. In this case, the power consumption was reduced by approximately 40%.



Main duct: ø 100 mm (Plan A) → ø 150 mm (Plan B)
Branch duct: ø 50 mm (Plan A) → ø 100 mm (Plan B)
Dimensions in parentheses refer to the length of the duct.
An AC motor is used for the motor (See p.251).

Fig. (2)-1 Two-storey model (AC motor)

Table (2)-1 Comparison of power consumption with different duct diameters (Zone V)

	Duct placement		Fan unit model	Airflow	Pressure loss	Power consumption	Power consumption comparison	Specific fan power
	Main duct	Branch duct		(m3/h)	(Pa)	(W)	(%)	(w/(m3/h))
Plan A (V)	100㎜	50㎜	Model a	160	149	36	100	0.23
Plan B (V)	150㎜	100㎜	Model b	160	39	23	64 (36% reduction)	0.14

Method 2:　Using high-efficiency devices

It is essential for a ventilation system, which usually operates 24 hours a day, 365 days a year, to increase the energy-efficiency of its fan units. Two types of motors, alternate current (AC) and direct current (DC), are available, of which DC motors are generally considered to be the more energy efficient as their input power is smaller when producing the same airflow.

- In addition to consuming less power, DC brushless motors offer superior control on elements such as the rotation speed, allowing for easier control to achieve a constant airflow or pressure difference across the fan unit. Using this feature, some devices even offer a function to allow for a constant airflow even when the pressure on the fan changes due to factors such as changes in the outside wind pressure.
- Some recent AC motors offer a comprehensive high efficiency. It is therefore advisable to select a fan by consulting many fans' specific fan power (W/(m3/h)), which indicates the amount of input power required to send 1 m3/h of air at its designed airflow rate.
- The formula for calculating the specific fan power is as follows:

  Specific fan power = Power consumption ÷ airflow

  Power consumption: The W (watt) value listed in the catalog.

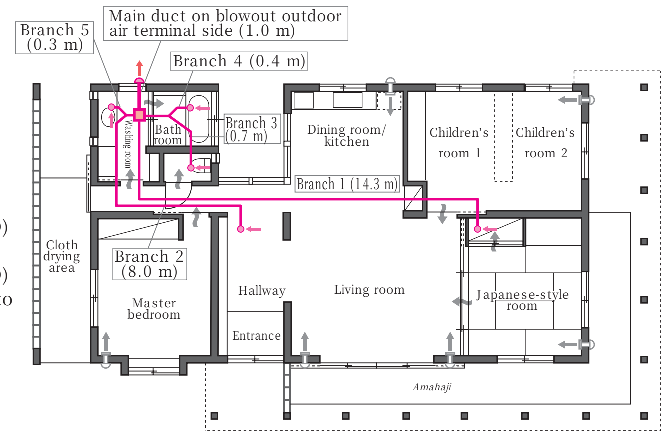
  Airflow: The m3/h value obtained from the pressure loss calculations. (Note that this airflow does not refer to the airflow when the fan unit is left alone for the test, meaning when ventilation components are not attached.)
- This document refers to systems with 0.2 W/(m3/h) or less as high-efficiency systems.

Key Point

Example of energy-saving effect when using a high-efficiency device

1)　House in Zone Ⅵ (reinforced concrete and bungalow)

- The figure below shows the estimation calculation of the energy-saving effect after changing the diameter of the duct in duct placement planning using a DC motor. In this example, an operation mode is used that allows the constant airflow. This is a unique function of DC motors.
- Plan C uses a main duct with ø 100 mm and an indoor-side branch duct with ø 50 mm while Plan D uses ø 150 mm and ø 100 mm, respectively.
- Plan C, which uses smaller diameters, achieves a reduction in power consumption of approximately 10% compared with Plan A, while Plan D using larger diameters



Main duct: ø 100 mm (Plan C) →
ø 150 mm (Plan D)
Branch duct: ø 50 mm (Plan C) →
ø 100 mm (Plan D)
Dimensions in parentheses refer to the length of the duct.
A DC motor is used for the motor.

Fig. (1)-2　Bungalow model (DC motor)

Table:　Comparison of power consumption with different motors and duct diameters (Zone Ⅵ)

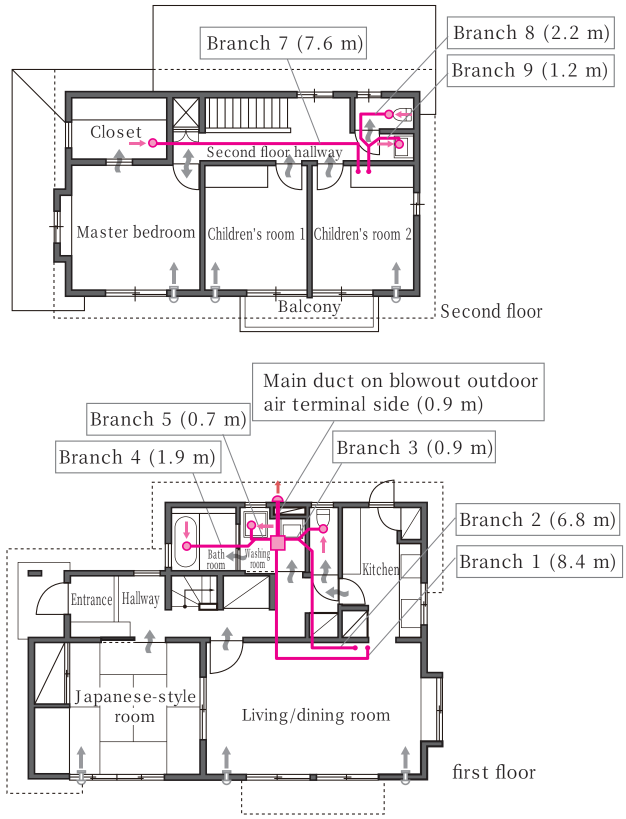
	Duct placement		Fan unit model	Airflow	Pressure loss	Power consumption	Power consumption comparison	Specific fan power
	Main duct	Branch duct		(m³/h)	(Pa)	(W)	(%)	(w/(m³/h))
Plan A (Ⅵ)	100㎜	50㎜	Model a	160	149	36	100	0.23
Plan B (Ⅵ)	150㎜	100㎜	Model b	160	39	23	64 (36% reduction)	0.14
Plan C (Ⅵ)	100㎜	50㎜	Model c	160	164	33	92 (8% reduction)	0.21
Plan D (Ⅵ)	150㎜	100㎜	Model d	160	19	17	47 (53% reduction)	0.11

Plan A and B: An AC motor is used; Plan C and D: A DC motor is used.

achieves a reduction of approximately 50%. Note that it is still necessary to keep the pressure difference across the fan unit small even when using a DC motor.

2) House in Zone V (Wooden, two-storey)

- The figure below shows the estimation calculation of the energy-saving effect after changing the diameter of the duct in duct placement planning using a DC motor. In this example, an operation mode is used that allows the user to set the airflow. This is a unique function of DC motors.
- Plan C uses a main duct with ø 100 mm and an indoor-side branch duct with ø 50 mm while Plan D uses ø 150 mm and ø 100 mm, respectively.
- Plan C, which uses smaller diameters, achieves a reduction in power consumption of approximately 10% compared with Plan A, while Plan D using larger diameters achieves a reduction of approximately 50%. Note that it is still necessary to keep the pressure difference across the fan unit small even when using a DC motor.



Main duct: ø 100 mm (Plan C) → ø 150 mm (Plan D)
Branch duct: ø 50 mm (Plan C) → ø 100 mm (Plan D)
Dimensions in parentheses refer to the length of the duct.
A DC motor is used for the motor.

Fig. (2)-2 Two-storey model (DC motor)

Table (2)-2 Comparison of power consumption with different duct diameters (Zone V)

	Duct placement		Fan unit model	Airflow	Pressure loss	Power consumption	Power consumption comparison	Specific fan power
	Main duct	Branch duct		(m³/h)	(Pa)	(W)	(%)	(w/(m³/h))
Plan A (V)	100㎜	50㎜	Model a	160	149	36	100	0.23
Plan B (V)	150㎜	100㎜	Model b	160	39	23	64 (36% reduction)	0.14
Plan C (V)	100㎜	50㎜	Model c	160	162	33	92 (8% reduction)	0.21
Plan D (V)	150㎜	100㎜	Model d	160	17	17	47 (53% reduction)	0.11

Plan A and B: An AC motor is used; Plan C and D: A DC motor is used.

Comment ● Points of caution when adopting a DC motor ventilation system

Many ventilation systems using DC motors offer superior control performance over systems with AC motors and come with features such as constant airflow control. Maintaining a constant airflow can be energy efficient if the pressure loss at ducts is small; however, this does not always hold true if the pressure loss is significant.

The figure below shows the comparison of power consumption and airflow between the regular mode and the constant airflow mode (300 m3/h) using a kitchen hood fan with a DC motor. With a moderate pressure loss at ducts (here, a 9 meter-duct with three bends is used for estimation), the energy consumption for both modes at 300 m3/h is 22 W but with a smaller pressure loss, the regular mode experiences an increase in airflow as well as power consumption. However, the airflow of the constant airflow mode is maintained at 300 m3/h, resulting in less power consumption.

Furthermore, when pressure loss is significant, the regular mode's power consumption is low despite not being able to achieve an airflow of 300 m3/h. A constant airflow mode, on the other hand, achieves the airflow requirement but its power consumption is significant. Based on these results, we can conclude that it is vital that the pressure loss be small in order to achieve an energy-efficient operation using a DC motor.

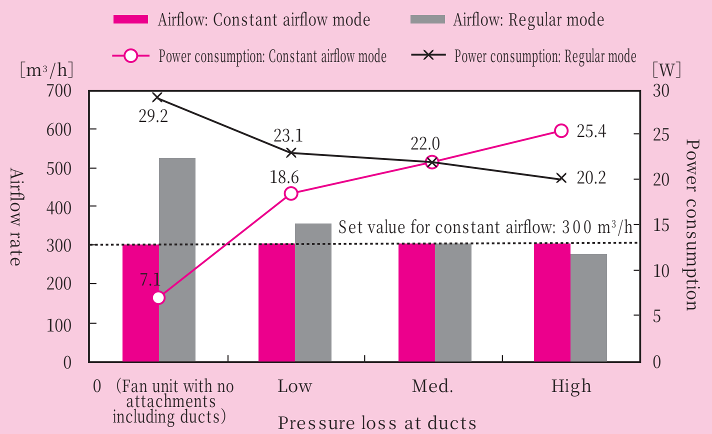


Fig. Relationship between power consumption and constant airflow mode with kitchen hood fan using DC motor

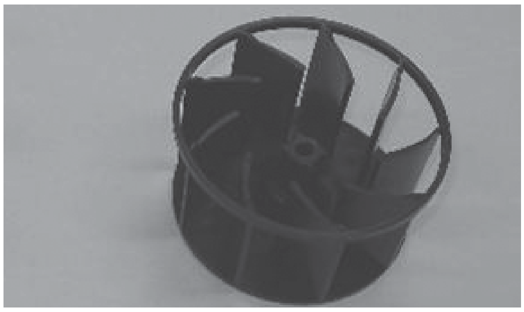
Type 2　Through-the-wall ventilation system (balanced, supply-only and exhaust-only)

Method 1:　Appropriately combining fans and outside air terminals

Blower fans used in through-the-wall ventilation systems generally have a smaller allowance (smaller blower fan capacity) for the pressure difference across the fan unit compared to those used in duct ventilation systems. This makes them more susceptible to the influence of pressure loss caused by bird nets or fire dampers attached to the outside hood as well as the outside wind pressure. Furthermore, they require regular cleaning as their airflow can decrease due to accumulated dust.

There are two shapes of the blower fans for through-the-wall ventilation systems: propeller and turbo (Fig. 3). Generally speaking, turbo fans have a higher allowance for the pressure difference across the fan unit and experience relatively fewer problems due to decreases in airflow caused by blocked filters. The fan shapes (propeller or turbo) are indicated in fan manufacturers' catalogs as a reference when selecting.

Propeller fan (left) and turbo fan (right)



Ventilation unit

Fig. 3 Examples of fans for through-the-wall ventilation systems

Key Point

Comparison of turbo fan and propeller fan characteristics

- The figure below shows an example of the characteristics of static pressure (the pressure difference across the fan unit) and airflow in a turbo fan and a propeller fan.
- The airflow for both is approximately 36 m3/h with no attachments, including ducts. However, as turbo fans can operate at a higher pressure difference across the fan unit than propeller fans, the following characteristics can be observed.
  a. More resistant against outside wind pressure;
  b. Can be used with hoods with slightly elevated level of pressure loss such as deeper outside hoods;
  c. Relatively fewer incidents of decreased airflow due to factors such as clogging caused by dust.

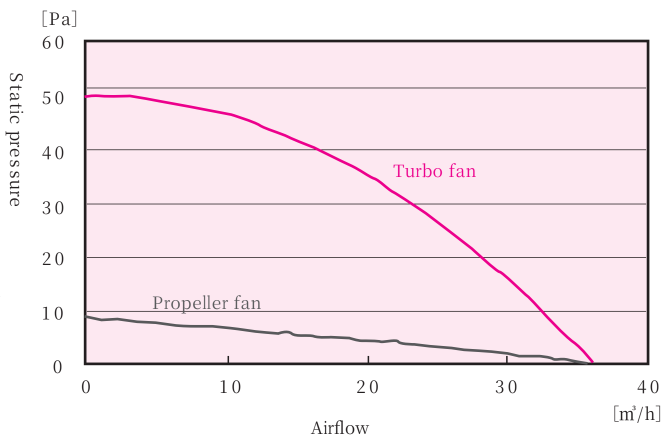


Fig.
Comparison of static pressure and airflow characteristics of turbo fans and propeller fans
(Airflow of fan unit with no attachments including ducts: 36 m³/h)

Key Point

Information on outside air terminal

- It is vital to select an outside air terminal with small pressure loss as many fan units for through-the-wall ventilation systems are designed to operate with a small pressure difference across the fan unit. A confirmation of an achievable airflow is required based on the pressure loss calculation if you are using an outside air terminal, where airflow when assembled with the fan has not been confirmed by the fan manufacturers.
- For your reference, the table below shows an example of measured value of pressure loss using common outside air terminals. The pressure loss was measured with airflow 40 m3/h. The largest pressure loss was shown to be more than 10 times that of the smallest. These outside air terminals are commonly used, and exhaust fan manufacturers have confirmed their airflow using these combinations; however, smaller design-oriented outside air terminals are known to show even greater pressure loss. It is thus critical to verify whether the airflow has been confirmed by the manufacturer and perform detailed pressure loss calculations.

Table: Specifications and pressure loss of outside air terminals

Specifications of outside air terminal		Pressure loss at 40 m^3/h*
Air unit A, louver-type		0.2 Pa
Air unit B, deep-type		2.0 Pa
Air unit C, round-type + fire damper + insect screen		2.6 Pa

* The value includes the pressure loss of duct (L: 15 cm, ø: 100 mm).

Key Point

Airflow of fan units for through-the-wall ventilation systems

- The tables below show the results of airflow rate measurements (the airflow when using a duct and outside air terminal) taken in the lab using a propeller fan and turbo fan attached to the above-mentioned outside air terminal.
- In this case, it is shown that airflow decreases by 20% even when using an outside air terminal commonly used with a propeller fan.
- The airflow might not reach the planned airflow rate if the pressure loss calculations are not performed, which indicates the importance of performing the calculations for through-the-wall ventilation systems as well.

Table a Results of airflow rate measurements for propeller fan (Catalog airflow: 36 m^3/h)

	Air unit A	Air unit B	Air unit C
Measured airflow	34.6m^3/h	32.0m^3/h	28.9m^3/h
Reduction rate*	4%	11%	20%

Table b Results of airflow rate measurements for turbo fan (Catalog airflow: 36 m^3/h)

	Air unit A	Air unit B	Air unit C
Measured airflow	33.9m^3/h	32.8m^3/h	30.8m^3/h
Reduction rate*	6%	9%	14%

* Reduction rate: The percentage of reduction when comparing measured airflow against the catalog airflow.

Comment ● Air vents on exterior walls with large opening area

The Building Standard Law stipulates that continuous mechanical ventilation can be substituted by an opening on the exterior wall if the effective opening area of the component is 15 cm2 (C = 15 cm^2/m^2) or more for every 1 m^2 of floor area and can be kept open at all times.

The energy-saving effect by applying this feature is especially promising in warm regions where the characteristic weather conditions allow for a longer period of time, compared to other regions, when the outdoor air can be brought directly indoors. However, issues such as wind and rain blowing indoors, closing during strong wind, protection against insects and security must be taken into account when selecting the opening component.

Fig. a shows an example of an air vent integrated into the opening (sash). This air vent can maintain an ample effective opening area of approximately 140 cm^2 when the weather outside is mild. When the wind is strong, its airflow adjustment mechanism (Fig. b) works to prevent excessive ventilation. Furthermore, during a reasonable rain or wind, it can also prevent the rain from blowing indoors even when the doors in the room are open.

There are few actual examples of natural ventilation systems using air vents; however, for a house with a total floor area of 100 m^2, it would require an effective opening area totaling 1,500 cm^2, or 11 air vents installed in windows, as shown in Fig. a.

Fig. a
Example of air vent integrated into sash

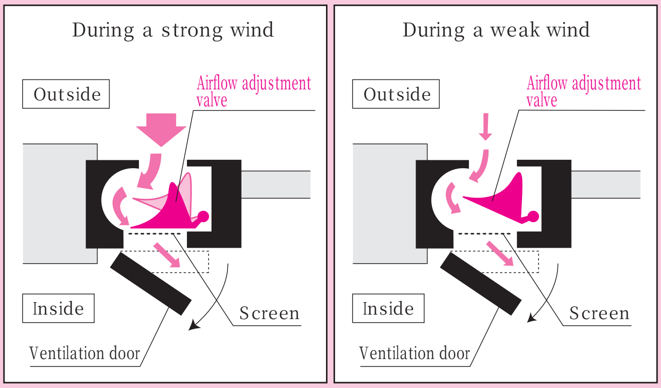


Fig. b
Structure of airflow adjustment mechanism for sash-integrated air vent

5.3.5 Considerations for Ventilation System Planning and Designing

1. Points of caution for ventilation system planning

1) Relationship between local ventilation and continuous overall ventilation

For a local exhaust fan in the kitchen of a house with an insulated envelope, it is essential to not disturb the rooms' thermal environment or other ventilation paths. To this end, it is vital to use an exhaust fan with air supply duct or supply fan or set up a dedicated air-supply opening (Zone V). Furthermore, ensure to select a device capable of efficiently eliminating polluted air (high trapping efficiency) produced by cooking with a small amount of exhaust air, which will be beneficial in terms of power consumption or reducing cooling and heating energy.

When the overall ventilation is performed by exhaust-only ventilation, depending on the air tightness of the housing, more air can come in through cracks than through the air supply openings. To ensure a balanced air supply into the rooms through planned air-supply openings, creative measures are required besides relying simply on the envelope's performance. For instance, a device can be installed to close the shutter when a local ventilation system, independent of the overall ventilation system, is not in use.

2) Ventilation system planning that takes maintenance into account

(1) Main unit

It is desirable to set up the continuous ventilation system where maintenance work can be performed with ease. Fig. 4 and Fig. 5 show examples of ventilation systems that can be installed on a wall. As they are not buried into the ceiling, filter and blade inspections or cleaning can be performed with ease. Even when this particular setup is not possible, some creativity is needed to facilitate inspections and maintenance work.

Fig. 4 Wall-mounted ventilation system

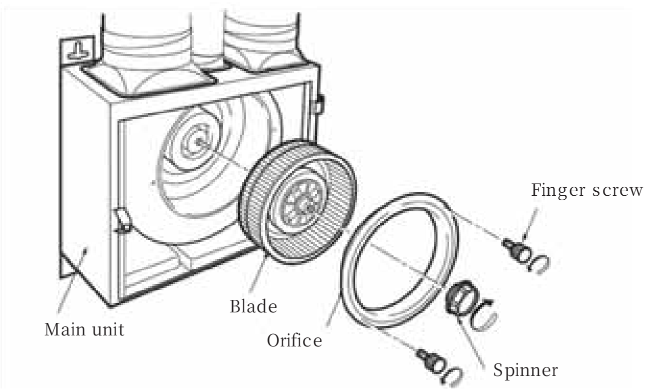


Fig. 5 Inspecting filter and blades

Ventilation devices that are hidden in places such as an attic make maintenance work difficult to perform and the occupants may not recognize dirt accumulating on parts including the filter. This will be a subject of improvement for the near future.

The following are three actions that can be taken in the planning phase regarding maintenance.

a. Fans with filters require regular filter cleaning while fans without filters need regular cleaning of the blades of the blower fan. In either case, select a device while taking into account the routine cleaning required.

b. Use creative ways to make cleaning easier. For instance, a ventilation system can be set up in a storage room or attic where the system can be exposed. The main ventilation unit can also be set up vertically.

c. Let the occupants know that the system requires regular cleaning.

(2) Air terminal device

The maintenance required for the outside air terminals (outside air intake openings), which tends to be overlooked, needs to be taken into account. Insect screens are often seen on outside air intake openings. These screens also require regular maintenance, without which the ventilation capacity is reduced (Fig. 6). On the second floor, by principle, the units need to be set up in such a place as a balcony, which is accessible for cleaning. Furthermore, on the ground floor, units tend to be installed where they cannot easily be reached from the ground; however, they still need to be installed in such a place where they can be accessed for cleaning purposes with a stepladder or the like.

Some air terminal devices have no insect screen on the device itself but rather a filter is installed on the indoor main unit. Ease of maintenance is again an issue to be considered in this case, and a bird net should be set up on the exterior wall to prevent birds from entering the duct.

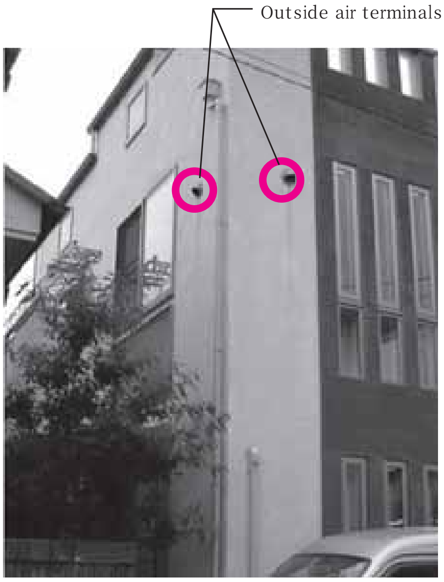


Fig. 6
Example of outside air terminals set up where it cannot be reached

Key Point

Survey result on frequency of cleaning of ventilation system

- The result of the survey conducted with 1,500 respondents throughout Japan demonstrated that virtually nobody cleaned the outside air terminals (hood).
- The figure below shows the cleaning frequency of the indoor air unit (including the fan's main unit) as well as the outside air terminals (hood). Although approximately 70% of respondents clean the indoor air unit once a year or more, more than 80% answered that they do not clean the outside hood including 16% who could not identify the outside hood in a photo. This result reiterates the importance of installing the air terminal device where it can be reached to facilitate regular cleaning.

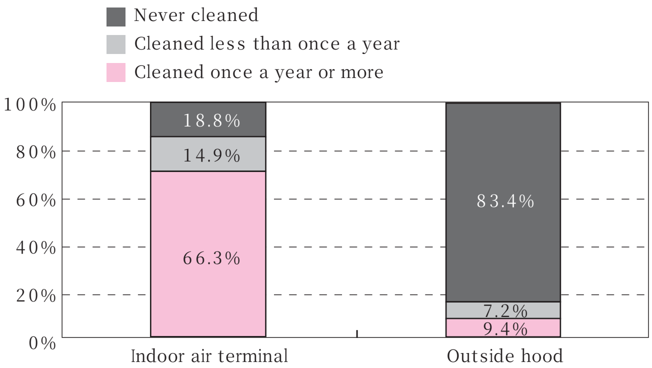


Fig.
Survey on cleaning frequency of ventilation system

3) Considerations regarding interference such as outside wind

Some through-the-wall exhaust fans (through-the-wall ventilation fans) designed for local ventilation come with an electronic airtight shutter. An airtight shutter is installed to prevent draft when the device is not in use; however, it consumes power during the period when it is open. Select a model without the electric airtight shutter when planning for a continuous operation to save energy. Keep in mind, however, that models with electric airtight shutters are sometimes selected if they are not to be used continuously during the winter months to reduce ventilation airflow.

By using a deep or wind-resistant air vent that has an outside hood or a damper (Fig. 7), you can ensure a relatively stable airflow without interference from the outside wind in regions that see many typhoons where outside wind is strong throughout the year. Furthermore, using salt-resistant outdoor air terminal device in regions adjacent to the ocean, especially if the sea breeze is also strong, can minimize rust.

When the outside wind is strong
(The damper is closed and reduces the amount of air going through.)

Normal condition
(The damper is open and lets air flow freely.)

Fig. 7 Example of air vent with damper preventing interference from outside wind

Comment ● Energy-efficiency and local ventilation system

Our survey results indicate that the length of usage per day for local ventilation systems such as kitchen hood fans and exhaust fans in toilets or bathrooms varies significantly depending on the individual. After analyzing the data, we estimated the approximate length of usage per day for a kitchen hood fan to be 100 minutes, 80 minutes for an exhaust fan in a toilet, and 200 minutes for an exhaust fan in a bathroom. In the bathroom exhaust fans, which are presumably used to dehumidify the room, are used by more than half of the respondents for over three hours a day. The power consumption by local ventilation is significant even when using a ventilation system with an energy-efficient DC motor, accounting for roughly half of the overall ventilation. Energy-efficiency is going to be a subject of improvement for local ventilation systems that operate intermittently.

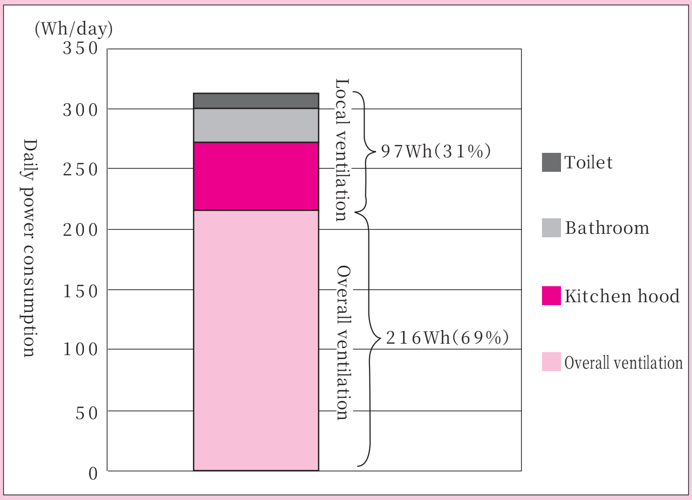


Fig.
Example of daily power consumption by ventilation (using exhaust-only ventilation with DC motor for overall ventilation)

4) Considerations regarding air supply opening placement and air supply methods

Consider adopting devices such as the radiant type (supplied air is diffused in all directions along the wall) to prevent cold air from directly entering the living space (Fig. 8).

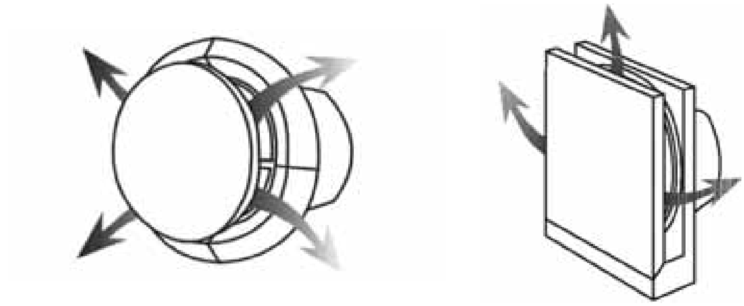
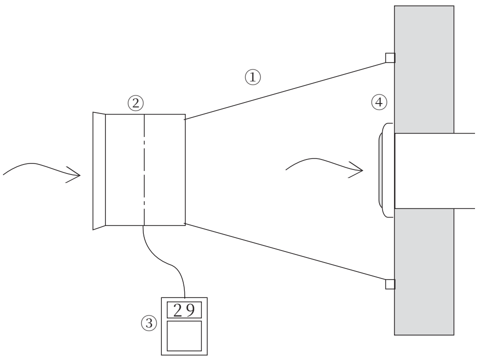


Fig. 8 Example of radiant-type air supply opening

5) Method and effects of airflow rate measurement

The most important aspect of planned ventilation is to ensure that the ventilation system can provide the planned ventilation airflow as well as the ventilation performance. To this end, it is vital to validate the airflow of the ventilation system after installation.

It is very common to use an airflow meter with a hood attached, as comparatively speaking they are readily available, when performing an airflow rate measurement on site of the ventilation system installation. As shown in Fig. 9 and Fig. 10, this airflow rate measuring instrument, generally known as “hood airflow meter”, is applied to either the indoor or outdoor air terminal device (such as indoor inlet/outlet terminal or outdoor hood) of the ventilation system.



①Hood ② Airflow detector
③Airflow display device ④Air terminal device to be measured

Fig. 9 Example of setup of airflow rate meter

Fig. 10 Airflow rate measurement being performed

Performing airflow rate measurements is effective in confirming that the planned airflow rate has been obtained; however, it can also serve as a tool to uncover problems by providing airflow measurements of air terminal devices. For instance, if a particular branch experiences low airflow, the branch may have a problem, while if the general airflow is low, it could be traced back to the main duct or the main fan unit.

Furthermore, if the results of the airflow rate measurements exceed the planned airflow rate, an adjustment can be made accordingly to lower the power consumption and the ventilation load to achieve more energy saving effect.

Comment ● Airflow rate measurement using k-factor method

Measuring airflow rate may at times be difficult due to the placement of the air terminal devices or, if indoors, furniture may obstruct access to the indoor air terminal device. When situations such as these arise, the k-factor method offers an alternative way to make taking the airflow rate measurements possible with a small margin of error.

The k-factor method is a method of airflow rate measurement employing a micro differential-pressure meter. Although there are no standards regarding this measuring method in Japan, it is already being used to measure airflow rate overseas, especially in Northern European countries.

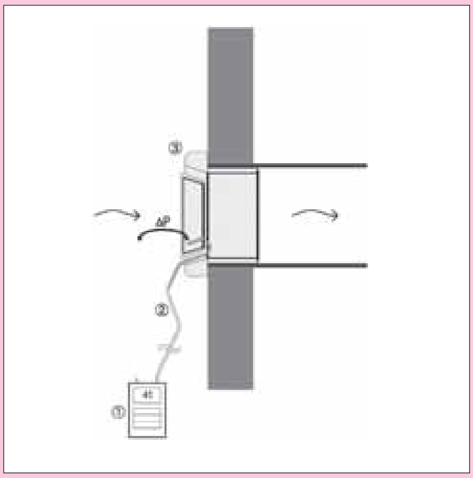


Fig. a Example of measuring instrument
①Micro differential-pressure meter
②Tube for measuring pressure
③Ventilation system component

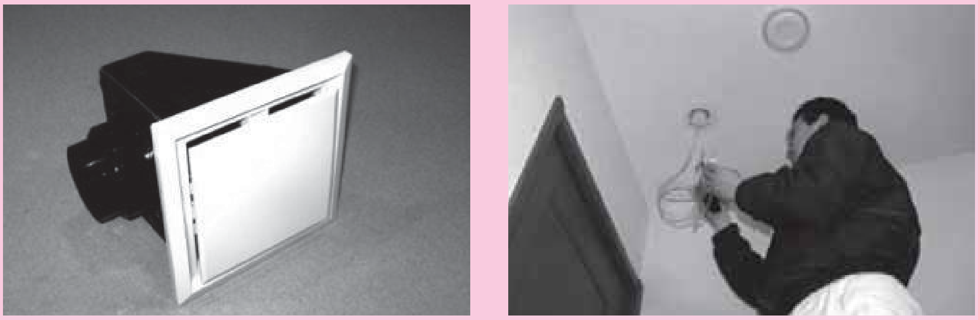


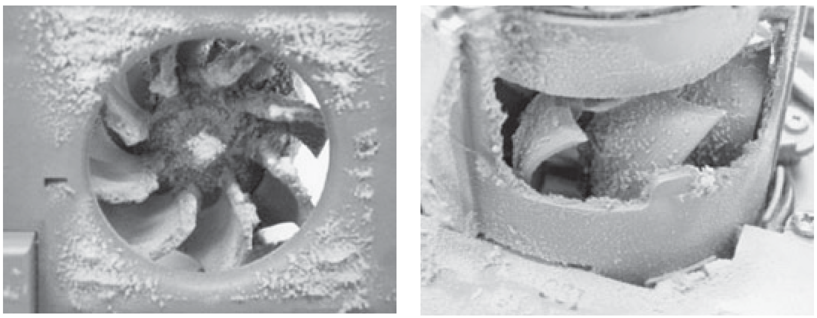
Fig. b Example of indoor air terminal device designed for k-factor method and actual measurement being taken

2. Design that takes into account the regular cleaning

1) Considerations for reduced capacity caused by dirt adhering to through-the-wall fans

The fan in Fig. 11 was used for two years in a toilet and found to have reduced airflow of roughly 75% of the initial measurement. When the ventilation capacity is reduced due to dirt adhering to the fan, not only is the ventilation rate reduced, but also the fan is consuming energy needlessly. To maintain the energy-saving effect, regular maintenance is key as cleaning will keep the device operating under the conditions similar to those when it was initially installed. Even when a filter is installed, neglecting maintenance will cause the filter to clog, which in turn will prevent the device from achieving the planned ventilation rate.

Fig. 11
Example of dirt adhering to through-the-wall fan
(Filterless model used for two years intoilet)

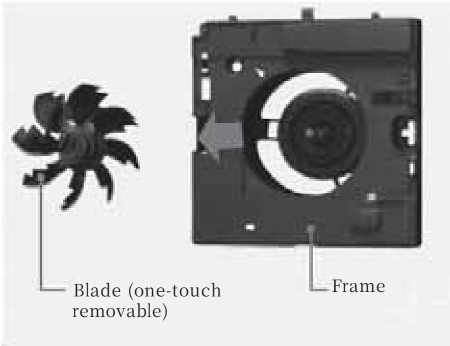


Front of the fan   Inside the pipe

2) Consideration regarding ease of maintenance

Performance can be maintained over the long term by selecting a device that people can easily clean and otherwise maintain (Fig. 12 and Fig. 13).

By selecting a device with an inlet opening that is protected by a filter, the amount of dirt on or damage to blades and clogging of the insect screen attached to the outdoor hood can be reduced. Dust that accumulates on the filter surface can be easily removed by using a vacuum cleaner.
Fig. 12 Cleaning filter of through-the-wall exhaust fan



If the model selected can be easily disassembled, cleaning the blades of dust is possible. Some devices have blades that can be removed without the use of tools.
Fig. 13 One-touch removable blades

3) Addressing the dirt in duct exhaust-only ventilation systems

Generally speaking, there are two types of maintenance required by a 24-hour overall ventilation system for a house: light maintenance performed by the occupants such as filter cleaning, and heavy-duty maintenance performed by professionals such as motor replacement and duct cleaning.

Duct exhaust-only ventilation systems commonly have filters in components such as indoor air terminal devices and main units, allowing occupants easy indoor access for cleaning. Although duct systems tend not to experience reduced airflow due to accumulated dust, not performing regular cleaning will eventually lead to difficulties in reaching the planned ventilation rate. Furthermore, installing attachments such as an insect screen on the outdoor hood may lead to reduced airflow caused by indoor dust being trapped and accumulating inside (Fig. 14).

Let the occupants know that placing furniture blocking the indoor air terminal device would not only hamper the cleaning but also prevent the system from reaching its planned ventilation volume.

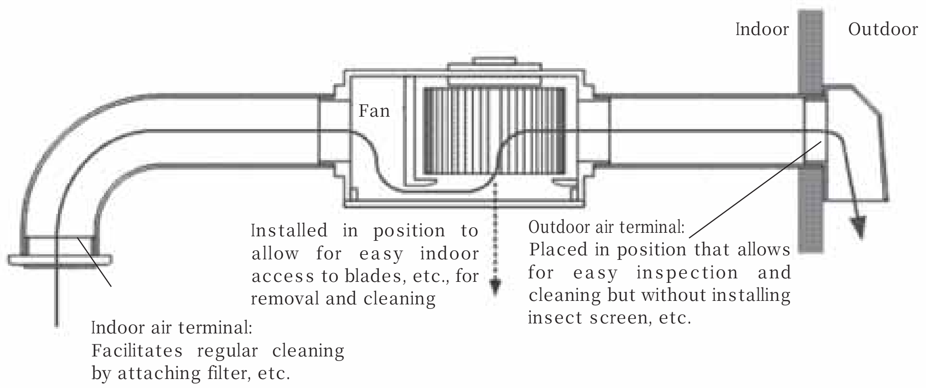
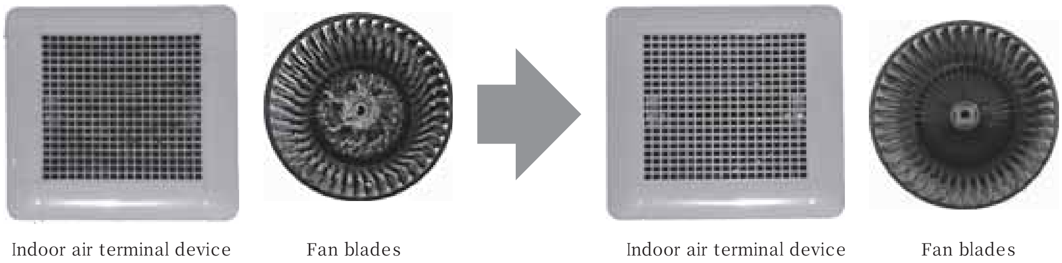


Fig. 14 Structure of duct exhaust-only ventilation system and measures for cleaning in each part

Key Point

Changes in airflow and specific fan power of ventilation system

- The figure below shows the change in ventilation airflow and specific fan power before and after the indoor air terminal device and the fan blades were cleaned for the first time after being used as 24-hour ventilation in a bathroom for two years.
- After the cleaning, the airflow increased roughly 30% while the specific fan power decreased by roughly 20%.



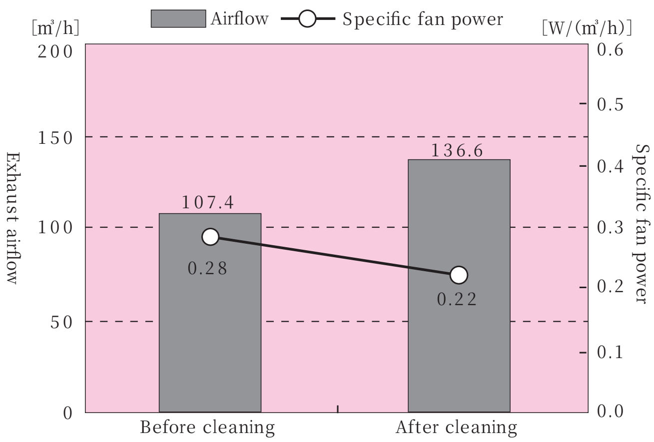
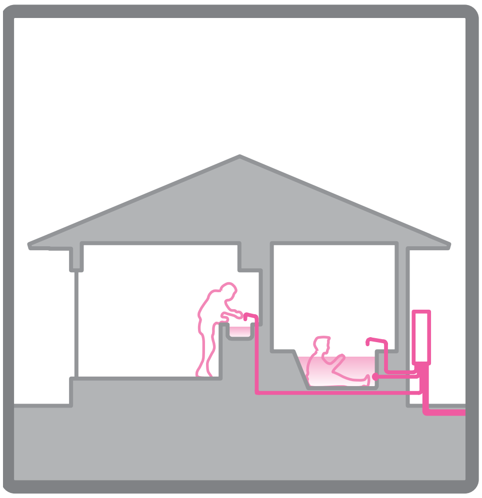


Fig.
Changes in airflow and specific fan power before and after cleaning

5

Chapter 5
Energy-efficient Equipment Technology
(Elemental Technology Application Method 3)

5.4 Domestic Hot Water System Planning



Domestic hot water systems have become indispensable in the way we live our lives today. Hot water accounts for a significant portion of household energy consumption. It is thus vital to make use of energy-efficient technologies when planning a domestic hot water system.

This chapter provides organized explanation of energy saving methods for domestic hot water system planning.

5.4.1 Purpose and Key Points of Domestic Water Heating System Planning

- The purpose of the energy saving methods for domestic water heating system planning presented in this document is to realize highly convenient living whereby hot water is provided in the required place, time and amount with minimal energy by applying various cutting-edge technologies.
- As hot water accounts for a significant portion, generally about 20 to 30% in hot humid regions, of the overall household energy consumption, the value of energy saving design in domestic hot water systems cannot be stressed enough.
- The most common method today is to set up a large heat source outside the house and connect it to the domestic hot water system through plumbing. This type, called the "central domestic hot water system" (Fig. 1), is the one presented in this document.
- The central domestic hot water system domestic hot water system is comprised of three parts: a heat source, a piping system, and finally, a domestic hot water faucet and a bathtub. Energy saving measures must be considered for each of these elements (Fig. 2).
- The heat source of a domestic hot water system can be gas, oil or electricity.
- When using gas or oil as the heat source, the hot water is heated by burning fuel; however, due to limitations of devices, not all the energy from the fuel can be used to heat the water. The resulting excess heat not used for heating is primarily emitted in the form of exhaust gas. However, recently a so-called "latent heat recovery" device, which uses this excess heat within the exhaust gas to increase the efficiency of the system, is becoming more commonplace.
- Electric heaters have been the most common electrical heat source used in systems; however, in recent years, a high-efficiency heat pump device, which collects heat from the air, has rapidly become more popular. If choosing to use an electricity-based system, the heat pump device will offer energy saving effects.
- It is extremely important to understand these characteristics when selecting a system type, based on various factors such as weather conditions, family composition and how the system will be used, to ensure that the heat source with the highest efficiency possible is selected.
- Energy saving effects can be dramatically improved by using a solar water heating system (See Section 3.5 Solar Water Heating on p.102). However, it is difficult to rely on it alone as bad weather and winter months can be problematic. It is therefore used in conjunction mainly with gas and oil heat sources.
- Although the "central domestic hot water system" is convenient, its piping tends to be long, which generally increases heat loss. It is therefore essential to pay careful attention to energy saving measures for the piping when designing the system.
- In order to increase energy saving effects, it is also necessary to consider adopting a faucet appropriate for saving hot water. A highly insulated bathtub is also effective as it reduces the need to reheat bathwater (this habit might be limited to the Japanese bathing style, in which family members usually share hot water in the bathtub when bathing).

It is currently extremely rare to combine an electric water heater with a natural refrigerant heat pump, a high-efficiency water heater, with a solar water heating system; however, some new products have been launched and may become more widely commercially available.

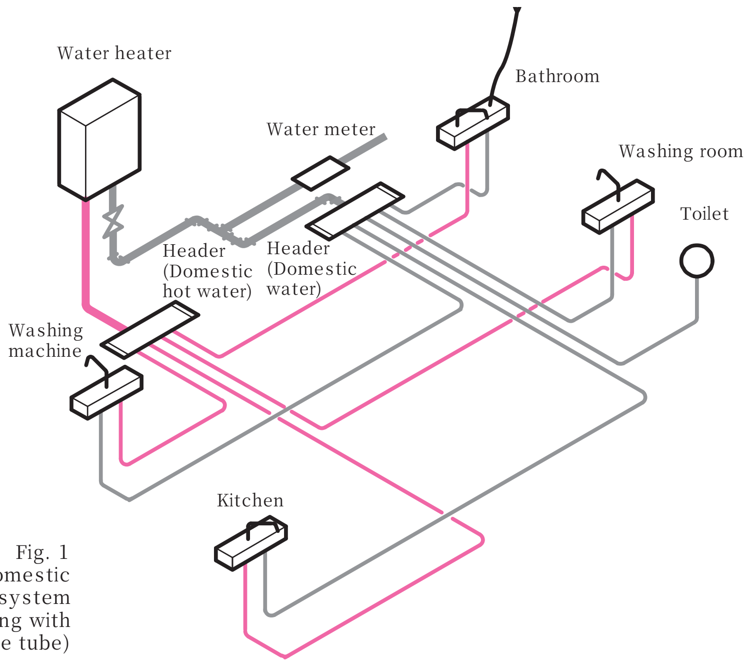
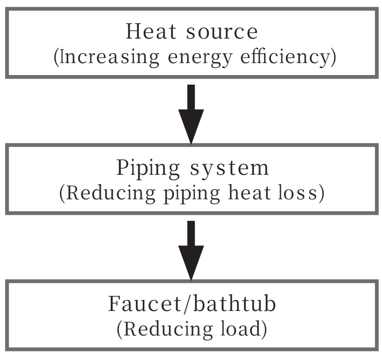


Fig. 1
Overview of central domestic hot water system (header-conduit piping with sleeve tube)



Increasing efficiency of heat source
- Make use of solar heat system as much as possible.
- If using gas or oil, select a latent heat recovery device.
- If using electricity, select a heat-pump device.

Reducing piping heat loss
- Adopt header-conduit piping with sleeve tube.
- Reduce the pipe length and diameter

Measures to reduce the load in bathtub and faucet
- Use highly insulated bathtub and bathroom.
- Use low-flow faucets and water-saving showerheads.
- Avoid discharging hot water unnecessarily by employing a single-laver faucet.

Fig. 2 Structure and energy saving measures of central domestic hot water system

5.4.2 Energy Conservation Target Levels for Domestic Hot Water System Planning

1. Definition of target levels

- Energy conservation target levels for domestic hot water system planning are divided into Level 1 to Level 4 as shown below. These levels indicate the reduction rate in energy consumption of a domestic hot water system.

Level −1	:	Domestic hot water energy increase	10% or more
Level 0	:	Domestic hot water energy reduction	None
Level 1	:	Domestic hot water energy reduction rate	At least 10%
Level 2	:	Domestic hot water energy reduction rate	At least 20%
Level 3	:	Domestic hot water energy reduction rate	At least 30%
Level 4	:	Domestic hot water energy reduction rate	At least 40%

- In 2000, the typical domestic hot water energy consumption was 13.8 GJ in Zone VI (approximately 21% of total energy consumption) and 19.2 GJ in Zone V (approximately 28%). (See Section 6.1 on p.339).
- Level 0 applies to a case in which no energy saving method was adopted related to domestic hot water when using a conventional gas water heater. Levels 1 through 4 indicate the domestic hot water energy reduction rate compared to Level 0. Any target level can be achieved by adopting domestic hot water planning methods.

2. Requirements for achieving target levels

- As shown on Table 1, this document presents three examples of domestic hot water system planning methods. The guidelines for energy saving effects (domestic hot water energy reduction rates) using each method are as shown on the table.

Table 1 Domestic hot water system planning methods and energy saving effects

Method	Description of method		Energy saving effect (Domestic hot water energy reduction rate)
Method 1	Using solar heat (adopting solar water heater or solar system)		
Method 2	Using high-efficiency water heater	Latent heat recovery gas/oil water heater	Approx. 15%
		Electric water heater with a natural refrigerant heat pump (CO_2 HP)* Only when boiling mode serves as “energy-efficient” mode	Approx. 35% (Zone V) Approx. 40% (Zone VI)
Method 3	Considering energy-efficient design/construction for each component of domestic hot water system (thermal insulation of piping/bathtub, hot water saving devices, etc.)		Approx. 10%

- Method 1 is a type of domestic hot water system planning that makes use of solar heat. Please refer to Section 3.5 Solar Water Heating. An explanation is provided on Method 2 and Method 3 in “5.4.4 Energy Saving Methods for Domestic Hot Water System Planning”.

3. How to achieve target levels

- Table 2 shows the relationship between the energy conservation target levels for domestic hot water system planning and the methods. Each method can be adopted on its own; however, combining them will enhance the energy saving effect.

Table 2 Target levels for domestic hot water system planning and how to achieve them

Target level	Energy saving effect (Domestic hot water energy reduction rate)	Application of method
Level −1	Increase of 10% or more	Method 2 (CO_2 HP used for “Maximum boiling mode” and “Maximum late-night only mode”)
Level 0	0	Uses a conventional domestic hot water system device only and does not apply any energy saving methods.
		Method 2 (CO_2 HP used for “Medium late-night only mode”)
Level 1	10% or more	Method 2 (latent heat recovery gas/oil water heater)
		Method 2 (CO_2 HP used for “Medium boiling mode (Zone V))
		Method 3
Level 2	20% or more	Method 2 (latent heat recovery gas/oil water heater) + Method 3
		Method 2 (CO_2 HP used for “Medium boiling mode” (Zone VI))
Level 3	30% or more	Method 2 (CO_2 HP used for “Energy efficient mode” (Zone V))
Level 4	40% or more	Method 1
		Method 2 (CO_2 HP used for “Energy-efficient mode” (Zone VI))
		Method 2 (CO_2 HP used for “energy-efficient mode”) + Method 3

* The energy saving effect of CO2 HP will vary depending on the boiling mode. See p.279 for details.

Electric water heater with a natural refrigerant heat pump
This document refers to an electric water heater that uses a natural refrigerant heat pump as “electric water heater with a natural refrigerant heat pump”. As heat pump is often abbreviated as “HP” and virtually all natural refrigerants are made of carbon dioxide (CO_2), it is abbreviated mainly as CO_2 HP throughout this text. Since CO_2 is a type of greenhouse gas, it may give the impression of being counterproductive to measures against global warming; however, at approximately 1 kg, the amount of CO_2 that fills the CO_2 HP is miniscule. Fluorocarbon refrigerant, the other type of refrigerant commonly used in heat pumps, creates several hundred to several thousand times more greenhouse effect. Comparatively speaking, CO_2 can therefore be considered to have virtually no environmental burden.

5.4.3 Steps for Considering Domestic Hot Water System Planning and Requirements for Selecting System Type

1. Steps for considering hot water system planning

Step 1 Considering and verifying selection requirements for domestic hot water system type

Consider and verify selection requirements such as site conditions and how the occupants use their domestic hot water system for selecting a domestic hot water system type.

1) Verify the site conditions.

2) Verify how the domestic hot water system will be used.

▼

Step 2 Selecting domestic hot water system type and consider its design/construction, etc.

Select the appropriate domestic hot water system based on requirements in Step 1 and consider adopting energy-efficiency design, construction and the like.

If using solar water heating

Method 1: Adopting solar water heater or solar system (3.5 Solar Water Heating)

Select a water heater to work in conjunction.

If not using solar water heating

Method 2: Using high-efficiency water heater

Consider using a high-efficiency water heater with superior energy efficiency.

1) Latent heat recovery water heater (condensing type water heater) (if using gas or oil as the heat source)

2) Electric water heater with a natural refrigerant heat pump (if using electricity as the heat source)

Method 3: Considering energy saving design and construction for each component of domestic hot water system

Consider which piping method or hot-water volume control method to adopt.

1) Consider piping method.

2) Consider hot water saving devices.

2. Requirements for selecting domestic hot water system method

1) Regarding site conditions

(1) Condition of the building site and other factors

When considering the use of solar water heating, it is important to verify whether or not sunlight can be secured. Verify the condition of the surrounding area of the building site (See Section 3.5.3 Steps for Examining Solar Water Heating on p.107).

(2) Condition of energy supply

Options available for heat source can be limited by whether or not processed natural gas is supplied to the site.

(3) Water pressure

If there is no pump attached to the water heater, it may be difficult to set up a bathroom on the second floor. Other limitations may also occur.

(4) Set-up space

Verify the size of the device to be installed and the space available. If using a domestic hot water system that comes with a hot water tank, the availability of set-up space for the tank becomes an important condition.

(5) Measures against salt damage

When installing a system on a site near the ocean, select a device specifically designed to resist and prevent salt damage. These devices are treated with rust-preventive agents and other special treatments.

(6) If using solar water heating system

If using solar water heating system, it is vital to consider the efficiency of the heat source for water heaters working in conjunction with solar water heating systems.

2) Selecting appropriate device capacity according to occupants' habits and intended use

When selecting a water heater, it is necessary to understand how the occupants actually consume hot water so as to select a device with an appropriate capacity.

(1) Family composition (Number of people)

- Fig. 3 shows the result of a survey on typical hot water consumption according to the household size. All the numbers represent the average hot water volume per day (converted to 40°C) for an entire year.
- The average for a one-person household was approximately 180 L and increased as the household size increased. A four-person household consumed approximately 450 L.
- On the other hand, the average consumption per person showed that a person in a four-person household consumed approximately 112 L while a person in one-person household simply consumed all of the hot water, which was 180 L. This result shows that hot water consumption would be comparatively higher for smaller households. We are currently seeing an increase in the number of smaller households (one- or two-person), which is a source of concern as it may become one of the factors in increased hot water consumption.
- Furthermore, hot water consumption varies greatly even among households of the same size. Fig. 4 shows the distribution of hot water consumption (annual average) among one- and two-person households and three- and four-person households. In both cases, the distribution is spread out with some households consuming more than twice the average consumption.
- If the occupants are known at the time of designing, it is useful to engage in discussions with them on their hot water consumption in advance as hot water consumption varies greatly among households. The verification is also recommended regarding their past fuel consumption (electricity, gas, and oil) or water meter readings (normally for a two-month period, the average consumption for a four-person household is 48 to 60 m3, half of which can be presumed to be for hot water).

(2) Intended use

- It is vital to verify the functions of the bathtub (automatic filling or reheating) as well as whether the water

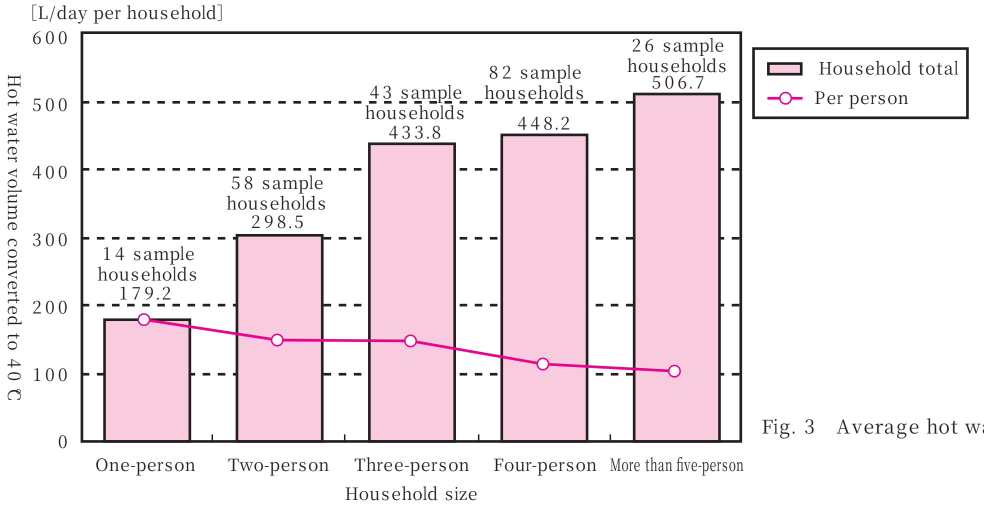


Fig. 3 Average hot water consumption by household size

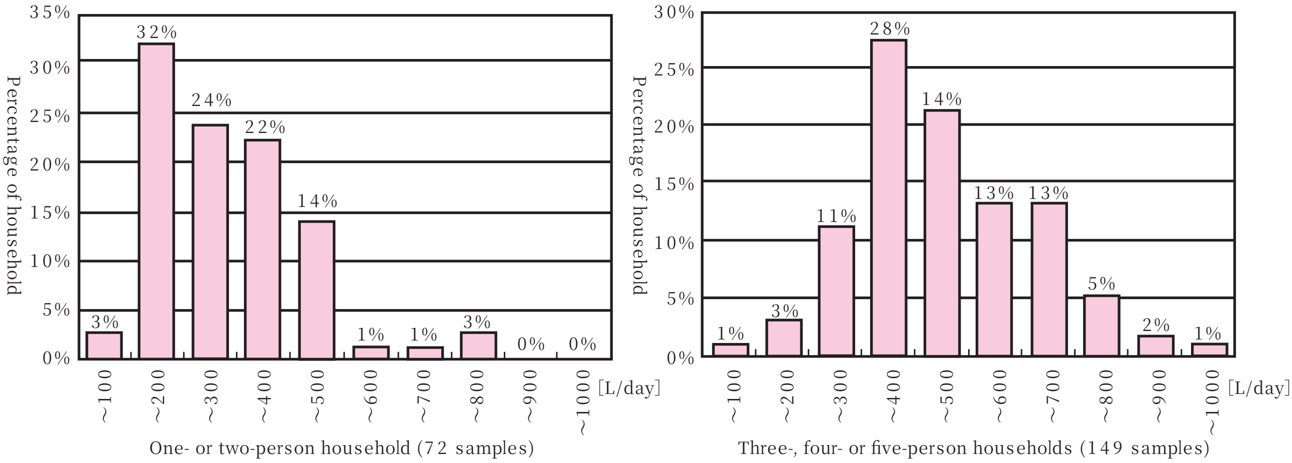


Fig. 4 Distribution of hot water consumption*

* Surveys mainly conducted on detached or multi-family houses in Kanto and Kinki regions

Source: Research Committee on Planning/Evaluation Methods for Energy-efficient Domestic Hot Water System for the New Generation, The Center for Better Living heater will be used in conjunction with heating (floor heating) to be able to select a water heater with an appropriate capacity and functions. The capacity of a water heater generally refers to the instant heating capacity for instant water heaters (most gas and oil water heaters) and the hot water storage capacity for the hot water storage type (electric water heaters and CO_2 HPs). For instant water heaters, the higher the instant heating capacity the bigger the discharge of domestic hot water would be. For hot water storage water heaters, the higher the hot water storage capacity, the more hot water would be available for use during the day as they can store more hot water using late-night power.

- Bathtub functions are standard nowadays and there are very few water heater models that are domestic hot water supply-only without bathtub function.

(3) Determining capacity for hot water storage heaters

- Most water heaters employing electricity as a heat source (such as electric water heaters and CO_2 HPs) are of the hot water storage type that uses late-night power. With this type of water heater, it is important to select an appropriate capacity for the hot water storage tank as this limits the amount of hot water available for use during the day. The most common capacities for a hot water storage tank are 300 L, 370 L, and 460 L. Although very rare, there are also tanks with a capacity of less than 200 L or more than 500 L.
- As the hot water storage tank stores water at a high temperature (65°C or more), the hot water is used after mixing it with tap water. This means that the actual amount of hot water available for use is even greater than the capacity of the tank.
- A typical four-person household usually selects 460 L as the capacity for their electric water heater while 370 L is the most common for CO_2 HPs. However, as mentioned previously, hot water consumption varies greatly among households. Select larger hot water storage tank if the hot water consumption is expected to be high.
- If a household consumes extremely large or extremely small amount of hot water, a hot water storage heater is not an appropriate choice.

(4) Determining capacity of instant water heaters

- Most water heaters employing gas or oil as a heat source are of the instant type. As this type heats water at the time of supply, the amount of hot water available at any given instant is limited.
- The instant heating capacity of a water heater is customarily expressed in numbers (#) with bigger numbers being capable of simultaneously supplying more hot water for multiple uses. Currently, #32 is roughly the maximum available for home use.
- However, a more common capacity (#20 to 24) is more than enough to handle the hot water consumption of an entire four-person family. Even during the winter months, it can supply more than enough hot water for the shower and the kitchen simultaneously.
- The capacity of the reheat function of a bathtub is usually around 10 kW, which is more than enough capacity for a typical household. (As reheating reduces the energy efficiency, it is recommended to avoid using it whenever possible.)
- If space heating function by hot water is available, it is necessary to determine the needed capacity after considering factors such as the size of the area to be heated and the insulation performance of the house.
- Unlike the hot water storage type, the instant type does not put a limit on the amount of hot water it can supply per day. It is common to select this type for small households (one- or two-person) with low hot water consumption as well as households with extremely high hot water consumption.

3) Relationship with costs

- Although the initial cost of energy-efficient domestic hot water systems can be relatively high, it is best to select the type while considering the reduction in CO_2 emissions as well as the reduction in running cost.
- Using hot water saving devices such as thermostatic mixer faucets or devices with shut-off valves is highly recommended as there is very little initial cost associated with them and their effectiveness has been validated.
- Some government agencies and local governments offer subsidy programs from which people can benefit. It is therefore necessary for the designers to be thoroughly familiar with these programs from the point of view of the client.

* In the past, electric water heaters could not heat water during the day when they ran out of hot water as late-night electricity contracts were the standard. The capacity for those water heaters was therefore set well above the actual need to make allowance for extra water. On the other hand, the use of CO_2 HPs is usually based on a time-of-day contract, which allows heating during the day. For this reason, it is common for CO_2 HPs to have a smaller capacity than electric water heaters so as not to store an excessive amount of hot water.

* "Domestic hot water capacity #24" denotes that the water heater has the capacity to heat 24 L of water from 15°C to 40°C in one minute. "#1" is equivalent to 1.75 kW

3. Styles and types of water heater

1) Styles of water heater

There are a variety of styles of water heater currently available. Table 3 shows some of them and the most common fuel and characteristics.

Table 3 Styles, fuel and characteristics of water heaters

Instant type	Gas and oil	・The burner heats the water in the boiler the moment the hot water is supplied. ・The control of the hot water discharge temperature has vastly improved due to technological advances. ・Very popular due to its large output and the compact size.
Hot water storage type	Electric water heater (not mentioned in this document)	・Mainly uses late-night power to heat and store hot water heated by an electric heater. ・Requires a large set-up space as the size of the hot water storage tank is substantial. ・Compared to heat pumps, its efficiency is significantly low as it uses an electrical resistor.
	CO_2 HP	・Similar to the electric water heater, it uses late-night power; however, the efficiency during the heating has greatly improved by using a CO_2 heat pump. ・Note that its efficiency is heavily dependent on the boiling mode. ・As it uses a natural refrigerant (CO_2), its global warming coefficient and the environmental burden are smaller compared to the conventional fluorocarbon refrigerant. ・Requires a large set-up space as the size of the hot water storage tank is substantial. ・Becoming rapidly more common in recent years.
	Heat pumps other than CO_2 HP	・Commonly use fluorocarbon refrigerant. ・Tend to have a lower efficiency at high temperature compared to those using CO_2 refrigerant.
Instant hot water storage type	Oil	・As it is relatively difficult to control combustion with oil, it tends to have a smaller hot water storage tank to control the temperature change. ・As it is becoming more common to use oil for instant water heaters, the number of new installations for this type is decreasing.

2) Functions of water heaters

Water heaters possess a variety of functions (Table 4). In the past, it was common to have different models and functions for different purposes. For instance, the bathroom would have a bath boiler while a small water heater would serve the kitchen. However, now that the central domestic hot water system is becoming more commonplace, we are seeing one main water heater equipped with all the functions. One notable characteristic unique to Japan is that we tend to focus more on the functions related to bathing.

・There are two types of piping for the bathtub system: single-pipe and double-pipe. The single-pipe system limits the number of functions as it does not allow circulation.
・A domestic hot water faucet dedicated to the bathtub was a must in the past; however, we are now seeing many bathtubs without a faucet.
・In recent years, an increasing number of water heaters are being equipped with a space heating function partly due to the popularity of floor heating. Table 4 shows a variety of functions that enhance the convenience of the water heater. It should be noted, however, that if not used properly, these functions could be detrimental to the energy-efficiency performance by, for example, disturbing the temperature stratification in the hot water storage tank.
・For more detail on energy-efficient bathing, see Key Point on p.285.

Table 4 Functions of water heaters

Domestic hot water supply function		・This function directly supplies hot water from the hot water pipe and faucet. Models offering only domestic hot water supply as a function are now rare as the central domestic hot water system has become commonplace.
Bathtub functions	Automatic filling	・This function fills the bathtub with hot water at the set temperature to the set water level.
	Keep-warm (double-pipe only)	・This function maintains the set water temperature for a set period of time after filling. ・Some of the water in the bathtub is returned to the water heater and released after being reheated. ・As this function requires hot water circulation in the bathtub, the bathtub piping must be double-pipe. ・Some water heaters can also maintain the water level.
	Reheat (double-pipe only)	・This function resembles the “keep warm” function but it reheats water that has reached a low temperature long after filling (i.e. remaining water from the day before). ・As this function requires much more reheating capacity than the “keep warm” function, some models equipped with the “keep warm” function do not offer the “reheat” function.
	Hot water adding	・This function adds a set amount of high-temperature hot water to cold water in the bathtub.
	Water level maintenance	・This function adds hot water when the water level in the bathtub decreases.
Heating functions	Low temperature (60°C or less)	・This function heats and circulates hot water mainly for floor heating.
	High temperature (Approx. 80°C)	・This function circulates and supplies high-temperature hot water to a bathroom heater/dryer or a radiator.

5.4.4 Energy Saving Methods in Domestic Hot Water System Planning

Method 1 : Adopting a solar water heater or a solar system

See Section 3.5 Solar Water Heating on p.102.

Method 2: Using a high-efficiency water heater

Table 5 shows a comparison of the energy saving effects by heat source for the types of high-efficiency water heaters recommended in this document and the traditional domestic hot water system.

Table 5 Recommended high-efficiency water heaters and energy saving effects

Heat source	High-efficiency water heater (standard name given in parentheses)		Energy saving effect*
Gas	Latent heat recovery gas water heater (Eco Jozu)		Approx. 15%
Oil	Latent heat recovery oil water heater (Eco Feel)		Approx. 15%
Electricity	Electric water heater with a natural refrigerant heat pump (CO2 HP and Eco Cute)	Maximum boiling mode: late-night only maximum mode	-10% (increase)
		Late-night only medium mode	0%
		Medium boiling mode	10% (Zone V) 20% (Zone VI)
		Energy saving mode	Approx. 35% (Zone V) Approx. 40% (Zone VI)

*1: The calculation for the energy saving effect for gas and oil water heaters took power consumption into account.
*2: The energy saving effect for CO_2 HP may vary depending of its boiling mode. See p.279 for details.

Key Point

Efficiency of water heater

- Although efficiency values indicated in catalogs are used when designing, it should be noted that these values are not based on imitated actual usage as they are measured under certain set conditions relatively easy to recreate (Table a). Furthermore, these values cannot necessarily be compared since their definitions also vary depending on the type of heat source used by the water heater.
- Catalog efficiency figures have been difficult to compare under common conditions in the past as they vary from model to model. This document therefore evaluates the performance of various types of water heaters uniformly by conducting tests based on actual usage.

Table a Conditions for measuring efficiency shown in catalogs

Type	Standard name	Characteristics and points of caution
Gas water heater	Japanese Industrial Standards JIS S 2109 Domestic gas water heater	• "Heat efficiency" is the ratio between the amount of hot water heating and the amount of gas heat generated when the water heater was continuously operated at its maximum capacity (rated). • Does not take into account the actual usage including the intermittent partial load. • Does not include power consumption. • Outside conditions, etc., are set and do not take into account seasonal changes, etc. • The efficiency for reheating is referred as "bath heating efficiency", which is the efficiency to heat the bath water (increase in water temperature by 30 °C for 180 kg of water between 10 °C and 25 °C).
Oil water heater	Japanese Industrial Standards JIS S 3031 General Provisions on Testing Methods for Oil Heating Appliances	• The ratio between the amount of hot water heating and the amount of oil heat generated when hot water was continuously operated at its maximum capacity (rated). • Does not take into account the actual usage including the intermittent partial load. • Does not include power consumption. • Outside conditions and other factors are set and do not take into account seasonal changes, etc.
Heat pump water heater (CO_2 HP and others)	Japan Refrigeration and Air Conditioning Industry Association JIRA4050:2007 Domestic heat pump water heater	• Provides information on items related to safety and efficiency regarding domestic heat pump water heaters including CO2 HPs. • Efficiency of a heat pump alone under four different conditions (COP for energy consumption efficiency). • Conducts hot water output for a day of imitated actual usage (IBEC L mode) and calculates the annual efficiency of the entire system (annual performance factor of hot water supply or APF). • For APF, the boiling mode is generally presumed to be the factory-set mode (Indicated in the catalog when it differs). • Needs to be converted by primary electricity conversion as it uses secondary electric conversion for both COP and APF.

* Efficiency and energy consumption figures mentioned in Chapter 5 and Chapter 6 were obtained from the results of tests conducted based on imitated actual usage. The values thus may vary from the catalog values shown on the left. Note, however, that the section on the heat balance of domestic hot water systems in Chapter 5 uses the catalog values shown on the left for clarity and convenience.

- As catalog efficiency values for water heaters such as "heat efficiency", COP, and APF are measured under specific conditions, they generally tend to differ from the efficiency values when the water heaters are actually used. Furthermore, regional differences in weather conditions are not taken into account, either.
- The efficiency values used to estimate energy consumption, as well as actual energy consumption, were all obtained by conducting tests with actual usage in mind. Regional differences in weather conditions have also been taken into account. The values shown therefore will differ from the catalog values.
- IBEC L mode has been long used in the past as the typical hot water discharge pattern (domestic hot water supply mode) that imitates the actual consumption of domestic hot water; however, this mode was created based on the hot water consumption of a four-person household 30 years ago and no longer fits our current lifestyle. For instance, the number of hot water discharges was presumed to be only 13 times a day.
- This document uses "Corrected M1 mode", which is a model for a hot water discharge mode that imitates actual usage. This mode is based on a typical four-person household of today and takes into account the latest information to create the most standardized values for averages, day-to-day changes, and distributions throughout the day. "Corrected M1 mode" is comprised of six typical days with actions during the day set in detail (Table b). It also recreates short bursts of hot water discharges common in real life and counts a maximum 38 hot water discharges a day. The average value for "Corrected M1 mode" for a four-person household is set at 450 L/Day, which is the actual average, as shown in the figure on the next page. Furthermore, daily changes are designed to be standardized over the course of the month.
- Tests were mainly conducted between 2004 and 2008 at the Validation Experiment Building of the Building Research Institute, an independent administrative agency in Tsukuba City, Ibaragi Prefecture. We recreated the efficiency during actual usage by actually opening and closing faucets according to the above-mentioned "Corrected M1 mode". The results obtained were then adjusted for differences in weather conditions and noted by region.

Table b　Hot water discharge schedule for typical six days of “Corrected M1 Mode”

Weekday (Large)			Weekday (Small)			Weekend at home (Large)			Weekend at home (Small)			Weekend away (Large)			Weekend away (Small)		
Time	Amount (L)	Faucet	Time	Amount (L)	Faucet	Time	Amount (L)	Faucet	Time	Amount (L)	Faucet	Time	Amount (L)	Faucet	Time	Amount (L)	Faucet
06:30	3	Washing room	06:30	3	Washing room	07:15	10	Washing room	07:15	10	Washing room	06:30	2	Washing room	06:30	3	Washing room
06:35	3	Washing room	06:35	3	Washing room	07:55	10	Washing room	07:55	10	Washing room	07:45	2	Washing room	07:45	3	Washing room
07:15	5	Kitchen	07:15	5	Kitchen	08:10	10	Washing room	08:10	10	Washing room	08:00	2	Washing room	08:00	3	Washing room
07:20	10	Kitchen	07:20	10	Kitchen	08:30	10	Kitchen	08:30	10	Kitchen	08:15	2	Washing room	08:15	3	Washing room
07:25	3	Washing room	07:25	3	Washing room	08:35	10	Kitchen	08:35	10	Kitchen	08:45	10	Kitchen	08:45	10	Kitchen
07:30	3	Washing room	07:30	3	Washing room	08:40	10	Washing room	08:40	10	Washing room						
08:25	3	Washing room	08:25	3	Washing room							20:00	6	Washing room	20:00	9	Washing room
09:30	3	Washing room	09:30	2	Washing room	11:55	12	Washing room	11:55	12	Washing room						
10:15	3	Washing room	10:15	2	Washing room	12:45	20	Kitchen	12:45	15	Kitchen	20:30	150	Bath			
						12:50	20	Kitchen	12:50	15	Kitchen						
12:45	5	Kitchen	12:45	5	Kitchen	12:55	20	Kitchen	12:55	20	Kitchen	20:50	25	Shower	20:50	25	Shower
12:50	10	Kitchen	12:50	10	Kitchen							20:55	25	Shower	20:55	25	Shower
13:45	3	Washing room	13:45	2	Washing room	16:00	9	Washing room	16:00	9	Washing room						
												21:15	25	Shower	21:15	25	Shower
16:00	3	Washing room	16:00	2	Washing room	17:05	25	Shower	17:05	25	Shower	21:20	25	Shower	21:20	25	Shower
17:15	3	Washing room	17:15	2	Washing room	17:10	25	Shower	17:10	25	Shower	21:45	2	Washing room	21:45	3	Washing room
18:00	3	Washing room	18:00	2	Washing room	17:15	3	Washing room	17:15	3	Washing room						
18:15	3	Washing room	18:15	2	Washing room							22:00	25	Shower	22:00	25	Shower
						18:00	3	Washing room	18:00	3	Washing room	22:05	25	Shower	22:05	25	Shower
19:15	3	Washing room	19:15	2	Washing room	18:25	12	Washing room	18:25	12	Washing room	22:15	2	Washing room	22:15	3	Washing room
19:20	3	Washing room	19:20	2	Washing room												
19:25	3	Washing room	19:25	2	Washing room	19:30	20	Kitchen	19:30	15	Kitchen	22:30	25	Shower	22:30	25	Shower
						19:35	20	Kitchen	19:35	15	Kitchen						
20:15	15	Kitchen	20:15	10	Kitchen	19:40	20	Kitchen	19:40	15	Kitchen	22:35	25	Shower	22:35	25	Shower
20:20	15	Kitchen	20:20	10	Kitchen	19:45	20	Kitchen	19:45	15	Kitchen	23:00	2	Washing room	23:00	3	Washing room
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20:30	15	Kitchen	20:30	10	Kitchen	19:55	20	Kitchen	19:55	15	Kitchen						
20:35	15	Kitchen	20:35	15	Kitchen												
20:40	15	Kitchen	20:40	15	Kitchen	20:45	150	Bath	20:45	150	Bath						
20:45	150	Bath	20:45	150	Bath	21:15	25	Shower	21:15	25	Shower						
						21:20	25	Shower	21:20	25	Shower						
20:55	20	Shower	20:55	20	Shower	21:45	5	Washing room	21:45	5	Washing room						
21:00	3	Washing room	21:00	3	Washing room												
						22:00	25	Shower	22:00	10	Shower						
21:25	25	Shower	21:25	10	Shower	22:05	25	Shower	22:05	10	Shower						
21:30	25	Shower	21:30	10	Shower	22:10	5	Washing room	22:10	5	Washing room						
21:45	3	Washing room	21:45	3	Washing room												
						22:30	25	Shower	22:30	10	Shower						
22:00	10	Shower	22:00	10	Shower	22:35	25	Shower	22:35	10	Shower						
22:05	10	Shower	22:05	10	Shower	23:00	11	Washing room	23:00	11	Washing room						
22:15	3	Washing room	22:15	3	Washing room												
22:30	25	Shower	22:30	10	Shower												
22:35	25	Shower	22:35	10	Shower												
23:00	3	Washing room	23:00	3	Washing room												
23:05	3	Washing room	23:05	3	Washing room												
Total	470	L	Total	380	L	Total	650	L	Total	550	L	Total	380	L	Total	240	L
# of actions	38	回	# of actions	38	回	# of actions	32	回	# of actions	32	回	# of actions	18	回	# of actions	17	回

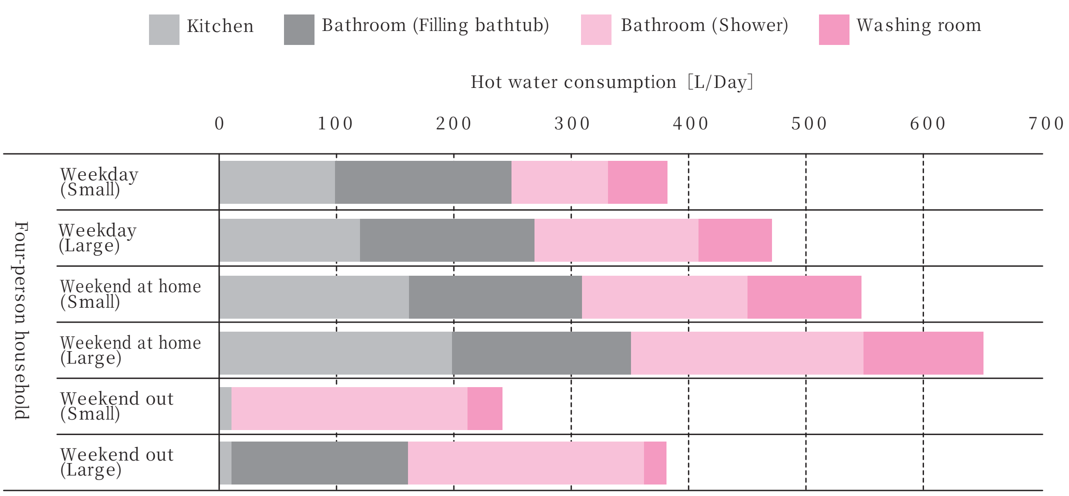


Fig.　Hot water consumption during typical six days of “ Corrected M1 Mode ”

5

Chapter 5
Energy-efficient Equipment Technology
(Elemental Technology Application Method 3)

1. Latent heat recovery gas water heater ("Eco Jozu")

- The "heat efficiency" of a conventional gas water heater for the domestic hot water function is approximately 83% while that of a more efficient latent heat recovery gas water heater is approximately 95%. (The heat efficiency is a type of efficiency based on the amount of gas heat set by the Japanese industrial Standards (JIS S2109) and does not include power consumption.)
- The reason for its increased heat efficiency is that it recovers the heat created by vapor (latent heat) mixed in the exhaust gas instead of eliminating it as a conventional water heater would do. This recovered heat is then used to preheat the tap water (Fig. 5).
- Fig. 5 is based on the test results using "Corrected M1 Mode", which imitates the actual usage. The efficiency during the actual usage is slightly lower than the catalog efficiency; however, it still demonstrates high efficiency at approximately 90% even after including power (secondary energy conversion).
- The "bath heat efficiency" based on the reheating of bath water is approximately 80%, which is quite similar to that of a conventional water heater. This is due to the decreased efficiency of latent heat recovery during circulation heating.
- The Energy Conservation Law (Law Concerning Rational Use of Energy) defines the energy consumption efficiency of gas water heaters and these values are generally indicated in catalogs as well. It is obtained by calculating the weighted average of "(hot water) heat efficiency" and "bath heat efficiency" at the ratio of 3.3:1.
- The appearance, size and the installation site of a latent heat recovery gas water heater are very similar to those of a conventional instant gas water heater (Fig. 6). Its price has come down considerably since it was first introduced in 2000 when it was significantly more expensive than a conventional type. Since the price difference between the two types are now small, we hope that latent heat recover gas water heaters will become more and more popular.
- Although most latent heat recovery gas water heaters are equipped with bathtub functions as well as space heating by hot water, we are also seeing recently a few models that perform water heating function only. Some models are compact-sized such as the through-the-wall type balanced flue water heater that fits into an exhaust opening (Fig. 6).
- The domestic hot water capacity of many models is #24, which is more than enough to use for a shower during the winter when the domestic hot water temperature decreases.
- Its efficiency when in use is barely influenced by the amount of hot water consumption, which is a common characteristic of all instant water heaters. Compared to conventional water heaters, this type is able to maintain higher efficiency regardless of the family composition of the household where it is installed or its hot water consumption. However, instant water heaters tend to experience a decrease in efficiency when a

Glossary: Balanced flue water heater
A balanced flue water heater is a type of water heater that utilizes natural convection, as opposed to mechanical power for air supply and exhaust when burning gas. Because of its use of natural convection, its air supply and exhaust opening (flue) tends to be large. In the past, a bathtub water heater was often installed next to the bathtub. During renovation, it is often the case that the bathtub water heater is eliminated to make more room in the bathroom and a "through-the-wall" type compact water heater is fitted into a large air supply exhaust opening in its stead.

Fig. 6 Example of latent heat recovery gas water heater

Through-the-wall type

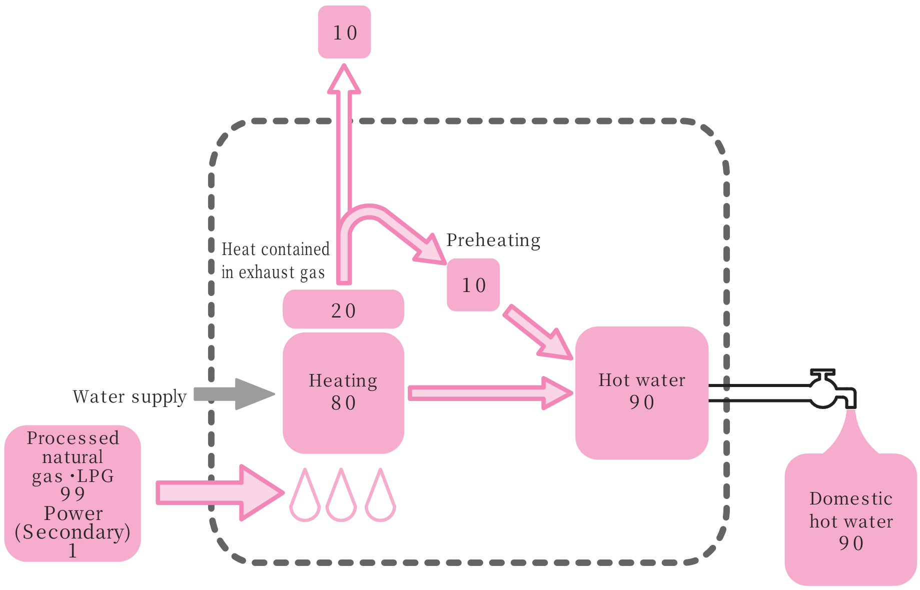


Fig. 5 Secondary energy flow of latent heat recovery gas water heater (Estimated annual average values for Kagoshima)

small amount of hot water was discharged in bursts. It is important to be mindful not to inadvertently discharge hot water if using a single-lever faucet (See Key Point on p.287).

- As it recovers latent heat contained in vapor, the vapor is eliminated from the device as water (drainage water). It is necessary to take this into consideration when designing so that the drainage water can be appropriately eliminated, for example, through a rainwater drainpipe.
- The drainage water is acidic in nature; however, the device has an integrated neutralizing agent that renders it harmless.

2. Latent heat recovery oil water heater ("Eco Feel")

- The continuous water heating efficiency of a conventional oil water heater is approximately 86% while that of a more efficient latent heat recovery oil water heater is approximately 95%. (The continuous water heating efficiency is a type of efficiency set by the Japanese industrial Standards (JIS S3031) and does not include power consumption.)
- The technologies to increase the heat efficiency are the same as those for latent heat recovery gas water heaters. It recovers the heat created by vapor (latent heat) mixed in the exhaust gas instead of eliminating it as was done in the past. This recovered heat is then used to preheat the tap water (Fig. 7).
- This device was first introduced in 2006 and is relatively new to the market. Not many models are therefore available. Although domestic hot water supply-only models (Fig. 8) were dominant in the beginning, we are now seeing models with bathtub functions as well as space heating by hot water.
- As with latent heat recovery gas water heaters, the drainage water treatment needs to be taken into consideration.
- Fig. 7 is based on the test results using "Corrected M1 Mode", which imitates the actual usage. The efficiency during the actual usage is slightly lower than the catalog efficiency; however, it still demonstrates high efficiency at approximately 90% even after including power (secondary energy conversion).

Fig. 8
Example of latent heat recovery oil water heater

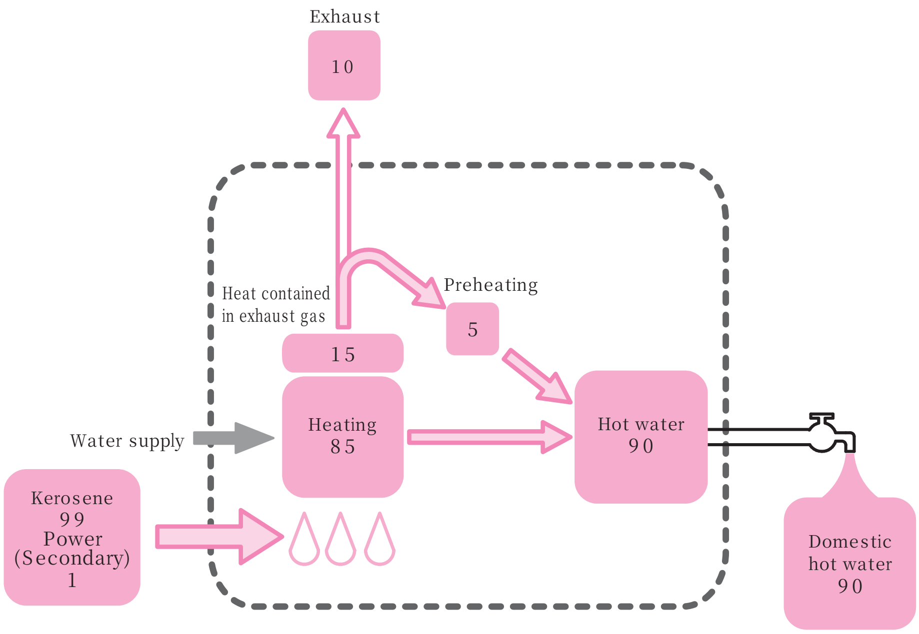


Fig. 7 Secondary energy flow of latent heat recovery oil water heater (Estimated annual average values for Kagoshima)

3. Electric water heater with natural refrigerant heat pump (CO_2 HP: "Eco Cute")

- A heat pump is a highly efficient heat source that has traditionally been used for space heating and cooling devices such as air conditioners. By compressing the refrigerant and transferring the heat through the heat collection section and the heat releasing section, it makes it possible to obtain more heat than the energy consumed. For home use, an electric motor is generally used for power (Fig. 9).
- As a heat pump is a device that transfers heat, it requires a heat source from which this can be collected. Generally, the most common hump pump is the air type that uses the outside air as its heat source; however, the efficiency of the heat pump can fluctuate significantly according to the season as the outside air

* It was difficult in the past to reach a high temperature necessary for water heating with a heat pump using fluorocarbon refrigerant. Some models do continue to use fluorocarbon refrigerant today; however, they cannot be labeled "Eco Cute" as they do not use natural refrigerant.

goes through considerable seasonal changes in temperature.

- In hot humid regions where the outside air temperature is high throughout the year, the heat collection from the air is easier and the energy efficiency remains high. It can therefore be said that CO_2 HP is a type most suited for hot humid regions.
- With the introduction of CO_2 HP, which uses high-pressure CO_2 refrigerant, domestic hot water supply through a heat pump became possible. Generally, CO_2 HP can provide hot water between 65 and 90°C (HP hot water discharge temperature).
- Since it first appeared on the market in 2001, its efficiency has rapidly improved. Its functions have also multiplied and models that offer not only water heating but also bathtub functions as well as space heating by hot water are becoming more and more prevalent.
- Those equipped with a bathtub circuit can be divided into two categories: single-pipe system (reheating and keep-warm functions not available) and double-pipe system (reheating and keep-warm functions available).
- It is necessary to ensure that there is enough set-up space after taking into consideration the size and the shape of the heat pump unit as well as the hot water storage unit that comprise the electric water heater with a natural refrigerant heat pump (Fig. 10).
- A common CO_2 HP is the "single cylinder" type, which has a cylindrical hot water storage tank. Another type, called the "double cylinder" type with two small side-by-side hot water storage tanks, aims to keep the size of the hot water storage unit compact; however, as it increases the surface area, it also increases the heat loss.
- Using a heat pump will achieve greater efficiency than that of a heater-type; however, it is a hot water storage type and uses late-night power and it is therefore essential, for energy-saving purposes, to select an appropriate tank capacity according to the household where it is being installed.
- The typical household size is currently set for a three-person household, and 300 L, 370 L, and 460 L are most common. The general recommendation for two- to four-person households is 300 L, for three- to five-person households, 370 L, and for four- to six-person households, 460 L. The product range of those possessing a capacity of 200 L or less as well as 500 L or more are limited. In consequence, there is currently no recommended product for one- or two-person households.
- As the hot water storage tank stores water at a high temperature (usually 65°C or more), the hot water is used after mixing it with tap water. This means that the actual amount of hot water available for use is even greater than the capacity of the tank.
- Unlike the instant type, its efficiency tends to fluctuate significantly depending on how it is used (See Key Point on p.279).
- Fig. 9 is based on the test results using "Corrected M1 Mode", which imitates actual usage. It demonstrates that, by collecting heat from the air, the power required is considerably reduced compared to heater type electric water heaters.

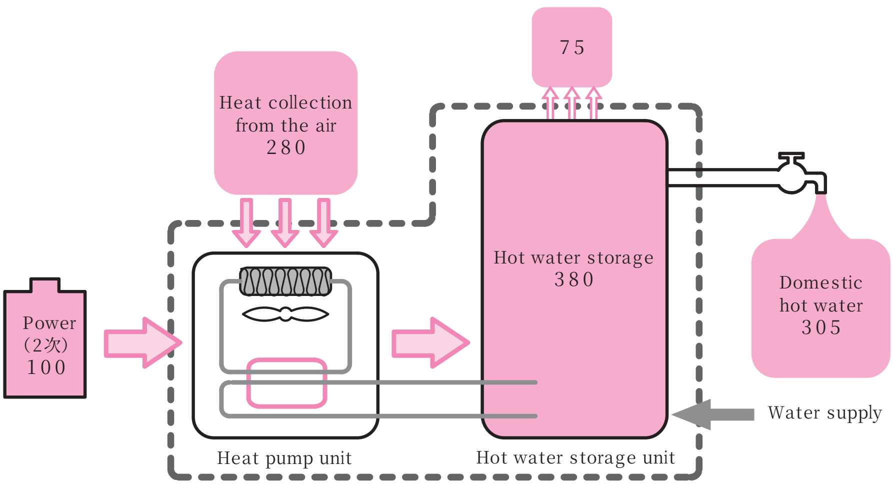


Fig. 9 Secondary energy flow of electric water heater with natural refrigerant heat pump
(Estimated annual average based on 2005 model of "Energy-saving mode" by Company A in Kagoshima)

Fig. 10
Example of electric water heater with natural refrigerant heat pump

Heat pump unit

Hot water storage unit

Key Point

Understanding efficiency according to fuel type

The efficiency evaluation figures do not mean the same thing for gas, oil and electricity. This is why, for example, the heat efficiency of a gas or oil water heater cannot be compared to the annual performance factor of hot water supply (APF) of a CO_2 HP.

- "Power 100" on Fig. 9 on p.276 expresses the secondary energy supplied to the water heater. Secondary energy is a pure electric energy generated by a power station. However, the power generation efficiency of a power station is limited as it can only convert part of the heat generated by burning fuel into electricity. The amount of heat that was consumed at the power station is called primary energy.
- It is common to use the primary energy conversion when comparing electricity, gas, and oil. Currently, it is determined that 9,760 kJ of primary energy is required to generate 1 kWh (3,600 kJ) of electricity. In other words, a power station consumes roughly 2.7 times more energy than the amount of electricity it actually generates and supplies. For devices that use late night power, the primary energy conversion values differ according to the time of the day, that is 9,970 kJ/kWh during daytime (07:00 to 23:00) and 9,280 kJ/kWh for late-night hours (23:00 to 07:00).
- Power worth 100 secondary energy is equivalent, when converted, of roughly 270 primary energy . Based on the primary energy, then, the energy input on Fig. 9 would be approximately 270 (= 100 x 9,760/3,600). Hot water discharge obtains energy worth 305 and its efficiency would be 113% ((305/270) x 100 = 113%).
- As it is a heat-pump type that collects heat from the air, it can be said that CO_2 HP is highly efficient even based on the primary energy conversion that takes into account the loss at the power station and the power transmission line.
- On the other hand, a previously popular electric water heater uses a heater and generates heat worth 100 using secondary energy worth 100. For this reason, its efficiency based on the primary energy conversion is extremely low (Fig.). Consequently, the heat-pump type must be selected if the heat source of the device is electricity.
- Note that the heat efficiency of gas or oil water heaters generally measures only the amount of heat generated by gas or oil and does not take into account the electricity consumed by parts such as blowers, pumps, the control circuit, and the freeze protection circuit. The efficiency is also measured when discharging hot water at the maximum output (rated) and differs from the efficiency when discharging a small quantity intermittently, which often happens in actual usage.
- Note also that APF for CO_2 HP takes into consideration the temperature changes throughout the year while the heat efficiency for gas or oil is measured under constant outside air conditions .

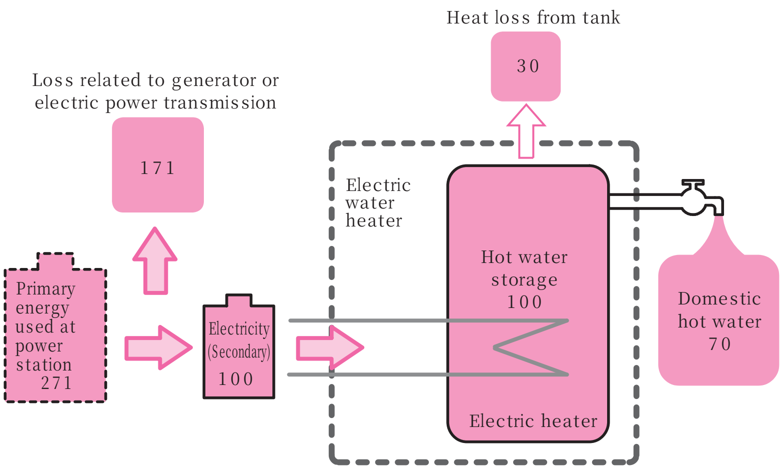


Fig. Efficiency of electric water heater

Secondary energy efficiency = 70 / 100 = 70%
Primary energy efficiency = 70 / 271 = 26%

Key Point

Efficiency indicated for Eco Cute

There are two types of efficiency values indicated in catalogs for CO_2 HP.

- In-between seasons energy consumption efficiency (In-between seasons COP)
- Annual performance factor of hot water supply (APF)

(1) Energy consumption efficiency (Heat pump unit)

- The energy consumption efficiency (COP) has traditionally been used as an efficiency value to indicate the performance of the heat pump unit alone and the amount of water heating made by the power equal to 1. On Fig. 9, the power worth 100 makes heat equal to 380 and COP is therefore 3.8. As the most common CO_2 HPs use air as a heat source, their efficiency is heavily influenced by seasonal changes in the outside air temperature. To address this issue, The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) has set the following four seasonal conditions.

Table: Testing conditions for heat pump unit set by JRAIA Unit (°C)

	Outside air temperature	Temp. of water entering HP	HP discharge hot water temperature
Summer	25	24	65
In-between season (rated)	16	17	65
Winter	7	9	65
Winter using high temp. setting	7	9	Maximum temp. (Commonly 90°C)

* Winter conditions may not be included in catalogs for the energy consumption efficiency (COP) of a heat pump.

- Generally, the energy consumption efficiency indicated as rated has been measured under the in-between season conditions; however, efficiency values for the summer, winter, or winter using a high temperature setting can be obtained by dividing the heating capacity for each by the power consumption.
- Fig. a shows that the efficiency is at its highest during the summer when the outside air temperature is at its highest and decreases during the winter. The efficiency was the lowest during the winter using a high temperature setting. It is also noticeable that the efficiency of heat pumps has improved dramatically due to technological advances.
- COP value is calculated using the amount of electricity obtained by secondary energy conversion.

(2) Annual performance factor of hot water supply (APF)

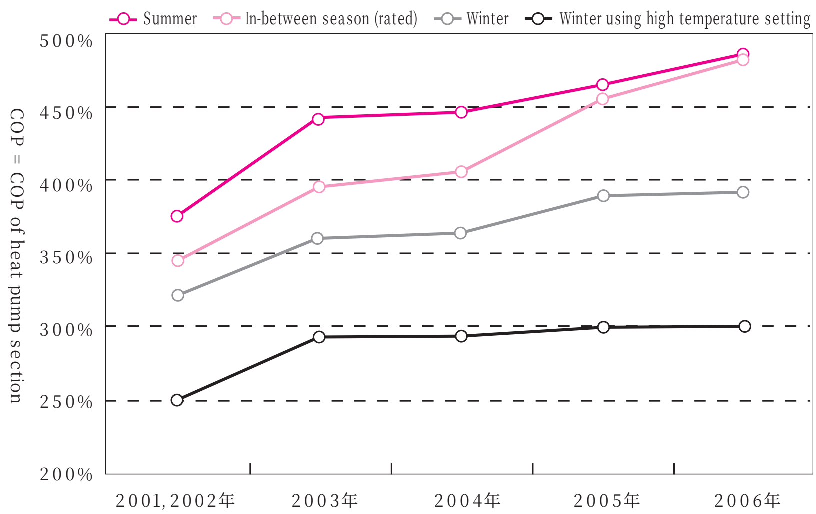


Fig. a Example of improvement in energy consumption efficiency (COP) of heat pump unit

- CO_2 HP not only comes with a heat pump unit but is also equipped with a hot water storage unit. As shown in Fig. 9 on p.276, heat loss can occur due to heat loss from the hot water storage tank. The heat loss needs to be taken into consideration here as CO_2 HP makes mostly use of late-night power and is required to store hot water for an extended period of time until the demand peaks during the evening. The heat loss can be reduced by reinforcing the insulation of the storage tank; however, the effect of this could not be evaluated using the energy consumption efficiency, which is designed to measure the performance of a heat pump alone.
- To address this issue, catalogs began indicating the annual performance factor (APF) of hot water supply. APF demonstrates the efficiency of the entire system including the hot water storage unit based on a hot-water discharge pattern mode called "IBEC L mode".
- Another characteristic of APF is that, as is evident in its name, it takes into account changes in outside temperature throughout the year (average temperatures in Tokyo and Osaka) and indicates the efficiency for the whole year. Unlike the energy consumption efficiency, it is thus unnecessary for us to consider values according to the season when using APF.
- APF is therefore a useful index that indicates the efficiency of the entire water heater including the hot water storage unit. It is recommended that you select a CO2 HP model with a higher APF.
- It should be noted that APF is usually based on the presumed weather conditions in Tokyo and Osaka. Generally speaking, devices would perform at a lower efficiency than their APF in colder regions and at a higher efficiency in hot humid regions. Furthermore, APF is measured based on one boiling mode (detailed explanation provided later in the chapter) and the efficiency can vary when using different boiling modes.
- APF, like COP, is calculated using the amount of power obtained from the secondary energy conversion (See p.277) and needs to be converted into primary energy when comparing with gas or oil.

* Although both COP and APF are used for the efficiency of air conditioners, they are called "space cooling and heating average energy consumption efficiency" and "annual energy consumption efficiency", respectively. As both are devices utilizing heat pumps, the content for these indicators are mostly identical.

Key Point

How to use CO_2 HP efficiently

(1) Improving the efficiency of CO_2 HP

- One of the characteristics of CO_2 HP is that its efficiency can vary greatly depending on how it is used. Occupants therefore need to understand the correct way of using the device so as to maximize its potential.
- The key point to maximize the potential of CO_2 HP is to use up the entire hot water store for the day. In other words, it is important to store the minimum heat quantity necessary.
- Since "Stored hot water heat quantity = amount of stored hot water x (hot water storage temperature – tap water temperature)", to minimize the stored hot water heat quantity, we can either "reduce the quantity of stored hot water" or "lower the stored hot water temperature". If the stored hot water heat quantity is kept low, it will also reduce the wasteful heat loss from the hot water storage unit as well. Furthermore, lowering the stored hot water temperature (≈ HP hot water discharge temperature) will not only reduce heat loss but also improve the efficiency of the heat pump. With better efficiency for both the hot water storage unit and the heat pump unit, the efficiency of the device as a whole improves greatly (Fig. a).
- If the remaining hot water display on the remote control shows that there is little hot water at the end of the day, it means that the user is taking full advantage of the performance potential of CO_2 HP (Fig. b). By the same token, if the remaining hot

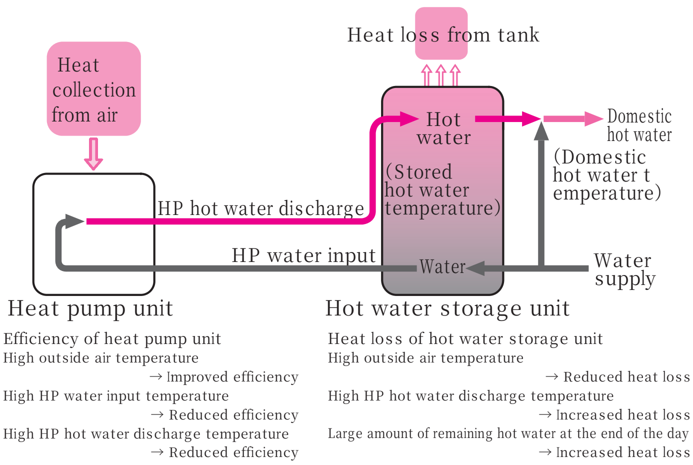


Fig. a Key points and points of caution to maximize potential of CO_2 HP

Note 1: The temperature of the hot water discharged from HP is called "HP hot water discharge temperature" while the temperature of the hot water stored in the tank is called "stored hot water temperature". Theoretically, both temperatures would be identical if it were not for the slight heat loss from the hot water storage tank. In reality, the stored hot water temperature is slightly lower.

Note 2: The temperature of the hot water can usually be set by the user via remote control. This temperature, called the "domestic hot water temperature", refers to the temperature of the hot water being discharged from the domestic hot water supply opening of CO2 HP toward the faucet. Note that CO2 HP mixes water with the stored hot water to supply domestic hot water and its stored hot water temperature is therefore higher than the domestic hot water temperature. Setting this domestic hot water temperature lower is an effective way to lower the HP hot water discharge temperature.

Note 3: Generally, the lower limit of the stored hot water temperature is set at 65 ° C for storage water heaters to prevent the spread of Legionella bacteria.

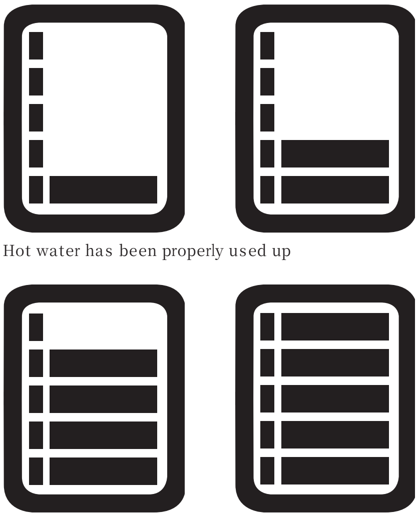


Fig. b Example of remaining hot water display
This model displays the remaining hot water level with black bars. Verify the details of the remaining hot water display with the user ' s manual.

water level is high at the end of the day, it means that the unit has been storing unnecessary remaining water throughout the day. This creates a situation where more loss from the hot water storage unit occurs. The stored hot water temperature also tends to be high in this situation, which leads to a reduced efficiency of the heat pump. In consequence, the efficiency of the device as a whole decreases significantly and the performance potential of CO_2 HP will not be maximized.

- Keeping the stored hot water temperature low is also very important in increasing the efficiency of the heat pump. Although, the HP hot water discharge temperature is commonly between 65 and 90°C, it is desirable to control the temperature as close as possible to the lower limit of 65°C throughout the year. It is also recommended to check periodically the stored hot water temperature by remote control.

(2) Setting boiling mode to "energy-efficient"

- The "boiling mode" controls elements such as the remaining hot water level and the stored hot water temperature. This mode can easily be changed using the CO_2 HP's remote control (See the device's instruction manual for details on settings).
- There are several boiling modes available on any models; however, the "energy-efficient mode" can significantly increase the efficiency of the device by learning the hot water consumption patterns of the household and adapting the remaining hot water level and stored hot water temperature accordingly.
- The actual name of the "energy-efficient" mode can vary from model to model (Table p.281). This "energy-efficient" mode is strongly recommended for households with a normal level of hot water consumption, as it is superior in both energy-saving and economic aspects. Fig. c shows the primary energy consumption by boiling mode.
- The initial setting of many CO_2 HPs in the past was not the energy-efficient mode. It is therefore recommended that users check the setting of their CO_2 HPs already installed. Almost all CO_2 HPs being shipped now are expected to be set at the energy-efficient mode as their initial setting and should be used as is for energy-saving purposes.
- Note that this document will present the energy performance of CO_2 HPs set at "energy-efficient" mode. However, these results were obtained by using the "energy-efficient" mode whereby the remaining hot water level was kept low throughout the year and the stored hot water temperature was maintained very near the lower limit of 65°C. In other words, the same results cannot be expected even when using the "energy-efficient" mode, if the remaining hot water level is high or the stored hot water temperature is considerably higher than 65°C.

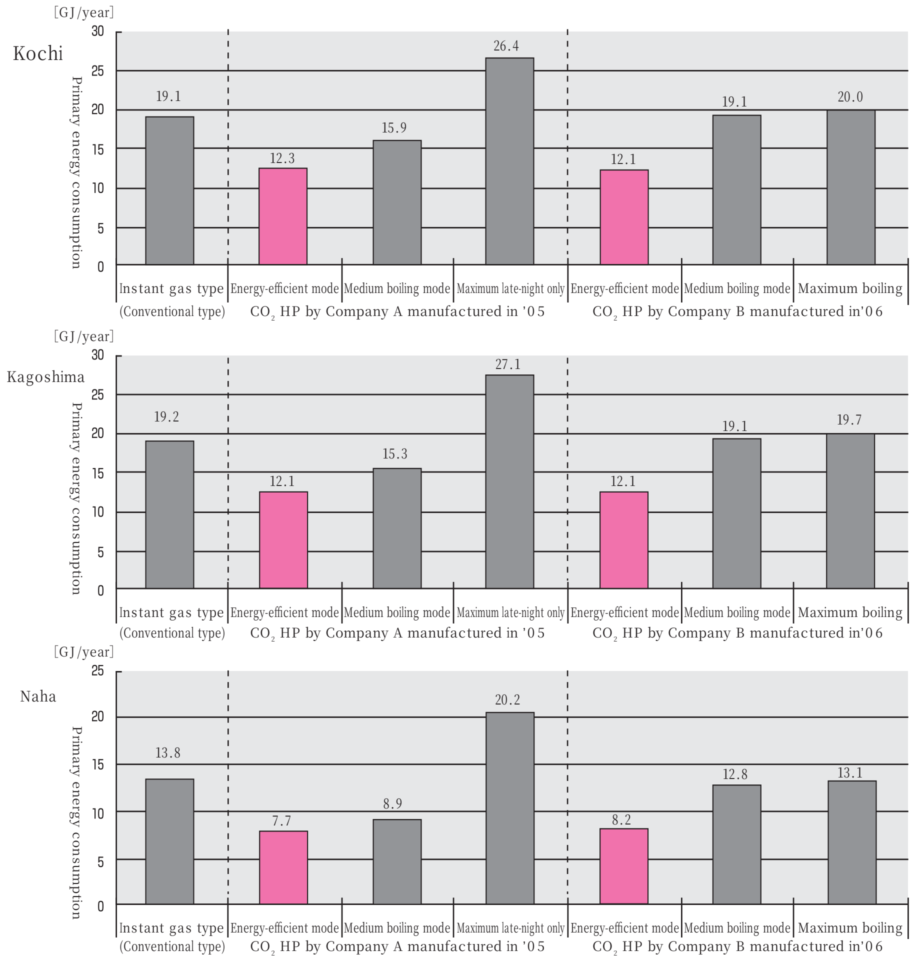


Fig. c Changes in annual primary energy consumption using CO_2 HP at various modes

Table: Types and characteristics of boiling modes

Type	Example of mode name	Characteristics
Energy-efficient mode (automatic learning control)	"Auto (low)", "Saving", "Low boiling", "Auto level 1", "Auto low", "Recommended", etc.	• Automatically learns from the past hot water consumption history and controls the remaining hot water level appropriately according to the household to maintain the remaining hot water at a low level. • Controls to keep the stored hot water temperature as close as possible to the lower limit (65°C). • Rarely runs out of hot water since it automatically starts additional daytime boiling when the remaining hot water falls below the set level. • Generally best in energy-efficiency and economy due to its low heat loss from the tank and the high HP efficiency. Strongly recommended.
Medium boiling (automatic learning control)	"Auto (medium)", "Auto", etc.	• Based on the past hot water consumption history, maintains the remaining hot water level at medium. • Slightly higher stored hot water temperature. • Boiling during the day when necessary. • Compared to "energy-efficient" mode, the heat loss from the tank is increased. Lower HP efficiency.
Maximum boiling (automatic learning control)	"Auto (high)", "Plenty"	• Based on the past hot water consumption history, maintains the remaining hot water level higher than strictly necessary. •The stored hot water temperature almost reaches the maximum allowed (90°C). • Extremely high heat loss from the tank. Significantly lower HP efficiency. Lowest In overall efficiency. • Performs frequent additional boiling when the remaining hot water level decreases. This increases the percentage of power used during the day, making it costly.
Medium late-night only (usually not equipped with automatic learning control)	"Late-night only, medium hot water level", "Late-night only", etc.	• Performs boiling only during the late-night power period. • Often fills up the hot water storage tank during the late-night power period. • Slightly higher stored hot water temperature. • nconvenient as the user must manually start the additional boiling if it runs out of remaining hot water. • Increased heat loss from the tank. Reduced HP efficiency. • Since efficiency is lower than the energy-efficiency mode, generally offers no economic advantages.
Maximum late-night only (usually not equipped with automatic learning control)	"Late-night only, high hot water level", etc.	• As with "medium late-night only", performs boiling only during the late-night power period. • Often fills up the hot water storage tank during the late-night power period. •The stored hot water temperature almost reaches the maximum allowed (90°C). • HP efficiency is greatly reduced as HP discharges hot water at the maximum temperature. • Extremely high heat loss as it fills up the hot water storage tank during the late-night period. • Very low overall efficiency. Not recommended.

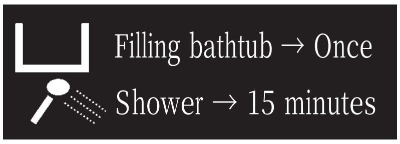


Fig. b Detailed display of remaining hot water leve

Fig. e Display of hot water consumption history

(3) Understanding characteristics of boiling mode

- There may be concern about running out of hot water with the "energy-efficient" mode since it maintains the remaining hot water at a low level; however, the actual risk of running out of hot water is minimal since it is programmed to automatically perform boiling when the level of the stored hot water falls below the lowest limit at times other than late-night, even during the day (daytime boiling).
- As electricity is more expensive during the day compared to late-night, some people set the device to "late-night only" mode that does not perform boiling during the day to be economical.
- However, the "late-night only" mode tends to boil more water than strictly necessary and, if the hot water usage is low, causes the efficiency to decrease due to an excess in the remaining hot water and an increased amount of heat loss. When this happens, from the economical point of view, the "late-night" mode is not more advantageous than the "energy-efficient" mode. Furthermore, when the device is not allowed to perform any daytime boiling, the user must set the boiling manually with a remote control when the remaining hot water level becomes low, which is rather inconvenient.
- Some models offer remote controls capable of displaying the remaining hot water level in more detail (Fig. d).
- When more hot water is required than usual, such as when having over-night guests, you can ensure that more hot water is available by performing a forced boiling.
- If the remote control frequently indicates that the remaining hot water level is low when using the "energy-efficient" mode, another mode needs to be selected to increase the remaining hot water level; however, do not immediately select the "maximum boiling mode" but rather increase the level slightly each time. It is also strongly recommended that effort be made to reduce hot water consumption as well.

(4) Useful tips on hot water consumption

- Some boiling modes such as the "energy-efficient" mode learn the hot water consumption patterns of the household (Fig. e); however, these modes tend to control the remaining hot water level according to days with higher hot water consumption to avoid running out of hot water.
- If the hot water consumption of the household fluctuates greatly from day to day, the efficiency of the device will be reduced on days with lower hot water consumption due to excessive remaining hot water caused by the device maintaining a higher remaining hot water level. Evening out the daily hot water consumption (preferably toward the lower end of the spectrum) increases the efficiency as well as the accuracy of the control of remaining hot water. Being mindful of hot water use is also important when using a CO_2 HP.
- Some models offer remote controls capable of displaying recent hot water consumption history. Understanding the household's hot water consumption by using functions such as this should facilitate even greater energy efficiency.
- Furthermore, it is best to avoid using a circulation reheating function since the efficiency of many water heaters including CO_2 HPs decreases when one is used. Some devices' initial setting may include the automatic "keep-warm" function after filling. It is recommended that the user change the setting to avoid using this function frequently.
- The use of the "hot water adding" function is recommended when the bathwater has cooled down; however, if a large amount of hot water is required to increase the temperature of the bathwater, small efforts such as getting rid of some of the cooled bathwater beforehand might prove beneficial.

● Some models of CO_2 HP do not allow circulation reheating and can only perform the "hot water adding" function when set at the "energy-efficient" mode.

1. Considerations for domestic hot water piping system

1) Hot water saving piping construction

- Two types of domestic hot water piping systems are available: the conventional branched piping system and the header-conduit piping with sleeve tube (Fig. 11).
- Adopting the header-conduit piping with sleeve tube allows you to reduce the diameter of the pipe that normally goes from the tip of the header to the system device installed in the house. This will in turn reduce the amount of wasted hot water compared to the branched piping system. As a result, the efficiency can be expected to improve by approximately 5%; however, note that the initial cost is expected to be higher than that of the branched piping system.

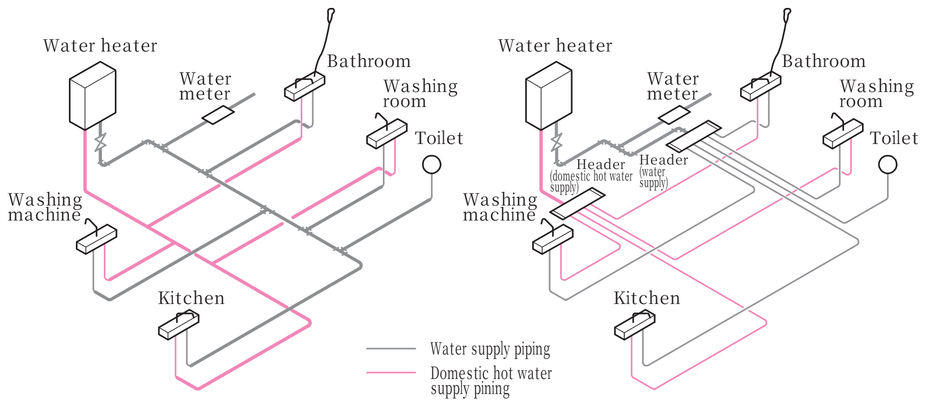


Fig. 11 Types of domestic hot water piping system

2) Minimizing pipe diameter and shortening length of domestic hot water piping route

- Even after the faucet has been turned off, some hot water still remains in the domestic hot water supply pipe. Reducing the amount of wasted hot water that remains in the piping, by either shortening the length of the domestic hot water piping route or reducing the diameter of the pipes, can be a way to save hot water. This will also reduce the amount of heat required to heat the piping as well as the heat loss from the piping and increase the efficiency of domestic hot water supply. Furthermore, it will shorten the wait-time for hot water and improve the amenity factor.
- Above-mentioned measures also apply to the header-conduit piping with sleeve tube.

3) Thermal insulation of domestic hot water piping

- Thermal insulation of domestic hot water piping is an important factor when using a circulation-type domestic hot water piping system such as reheating, automatic "keep-warm" or floor heating. (See "Key Point: Heat loss by heat source equipment and underfloor and piping insulation" of Section 5.2 Heating and Cooling System Planning on p.238 for more detail of thermal insulation of piping.)

4) Considerations for placement of water heater

- If the water heater is not placed in an appropriate space, the piping for domestic hot water supply as well as that for the bathtub may need to be longer, which may reduce the energy-saving effect and create inconvenience by making the wait-time longer for the hot water.
- The placement of the water heater needs to be carefully considered beforehand so as to make the piping route as short as possible between the water heater and various domestic hot water supply points.
- The hot water storage type such as the solar water heater and CO2 HP require an especially large set-up space, which may limit the choices of its placement. It is best to take this fact into consideration right from the initial stages of residential designing.

5

Chapter 5
Energy-efficient Equipment Technology
(Elemental Technology Application Method 3)

5) Thermal insulation of bathtub and bathroom

- Taking a bath, which is very common in Japan, consumes much energy as it requires not only the filling of the bathtub with hot water, but also the keeping of the water at a warm temperature, or its reheating when it cools down. Furthermore, keeping the water warm or reheating it decreases the efficiency of the water heater. Efforts therefore should be made to not have the hot water cool down in the first place.
- Insulating the bathtub is an effective way of preventing the hot water in the bathtub from cooling down. In recent years, we are seeing some with insulation material such as urethane sprayed on and others wrapped in double-layer insulation material to increase the thermal insulating performance (Fib. 12).
- The Eco Mark certification standards for bathtubs with high thermal insulation performance (No. 139 "Bath Unit for Dwellings") are now in place and expected to be commercially available in the near future (Fig. 13). The bathtub must demonstrate a high level of thermal insulation performance by keeping the loss in temperature of the hot water to less than 2°C during a four-hour period even in winter; however, it is essential to deploy a highly-insulated bathtub lid to maintain the temperature as the heat loss is greatest on the surface of the bathwater.
- It is also important to improve the thermal insulation performance of the bathroom as a whole. This will not only reduce the energy consumption related to bathing but also improve the comfort and the healthfulness of the space in the bathroom and other related rooms. Selecting an appropriate thickness of insulation material can also be an important issue as we are seeing whole bathroom units wrapped in insulation material in recent years (Fig. 14).

Fig. 12　Example of thermal insulation of bathtub

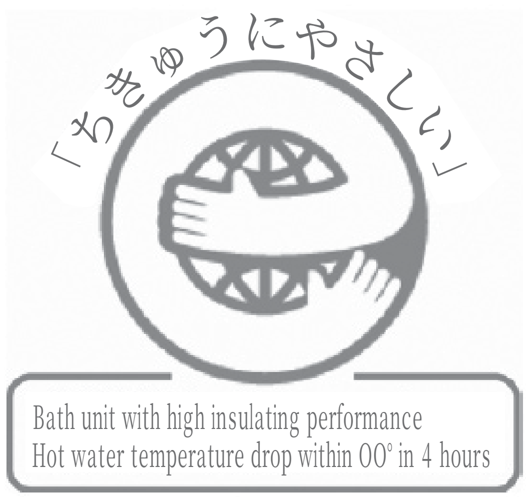


Fig. 13　Eco Mark ちきゅうにやさしい = Gentle on the Earth

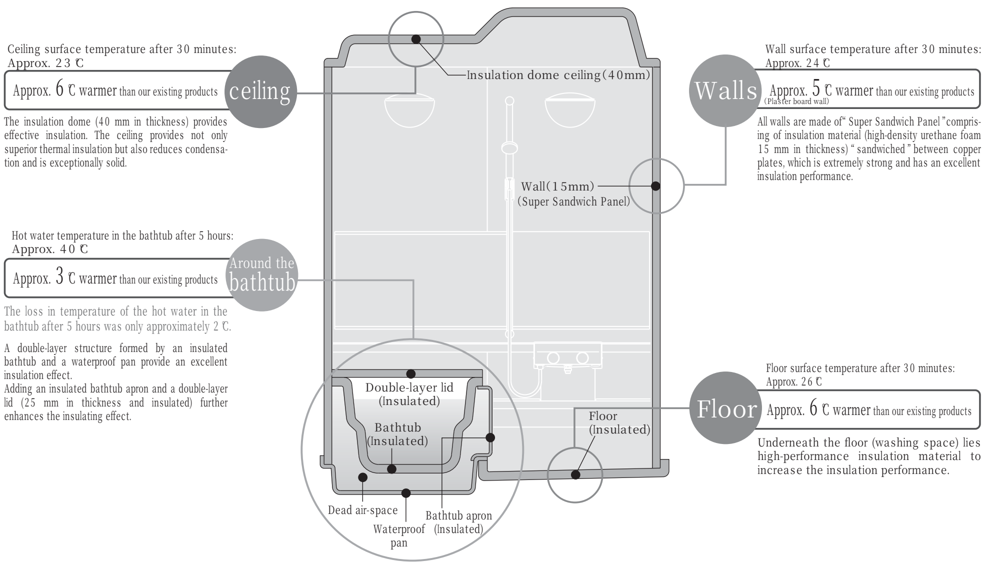


Fig. 14　Bathroom unit with high thermal insulation performance

Key Point

Bathing in energy-efficient manner

As bathing in the bathtub consumes the most energy in all domestic hot water, it is necessary to be mindful of energy-efficiency when doing so. As mentioned previously, thermal insulation of the bathtub (including the lid) as well as the bathroom is effective; however, the following key points should also be considered in order to realize better energy-efficiency.

(1) Water heater settings and tips on how to use it

- Today's common water heaters are equipped with a "keep-warm" function. This function automatically keeps the cooling bathwater warm when it detects that the bathwater temperature is low during the set "keep-warm" period. While convenient, this function can consume a large amount of energy when used frequently and reduces the efficiency of the water heater. It is therefore recommended to avoid using this function when possible to achieve better energy-efficiency.
- If using the "keep-warm" function, the following points should serve as important reminders.
  - a. The initial setting for the "keep-warm" period may be as long as four hours. This can lead to the hot water temperature being unnecessarily maintained. Verify the setting for the "keep-warm" period and set it as short as possible.
  - b. The last person to bathe must make sure to turn off the "keep-warm" function. Similarly, the function must be turned off when the bathtub is emptied. If the function is turned on after the bathtub is emptied, the water heater will attempt to maintain the water level and consume water unnecessarily.
- It is best to use an "adding" function instead, which adds high-temperature water from the faucet. As today's water heaters are most efficient when supplying hot water rather than maintaining temperature or reheating, the "adding" function is the most energy-efficient.

(2) Tips on how to bathe

- People have always been trying to devise ways to save water when bathing and some can still be relevant and effective today.
  - a. Take a bath as soon as possible after filling up the bathtub.
  - b. Organize the bathing time of the whole family within a short period of time so as to save energy required to keep the water warm. If that is not possible, make sure to turn off the "keep-warm" function of the water heater.
- In the past, people frequently reheated the remaining bathwater of the day before. While re-boiling of the remaining water (reheating) certainly saves water, is not necessarily energy-efficient as the bathwater would be completely cold unless in a high-performance insulated bathtub. Using the reheating function also reduces the efficiency of the water heater. It is not a recommended function to use especially with CO_2 HP, which tends to lack the capacity to reheat remaining water and the efficiency of which is heavily and negatively influenced by it. Furthermore, remaining water may contain bacteria, etc., and can be problematic health-wise. For these reasons, reheating remaining water may not necessarily be recommendable.

2. Considering hot water saving devices

・The energy saving effect can be improved upon by adopting hot water saving devices and not running the tap unnecessarily.

・Saving the amount of domestic hot water not only leads to energy-efficiency but also saving water resources.

1) Easy temperature adjustment of hot water with cold and hot water mixer faucet

・With a conventional faucet, there is much wasted water when adjusting the temperature every time domestic hot water is used or having to readjust due to other faucets being used. Thermostatic mixer faucets and single lever mixer faucets allow for an easy temperature adjustment of the domestic hot water and reduce wasted water when adjusting the temperature. It is recommended that these two be used instead of two -valve mixer faucets (Fig. 16).

・Water saving plumbing parts can also serve as another means to control the quantity of hot water.

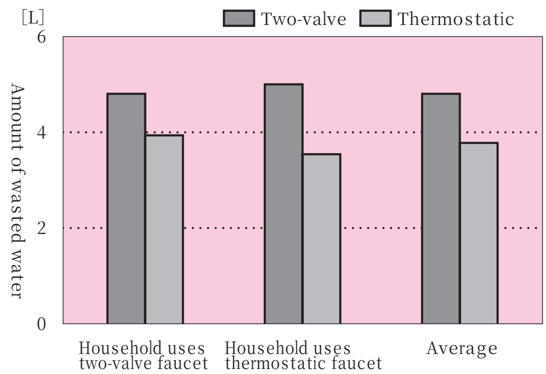


Fig. 15 Comparison of wasted water of mixer faucets

Thermostatic mixer faucet   Two-valve mixer faucet

Fig. 16 Examples of hardware for domestic cold and hot water supply faucets

2) Various devices with shut-off valves

・In the bathroom, it is effective to use a hand-held hot water saving shower head equipped with a shut-off mechanism (Fig. 17 and Fig. 18).

・It is recommended to use a shower faucet in the kitchen and the washing room and to install a foot-controlled water shut off (Fig. 19) or an automatic faucet.

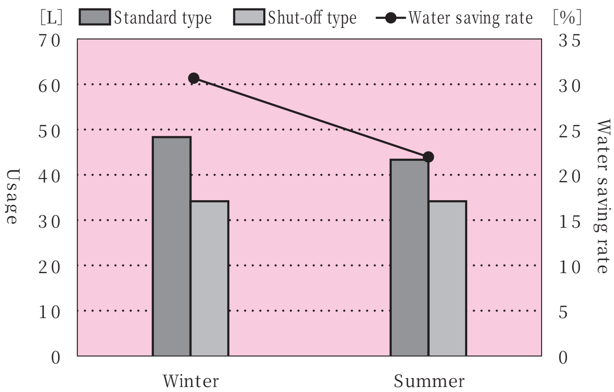


Fig. 17 Comparison of cold/hot water usage by type of showerhead

Fig. 18 Example of shower-head with shut-off mechanism

Fig. 19 Example of foot-controlled water shut off

Key Point

Single lever faucets

- It is now common to use single lever faucets in kitchens and washing rooms. While this type of faucet is very convenient, incorrect use can result in increased hot water consumption.
- Many people use their single lever faucets with the lever positioned in the middle. This means roughly an equal amount of domestic hot and cold water are mixed. Only when the lever is positioned to the extreme right will you get cold water alone (Fig.).
- It is probable that many people use domestic hot water mixed with cold water unintentionally even during the summer or in-between seasons when the water temperature is sufficiently high and mixing in hot water is not necessary.
- Furthermore, when water is used for a very short period of time, such as washing hands in the washing room, the faucet is turned on and off before the domestic hot water from the water heater reaches the faucet. When this happens, the hot water will cool down in the pipe and is completely wasted.
- Also, this type of short-period hot water discharge reduces significantly the efficiency of the water heater and leads to energy loss. This is especially true for instant gas or oil water heaters wherein the burner burns only for a short time.
- Single lever faucets therefore should normally be used at the "cold water only" position and the user should only move the lever to add hot water when necessary.

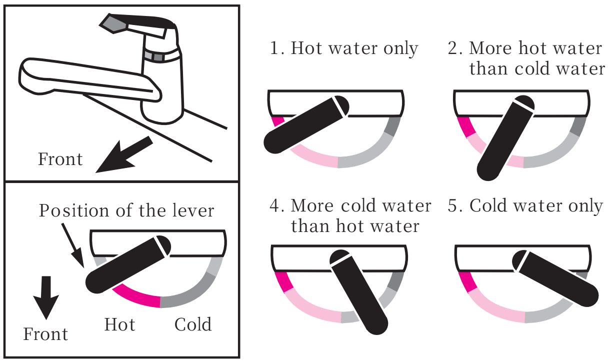
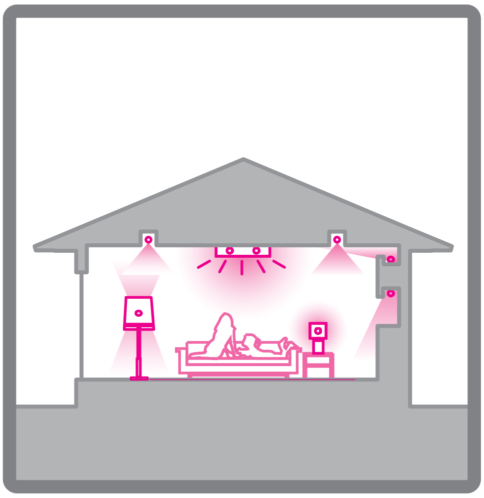


Fig. Operating lever of single lever faucet

5.5 Lighting System Planning



The purpose of lighting system planning is to supplement the lack of illuminance during the day when daylight utilization is not sufficient and maintain a good light environment during nighttime. Furthermore, a lighting system makes use of technologies aimed at reducing lighting energy consumption.

Its ultimate goal, it can be said, is to realize energy efficiency while maintaining and enhancing comfort. That being said, the way the light is perceived can vary from one individual to another depending not only on factors such as age and eyesight, but also on how people's eyes adapt to the level of darkness or brightness. Careful consideration is therefore required when planning a lighting system, as it is also relevant to the safety of the living space.

5.5.1 Purpose and Key Points of Lighting System Planning

- Lighting system planning makes use of technologies aimed at supplementing the lack of illuminance during the day when daylight utilization is not sufficient, creating an appropriate light environment suitable for the nighttime activities of each space, and reducing lighting energy consumption.
- The lighting system planning can offer a better energy saving effect as it combines the use of daylight utilization technologies (See Section 3.2 Daylight Utilization on p.066) such as the daylighting method and the daylight guiding method.
- There are three methods required to complete the energy saving method of the lighting system planning: the "method using device", which makes use of energy-efficient lighting devices to reduce energy consumption; the "method using operation and control", which makes use of various tools of control such as ON/OFF and dimming to provide the appropriate lighting for the appropriate time (providing an appropriate amount of lighting for an appropriate length of time); and the "method using design", with which one prepares an appropriate layout plan for lighting devices to provide the appropriate lighting for the appropriate place (providing an appropriate amount of lighting at an appropriate location).
- Fig. 1 shows the overview of the energy-efficient technologies of the lighting system planning. The underlying principle is to move from a one-light-per-room lighting system to a distributed multiple lighting system.

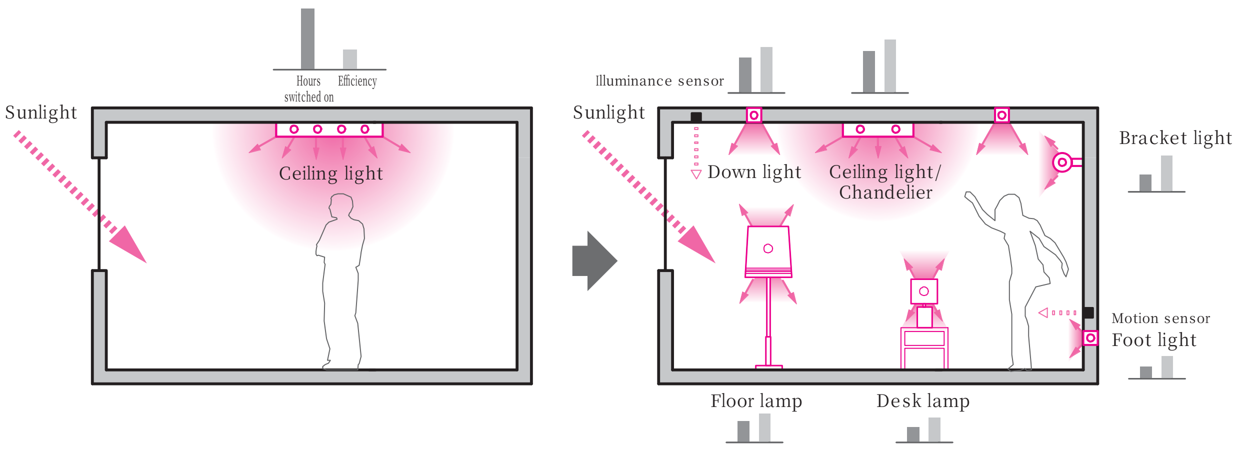


Fig. 1 Overview of energy-efficient technologies for lighting system planning

5.5.2 Energy Conservation Target Levels for Lighting System Planning

1. Definition of target levels

- As shown below, energy conservation target levels 1 to 3 for the lighting system planning are defined according to the lighting energy reduction rate of the entire household. Note that the reduction rate varies between Zone VI and Zone V.

			Zone VI	Zone V
Level 0	:	Lighting reduction	0	0
Level 1	:	Lighting reduction rate	Approx. 15%	Approx. 30%
Level 2	:	Lighting reduction rate	Approx. 20%	Approx. 40%
Level 3	:	Lighting reduction rate	Approx. 30%	Approx. 50%

- The typical lighting energy consumption in 2000 was 13.6 GJ (roughly 20% of the entire energy consumption) for Zone VI and 11.3 GJ (roughly 17%) for Zone V (See Section 6.1 on p.339).
- Any level mentioned above can be achieved by combining the “method using device”, the “method using operation and control”, and the “method using design”.

2. How to achieve target levels

- Table 1 shows guidelines for matching each energy conservation target level with the corresponding method to be applied.
- Level 0, which serves as the basis of the evaluation, employs the conventional one-light-per-room lighting system. This lighting system refers to the conventional lighting method that places one lighting device using an incandescent bulb or a common florescent bulb near or at the center of the ceiling.

Table 1 Target levels for lighting system planning and how to achieve them

Target level	Energy saving effect (lighting energy reduction rate)		Applied methods
	Zone VI	Zone V	
Level 0	0	0	Conventional methods
Level 1	Approx. 15%	Approx. 30%	Method 1: Method using device
Level 2	Approx. 20%	Approx. 40%	Method 1: Method using device Method 2: Method using operation/control
Level 3	Approx. 30%	Approx. 50%	Method 1: Method using device Method 2: Method using operation/control Method 3: Method using design

- Level 1 can be achieved by making use of energy efficient devices such as energy-efficient lamps (Method 1: Method using device).
- Level 2 can be achieved by implementing Level 1 and adding the energy saving effect of frequent control of on/off time of lighting devices (Method 2: Method using operation and control).
- Level 3 can be achieved by implementing Level 1 and Level 2, and placing multiple lighting devices at various locations (distributed multiple lighting system) in rooms used for multiple purposes such as the living room. This will allow the occupants to set an appropriate light environment by, for example, choosing lighting patterns (selecting which light to turn on or off).
- The change in reduction rate between Level 0 and Level 1 as well as Level 1 and Level 2 differs in Zone VI and Zone V. This is due to the fact that the model plan for Zone VI (See p.344-345) uses much incandescent lighting and its area of non-habitable rooms (not used for an extended period of time), where many devices with control are found, was smaller than that of the model plan for Zone V (See p.346-349). Its reduction rates therefore were also lower. On the other hand, the change in reduction rate between Level 2 and Level 3 is the same for both zones (simulated a simple distributed multiple lighting system). The reduction rate can be further improved by planning a full-fledged distributed multiple lighting system in Zone VI as the living room area there is larger than in Zone V.

Points of Caution
To achieve Level 3, along with the design of the system, the occupants must be made aware of the correct way of using it.

5.5.3 Steps for Considering Lighting System Planning

- Consider the light environment required for each space. When doing so, bear in mind that the occupants' age and eyesight need to be taken into account as well.
- Thoroughly determine the sunlight condition of each space during daytime and examine spaces where the light environment needs to be improved.
- Select the placement of lighting system as well as its light sources and types of devices for each space. When doing so, ensure to take into account how an individual would adapt to the dark or the light when moving from one space to another.
- Consider the method of control and the position of the switch for each lighting device.

Step 1 Considering light environment required for each space

1) Consider the activities that take place in each space.
2) Confirm the eyesight of the occupants using each space.

▼

Step 2 Considering locations where daylight is lacking

1) Understand thoroughly the sunlight condition and plan daylight utilization.
2) List locations where daylight is insufficient and how much.

▼

Step 3 Considering placement of lighting, light source and types of devices for each space

1) Consider the placement of lighting and the illuminance for each space (Method 3).
2) Select a light source as well as types of devices that offer superior energy saving effect (Method 1).
3) Consider the coordination between the interior design and the devices.
4) Verify the difference in illuminance when moving from one space to another.

▼

Step 4 Considering method of control and placement of switch for each lighting device (Method 2)

1) Consider the method of control of each lighting device.
2) Consider the placement of the switch.

5.5.4 Energy Saving Methods in Lighting System Planning

As previously discussed, to reduce lighting energy consumption, three methods—the method using device, the method using operation and control, and the method using design—must be combined appropriately during the planning phase. To realize this, the following steps are to be followed when designing. Note that a detailed explanation on each method will be provided later in this chapter.

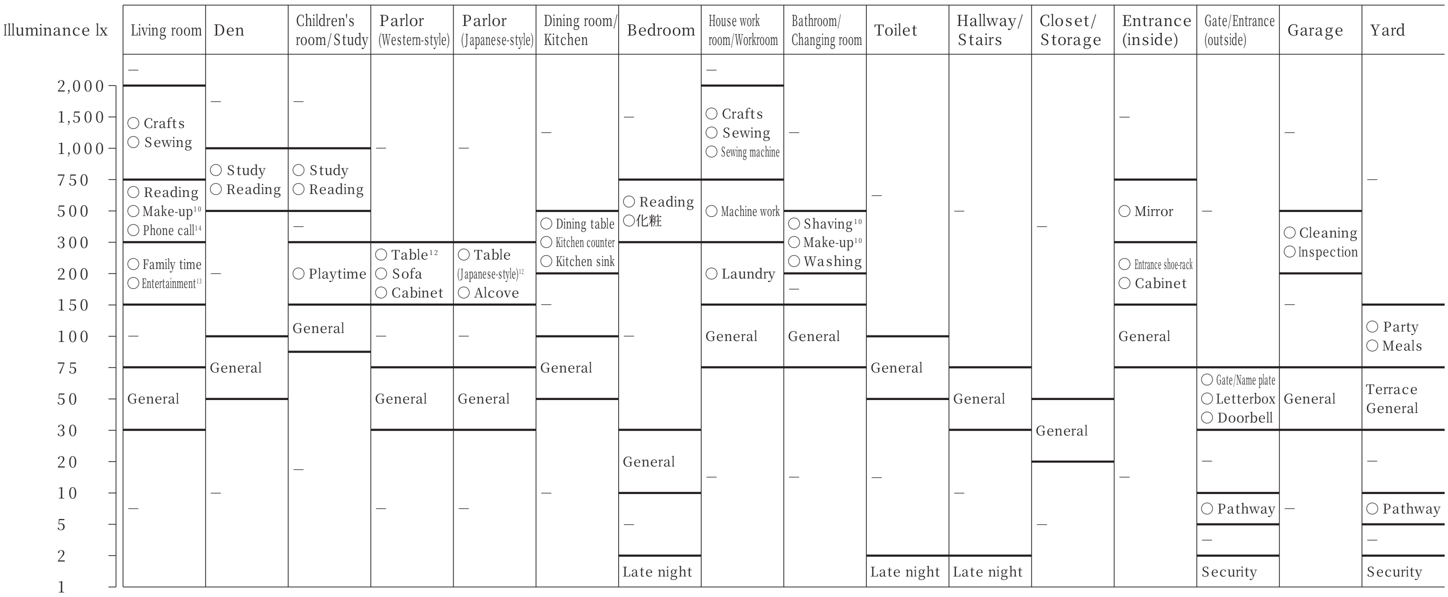
1) Verify activities conducted in space

It is necessary to examine the activities that take place in each space of a house on an hourly basis so as to determine the required light environment.

2) Verify basic required illuminance

Determine the required illuminance (lx) for each activity to take place in each space. Refer to Fig. 2 that shows the Japanese Industrial Standards "Recommended Levels of Illumination".

Fig. 2 Recommended levels of illumination for houses (JIS Z 9110)



10. Illuminance here mainly refers to the vertical illuminance on individuals.
12. The purpose here is to create local lighting locations where it is several times brighter than the general lighting so as to create differences in illuminance within the room and to avoid flat overall lighting.
13. Light reading is included in "Entertainment".
14. Applies to other locations as well.
Remark 1: It is preferable to make use of both general lighting and local lighting according to the purpose of the space.
Remark 2: It is preferable to install a dimmer to allow for lighting adjustment in the living room, the parlor, and the bedrooms.

The illuminance values serve as a guide and a strict adherence to them is not required. It is ideal to perform illuminance calculations and prepare an illuminance distribution diagram to examine the distribution of light; however, it is not necessary to be as strict when planning a system for home use. This is due to the fact that the proper amount of light in a house can vary greatly depending on the occupants' lifestyle and personal preferences. It is therefore important to discuss the matter with the occupants when determining the amount of light required.

The amount of light can be roughly determined simply by using the labels indicating the effective lighting area in number of *tatami* mats found on lighting devices that most light manufacturers use in their catalogs. For example, an inverter-type ceiling light using a fluorescent bulb is approximately 10 W per mat and provides approximately 100 lx to the floor surface. Even when using the distributed multiple lighting method, there should not be a problem as long as the total wattage of all the planned lighting devices is (10 W x number of mats). When doing so, bear in mind that it is assumed that incandescent light bulbs are being replaced by compact fluorescent lamps. The wattage therefore is divided by four when calculating. Furthermore, local lighting such as a small desk lamp is not to be included in the calculation. Note that the bedrooms would require roughly half of the above-mentioned illuminance as the calculation is based on rooms such as children's rooms or living rooms.

The shape of the devices and the interior finish also need to be taken into consideration since, if the bulbs of the lighting devices are exposed, they will be roughly 10 to 30% brighter than if they were covered and the reflectance of the interior finish will also enhance the illuminance.

The total wattage can often exceed the recommended value when an emphasis is placed on the atmosphere of the space or many lighting devices are placed to create various moods. To ensure good energy performance, however, it is recommended that you plan the lighting devices carefully and make concerted effort to not exceed the recommended wattage by more than 20%.

Key Point

Example of lighting device wattage calculation using distributed multiple lighting system

Recommended wattage: For 13 m² (8 *tatami* mats) = 10 W x 8 = 80 W

	When all are on	When some are on
Device 1: Four down lights with 13 W compact fluorescent bulbs	13 x 4 = 52 W	13 x 2 = 26 W
Device 2: Two bracket lights with 8 W compact fluorescent bulbs	8 x 2 = 16 W	8 x 1 = 26 W
Device 3: One floor lamp with 13 W compact fluorescent bulb	13 x 1 = 13 W	13 x 1 = 13 W
Total	81 W	47 W

Pay careful attention to the balance of brightness when local lighting is required in areas such as desktops. Adopting a down light to concentrate light from above or making use of auxiliary lighting such as a desk lamp can be helpful. To verify the direct downward illuminance of a device such as a down light, refer to the direct horizontal illuminance diagrams (relational diagram depicting the height of a device and its horizontal illuminance) shown in the manufacturer's catalog.

Key Point

Example of direct horizontal illuminance diagram of down light

- The diagram shows the relationship between the height of the down lighting device and the horizontal illuminance as well as the degree of the angle at which the light spreads.
- For example, if the height of the device is 2.0 m, the illuminance directly beneath the device is approximately 50 lx.
- The phrase "the angle at which the light spreads" refers to an angle where the brightness is half of what is directly beneath the device (half-beam angle). It may also refer to an angle where the illuminance is half of the direct illuminance, also known as half-illuminance angle.

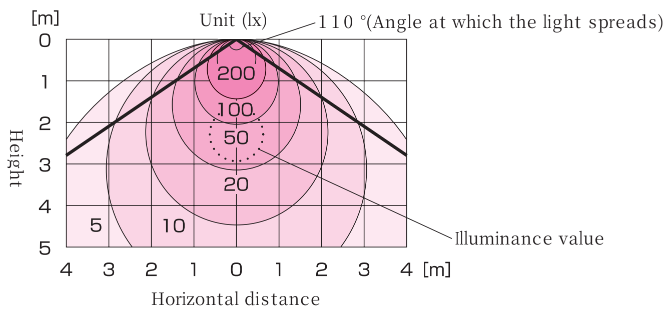


Fig. Example of direct horizontal illuminance diagram for down light

3) Correcting required illuminance according to changes in occupants

As eyesight often worsens with age, it may be necessary to correct the required illuminance for certain activities based on your understanding of the current occupants' condition and changes in the foreseeable future. It is therefore important to allow for some leeway with the required illuminance values.

Generally speaking, for seniors, it is desirable to add 50% or more to the Japanese Industrial Standards "Recommended Levels of Illumination".

4) Verifying the range and the amount of daylight utilization

Verify the areas and the amount of daylight utilization and determine the areas where artificial lighting is required to supplement the lack of daylight.

5) Planning lighting placement and selecting devices

Estimate which action may take place in which space and determine the placement of lighting to give the required illuminance. If it is highly likely that the actions taking place in the space will change due to occupants' moving furniture or other reasons, rather than depending heavily on positions of the furniture placement, plan the lighting by dividing the room into areas where light is needed and areas where it is not. Pay attention to the harmony between the lighting and elements such as the form of the room and the interior finish as well. If the space allows, adopting mobile lighting such as lamps is also effective.

When building a light environment, it is necessary to consider not only the functional lighting appropriate for actions but also the atmosphere that the light creates. For example, by brightening up the wall surfaces, the atmosphere of the room as a whole can be made brighter while the space will have a calmer feel with low lighting. The same devices placed in multiple locations will give a rhythm to the space while placing a chandelier will create a glamorous feel. When using indirect lighting, it can be effective to take into account the reflectance of the interior finish (See Section 3.2 Daylight Utilization on p.082).

Light colors are also an important element of light. Using different light colors to suit the purpose of the space is effective in creating an atmosphere. For example, white light creates a lively space while warm-colored light gives the room a calmer feel. Children's rooms therefore should have mostly white lighting and bedrooms, warm-colored lighting.

Furthermore, consider whether maintenance work such as cleaning and changing light bulbs can be done with ease. Also, select light bulbs that the occupants can easily obtain. If the lighting is for supplementing daytime utilization, ensure that the plan does not waste energy by carefully verifying the areas and the amount of light required.

6) Considering methods of control

Consider methods of control in order to create a lighting pattern appropriate for each action. If the area requires detailed lighting settings, use a device that allows dimming control. If not, an energy efficient device should be used for on/off controlled lighting. It is also effective to employ a motion sensor in areas which people use infrequently or an illuminance sensor where daylight utilization is expected. Consider also coordinating such elements with systems other than lighting such as a security system.

Also pay attention to the flow line and install switches where they can be easily reached. Install three- or four-way switches for locations such as stairs and hallways.

7) Verifying safety

Pay close attention to the safety of pathways where stairs or steps are present. Ensure that enough light is provided by referring to the Japanese Industrial Standards "Recommended Levels of Illumination". Various points of view need to be simulated as, even when lighting is available, one's feet can be in the shadow depending on the position. Do not neglect ensuring the safety of senior occupants.

It can often be difficult to see when one is moving from a brightly lit space to a dark one even when enough illuminance is provided. It is therefore crucial to ensure that there are no obstacles such as steps on the flow line.

Method 1: Method using device

Depending on the types of lighting system devices installed, it is possible to provide the same brightness with less energy or a brighter space and a better light environment with the same amount of energy. Characteristics and energy saving methods vary from one device to another. From the point of view of energy efficiency, it is desirable to select a device with lower energy consumption even if the initial cost is slightly higher. If the running cost is taken into consideration, the total cost often ends up being less in the end (Fig. 3). Be sure to collect relevant information regarding all devices and make an appropriate selection.

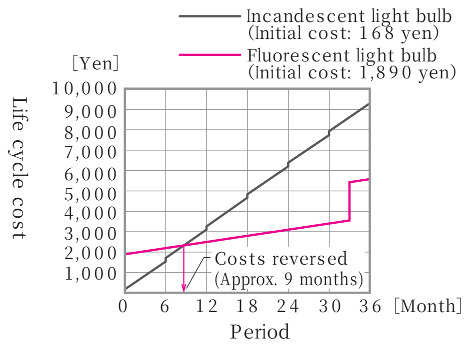


Fig. 3 Example of cost test calculation for incandescent light bulb and fluorescent light bulb

Source: *Lab Report for Everyday Life*, Tokyo Electric Power Company

■Trial conditions

Hours switched on: 6 hours per day

Incandescent light bulb: Power consumption = 54 W; approx. power cost per hour = 1.2 yen; changed twice a year

Compact fluorescent lamp: Power consumption = 12 W; approx. power cost per hour = 0.3 yen

Initial cost: Based on manufacturers' suggested retail prices; may vary from store to store

Power cost (incl. tax): 22.86 yen/kWh; second tier meter rate lighting service B provided by Tokyo Electric Power Company (September, 2008)

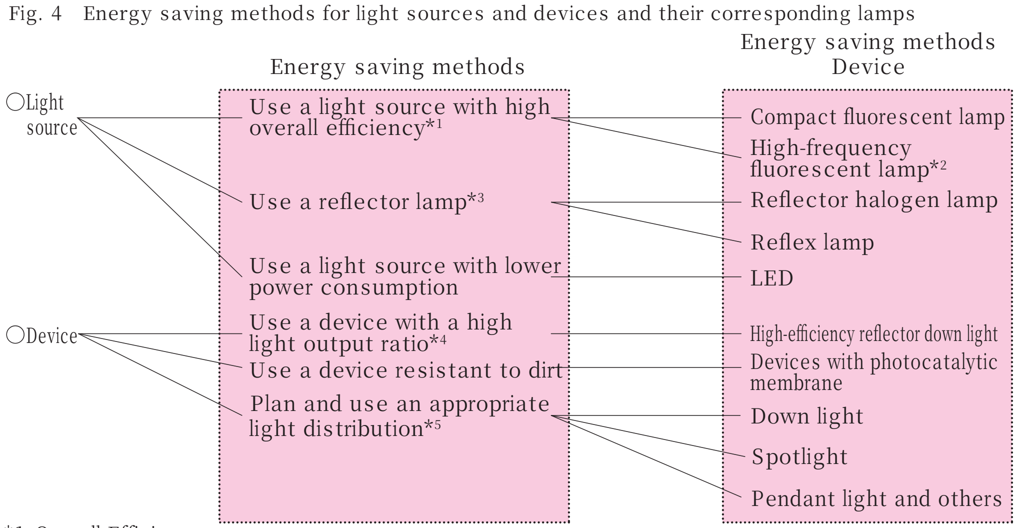
1. Energy saving methods using device alone

1) How energy saving methods and devices correspond

When considering lighting energy efficiency, the first key is to select the light source and the device. While you should select devices with low energy consumption, in order to create the desired light environment, it is also necessary to adopt each device upon understanding its characteristics.

Fig. 4 shows energy saving methods for different light sources and devices and their corresponding lamps.

Fig. 4 Energy saving methods for light sources and devices and their corresponding lamps



*1. Overall Efficiency
Denotes lamp light flux (light emitted by the lamp)/stabilizer input power and serves as the index for measuring the performance of a lamp and its stabilizer. (The higher the overall efficiency is, the better the energy saving effect will be.)

*2. High-frequency fluorescent lamp
Fluorescent lamp for high-frequency lighting. It increases the efficiency of the lamp by performing high-frequency lighting using an inverter as well as slimmer and longer tubes.

*3. Reflector lamp
Glass light bulb with a reflecting surface that increases the light distribution in a specific direction. It owes its high energy efficiency to its construction in which the light source and the device are one.

*4. Light output ratio
Denotes light flux emitted by lighting device/lamp light flux and serves as an index for measuring the performance of a device. (The higher the light output ratio is, the better the energy saving effect will be.)

*5. Light distribution
Distribution of light that describes how much light (luminosity) goes in which direction from the lamp or a device. See the data on light distribution provided by lighting device manufacturers.

Light distribution is indispensable when considering the distribution of brightness. Selecting the appropriate device requires a certain level of understanding of light distribution and a thorough familiarity with catalogs.

2) Types and characteristics of light sources

When selecting the light source, one needs to take into consideration the power consumption, light colors, and the product life. It is also important to select bulbs that are easy for the occupants to obtain and change.

The following shows the characteristics of the most common light sources.

Compact fluorescent lamp

Type A

Type D

Product life: 6,000 to 8,000 hours
Power consumption/heat generation: Low (1/5 to 1/4 of a regular incandescent light bulb)
Light color: Daylight (6,700 K), daylight white (5,000 K), regular (2,800 K)
Availability: High

Characteristics

- Virtually the same size as regular incandescent light bulbs.
- Three light colors available (daylight, daylight white, and regular).
- Compatible with E26 base as well as E17 base.
- Power consumption is 1/5 to 1/4 of a regular incandescent light bulb.
- Product life is 6 to 10 times longer than that of regular incandescent light bulb.
- Some light bulbs of this type now allow dimming, which can be expected to contribute to energy conservation if these bulbs become popular.

High-frequency fluorescent lamp

Straight tube type

Product life: 12,000 to 15,000 hours
Power consumption/heat generation: Low
Light color: Daylight (6,700 K), daylight white (5,000 K), white (4,200 K), warm white (3,500 K), and regular (3,000 K)
Availability: Somewhat low

Circular type

Product life: 9,000 to 12,000 hours
Power consumption/heat generation: Low
Light color: Daylight (6,700 K), daylight white (5,000 K), white (4,000 K), and regular (2,800 K)
Availability: Somewhat low

Double circular type

Product life: 10,000 to 16,000 hours
Power consumption/heat generation: Low
Light color: Cool (6,700 K), natural (5,000 K), warm (3,200 K), and regular (3,000 K)
Availability: Somewhat low

Characteristics

- Allows for thinner device due to small diameter.
- Low power consumption.
- Long product life.
- Allows dimming (incremental dimming for circular-type).

Reflector halogen lamp and reflex lamp

110V halogen lamp

Product life: 2,500 to 3,000 hours
Power consumption/heat generation: High
Light color: 3,000 K
Availability: Somewhat low

12V halogen lamp

Product life: 3,000 to 4,000 hours
Power consumption/heat generation: High
Light color: 3,000 K and 3,500 K (high color temperature)
Availability: Somewhat low

Reflex lamp

Product life: 1,000 to 2,000 hours
Power consumption/heat generation: High
Light color: 2,800 K
Availability: Somewhat low

Characteristics

- Allows for smaller opening diameter for down light.
- Allows occupants to change light distribution when changing light bulbs as reflector halogen lamps have different light distribution depending on shape of mirror (appearance is same).
- Halogen lamps are attractive and bright.
- Halogen lamps have high light-harvesting performance and create sharp contrasts in spaces.
- Although halogen lamps are not considered energy-efficient, they still offer better energy efficiency than regular incandescent light bulbs.

LED

Foot light

Down light

Desk lamp

Product life: 40,000 hours
Power consumption/heat generation: Low
Light color: Any
Availability: Low

Characteristics

- Long product life (40,000 hours).
- Low power consumption.
- Low heat generation.
- Allows for smaller devices.
- Can create any light color by mixing red, green and blue diodes when adjusting lighting.
- Potential next generation light source to replace incandescent light bulbs and fluorescent lamps.

* Although LEDs are currently not as energy-efficient as fluorescent lamps, their efficiency continues to improve. It is expected that sometime in 2009 or 2010, the efficiency of LEDs will be comparable to that of fluorescent lamps and will continue to improve. Presently, however, their initial cost is high, but may come down as they become more popular.
Another potential next generation light source is a surface-emitting organic electroluminescent, which can light a large area.

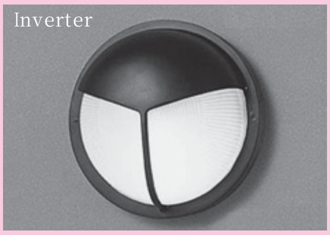
3) Types and characteristics of energy-efficient devices

In some cases, adopting high-performance devices after selecting an appropriate light source can further enhance the comfort and the energy saving effect. Some that fall under this category are devices that reflect the light from the light source with high efficiency and those that minimize the amount of dirt adhering to the light, which reduces the brightness.

High-efficiency reflector down light

Characteristics
- With evaporated silver.
- Produces cheerful and bright light.

Devices with photocatalytic membrane



Characteristics
- The surface of glass cover is coated with photocatalytic membrane.
- Dirt adhering to surface is naturally broken down by photocatalytic decomposition.

4) Variation in light distribution according to types of lighting devices

The way the light spreads (light distribution) changes depending on the light source and the lighting device. Selecting a product that offers the desired brightness distribution for the same power consumption can therefore create a better light environment.

(1) Example of pendant light and bracket light

Pendant light (light distribution control type)

Characteristics
- Controls light distribution to provide bright light to table surface while also lighting space as well as people's faces appropriately.

Bracket (light distribution control type)

Note: This device contains two lamps with one fitted with a reflector to mainly light upward and the other, downward. By using a wall switch, the user can choose which one to turn on and change the light distribution.

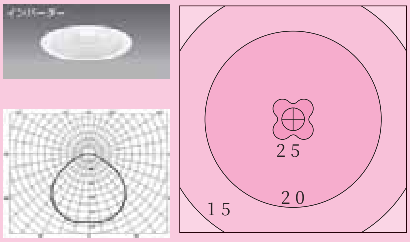
Characteristics
- Users can select three types of light distribution: "upward and downward", "upward", and "downward".

(2) Example of down light (when combining different devices and light sources)

The light distribution for a down light can vary greatly depending on the combination of the device and the light source. For example, a compact fluorescent lamp can light a surface evenly while a halogen lamp lights mainly directly below the device and its light does not cover a wide area.

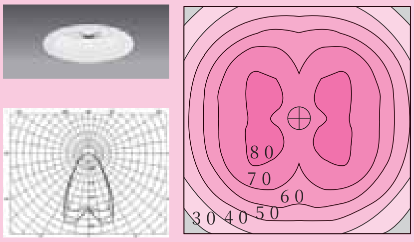
Variation in light distribution for down light

Compact fluorescent lamp: 13 W
(Light covers a wide area.)



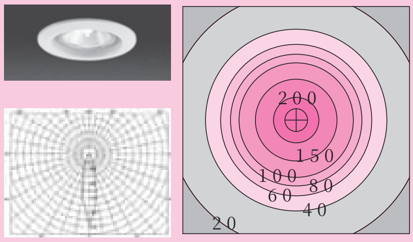
Unit: lx

Mini krypton lamp: 60 W
(Light covers a medium-sized area)



Unit: lx

Reflector halogen lamp: 50 W
(Light covers a small area)



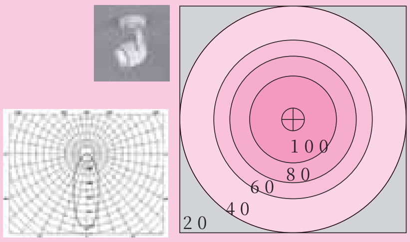
Unit: lx

(3) Example of spotlight (when changing the light source while using the same device)

When using a spotlight with a light source with mirrors attached, even with the same device the light distribution can vary greatly, as shown below, depending on the light source. If the beam angle of the light source is wide, the light will spread widely while a small beam angle will concentrate the light on a smaller area.

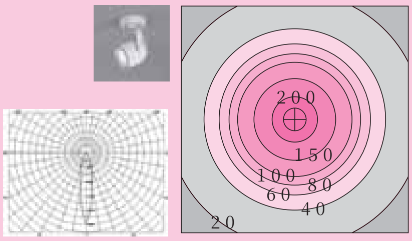
Variation in light distribution for spotlight (halogen lamp: 50 W)

Beam angle: 38 °
(Light covers a wide area)



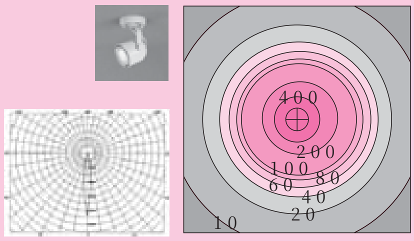
Unit: lx

Beam angle: 20 °
(Light covers a medium-sized area)



Unit: lx

Beam angle: 12 °
(Light covers a small area)

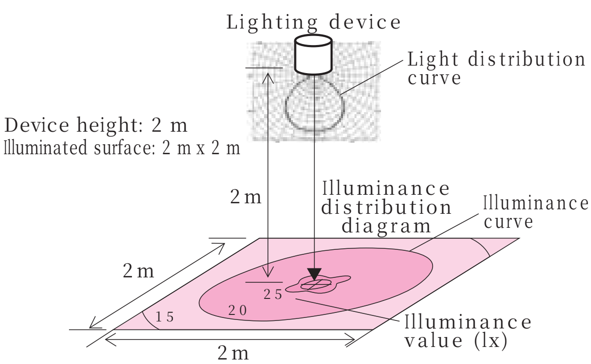


Unit: lx

Key Point

Interpreting light distribution curve and illuminance distribution diagram

- A light distribution curve shows how the light radiates from a device.
- Numeric values found on the illuminance curve on an illuminance distribution diagram represent the illuminance value (unit: lx).

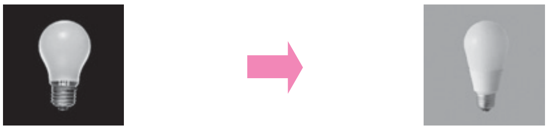
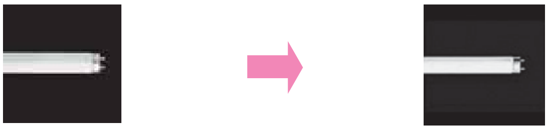
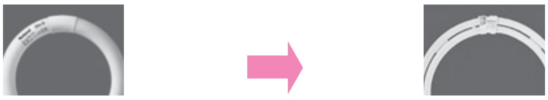
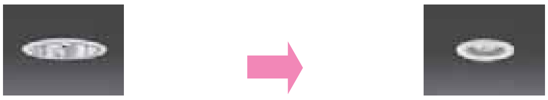
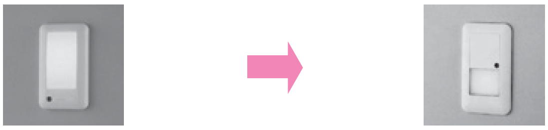
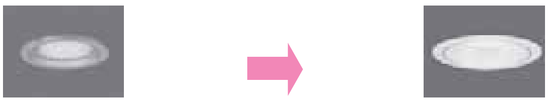
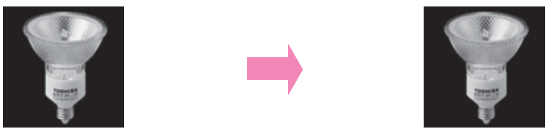


- The phrase "device height: 2 m" on the diagram on the left indicates the distance between the device and the illuminated surface. "Illuminated surface: 2 m x 2 m" indicates that the size of the illuminated surface on the illuminance distribution diagram is a square with 2 m-sides.

2. Examples of energy saving methods using devices alone

Table 2 shows examples of energy saving methods and their effects using light source or devices alone

Table 2 Examples of energy saving methods and their effects using devices alone

Example of energy saving method	Energy saving effect (Power reduction rate)[1]
Replace an incandescent light bulb (60 W) with a compact fluorescent lamp (13 W) 	78%
Replace a regular fluorescent lamp (40 W) with a high-frequency fluorescent lamp (32 W) 	20% Brightness up 14%
Replace a circular fluorescent lamp with a high-frequency double circular fluorescent lamp  Luminous efficacy = 57.1 (lm/W) → Luminous efficacy = 102.9 (lm/W)	45%
Replace a regular halogen lamp in a down light with a 12 V reflector halogen lamp  85 W halogen down light Average illuminance: 253 (lx) 12 V 50 W halogen down light Average illuminance 291 (lx)	41% Brightness up 15% (Illuminance on the table surface)[2] ■Conditions for the above calculation Device height: 2.0 m Table surface: 0.6 m x 1 m
Replace an incandescent light bulb (5 W) of a foot light with a LED (0.35 W) 	90%
Replace a regular down light with a high-efficiency reflector down light  Regular down light Reflector: Off-white matt Lamp: 22 W compact fluorescent lamp Average illuminance: 121 (lx) High-efficiency reflector down light Reflector: Evaporated silver finish Lamp: 22 W compact fluorescent lamp Average illuminance: 158 (lx)	0% Brightness up 31% (Illuminance on the floor surface) ■Conditions for the above calculation No. of lights: 4 Device height: 2.4 m Floor surface: 3.6 m x 3.6 m
Replace a wide-angle bulb (beam angle = 35°) with a medium-angle (beam angle = 20°) in a down light  40 W wide-angle halogen down light Average illuminance: 113 (lx) 30W medium-angle halogen down light Average illuminance: 149 (lx)	0% Brightness up 32% (Illuminance on the table surface)[2] ■Conditions for the above calculation Device height: 2.0 m Table surface: 0.6 m x 1 m

1. Power reduction rate (%) = 1 – (power consumption after replacement / power consumption before replacement)
2. It is also necessary to consider the illuminance distribution on the table surface when designing lighting.

Points of caution

Although a halogen lamp is not considered a high-efficiency lamp, it still offers better efficiency than an incandescent light bulb. Here, an example is presented using a reflector lamp to increase the efficiency. This bright lamp is effective for locations where attractiveness is to be enhanced.

Method 2 : Method using operation and control

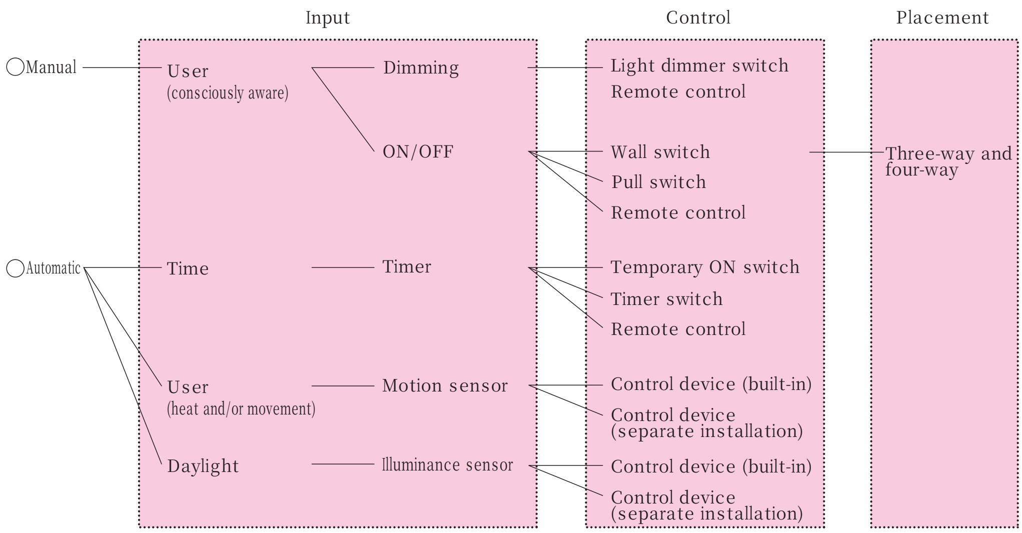
Frequently turning the lights off and dimming the lighting are directly linked to energy saving; however, this manual system is dependent on the occupants' consciously performing the task and is likely to increase the frequency of forgetting to turning off the lights. It is therefore necessary to install an automatic control system to prevent the lighting from being left on especially for rooms that people tend not to stay in for a long period of time. Three examples of effective control systems are: a timer control that keeps the lights on for a set period of time only; a motion sensor control that detects body heat or movement, and an illuminance sensor control that detects daylight.

1. Energy saving by methods of control

1) Types of methods of control

It is important to consider these various types of methods of control shown below while keeping in mind the lighting placement plan (Fig. 5, Table 3). If the purpose of the lighting is not compatible with its method of control, it may be inconvenient to use or may even be detrimental to safety. Careful consideration is especially required for locations such as stairs and steps where lack of appropriate lighting at one's feet can lead to a fall and other accidents.

Fig. 5 Types of methods of control



Light source that allows dimming.
Among common light sources used in homes, incandescent light bulbs and high-frequency fluorescent lamps allow dimming.

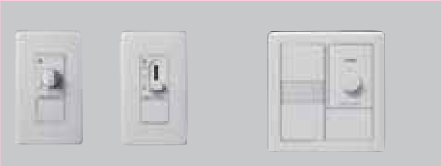
Table 3 Characteristics of methods of control and their energy saving effect

Method of control	Action	Advantage	Disadvantage	Energy saving effect
Light dimmer switch	Users dim light manually when necessary.	Can set light at most appropriate brightness.	Large switch plate	Small to medium
Remote control	Controls multiple devices on one mobile remote control.	User is not required to move to switch.	Losing the remote control is inconvenient; requires standby energy.	Small to medium
Timer	Keeps the light on for set period of time only.	No wasteful operation.	Requires users to set time period.	Small
Motion sensor	Detects body heat and/or movement of users.	No wasteful operation.	Turns off if no movement is detected.	Small to medium
Illuminance sensor	Detects illuminance (daylight).	No wasteful operation.	Does not detect accurate illuminance unless it is appropriately positioned.	Medium

2) Characteristics of methods of control

Light dimmer switch

For controlling one device



Rotary-type for incandescent light bulb | Sliding-type for incandescent light bulb | Rotary-type for high-frequency fluorescent lamp

* Although few, there are some models of light dimmer switches that are compatible with both compact fluorescent lamps and incandescent light bulbs.

For controlling multiple devices

(Living room)

Characteristics

- Users can set default dimming settings for multiple devices and store them in memory, recalling them with a push of a button.
- Compatible with incandescent light bulbs and high-frequency fluorescent lamps.

Remote control

For controlling one device

(Living room, Japanese-style room, and children's room)

Characteristics

- Remote controls have built-in receivers to control lighting devices at distances.
- Each remote control is dedicated to one specific lighting device.

For controlling multiple devices

(Living room)

Dedicated adapter

Characteristics

- Used in conjunction with dedicated adapter, one remote control can be used to operate multiple lighting devices that did not come with remote controls.

Timer

Temporary ON switch

(Storage)

Characteristics

- This switch turns off light automatically after set period of time.

Timer switch

Characteristics

- Allows for pre-settings for ON or OFF times.

Note: Rooms and locations indicated in ( ) are those for which these devices are recommended.

Motion sensor

Built-in-type

(Porch, kitchen sink, closet)
The device in the photo is for a porch.

Characteristics
- Has built-in motion sensor that turns light on automatically when it detects body heat. It then turns off after set period of time.

Separate installation type

Characteristics
- Multiple detectors can be connected to the main unit.

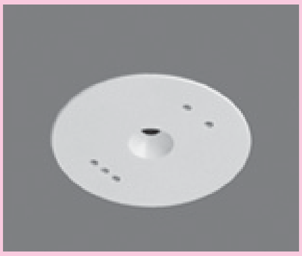
Illuminance sensor

Built-in type

(Porch, outdoor)

Characteristics
- Has built-in illuminance sensor that turns the light off or on automatically when it detects illuminance or lack thereof.

Separate installation-type



Characteristics
- Depending on amount of daylight, it maintains certain level of illuminance by turning multiple devices on and off or dimming lighting.
- This type is currently more common in offices but is expected to be more popular in homes in the future.

Note: Rooms and locations indicated in ( ) are those for which these devices are recommended.

2. Examples of energy saving design by methods of control

The following are design examples using motion sensors and illuminance sensors (Fig. 6).

1) Design example of motion sensor (separate installation)

This design example is based on a scenario where the lights are turned on and off by motion sensors. A motion sensor-controlled bracket light is installed at the entrance porch while a motion sensor-controlled down light is located at the back entrance under the eaves.

A motion detector is installed for each lighting device so as to separately control the porch light and the back entrance light for people approaching either the front or back entrance from outside. Determine the installation location for motion detectors after considering the flow line as well as the detection range of the sensor. A single main unit controls the various settings for multiple detectors connected to it. Furthermore, since motion sensor switches commonly have a built-in illuminance sensor, they can be set to not operate during daylight hours.

2) Design example of illuminance sensor (separate installation)

This design example is based on a scenario where the down lights are turned on and off in the living room and the kitchen by illuminance sensors that detect daylight.

In the living room, one illuminance sensor controls two circuits, each featuring two lights, while in the kitchen another illuminance sensor controls a single circuit featuring one light. The illuminance is set on two settings (high and low) in the living room with the high setting corresponding to the down light at the back of the room (Circuit 1) and the low setting to the down light by the windows (Circuit 2). With these settings, when it begins to grow dark outside, the down light at the back of the room turns on, while the down lights by the windows turn on only when it is very dark outside. The illuminance setting for the down light in the kitchen is set to turn the on when the light from the skylight grows weak. For both locations, the light can also be turned on manually using the wall switches. This system is not currently feasible from the cost-efficiency point of view; however, a less expensive daylight utilization system for home use may be developed in the near future.

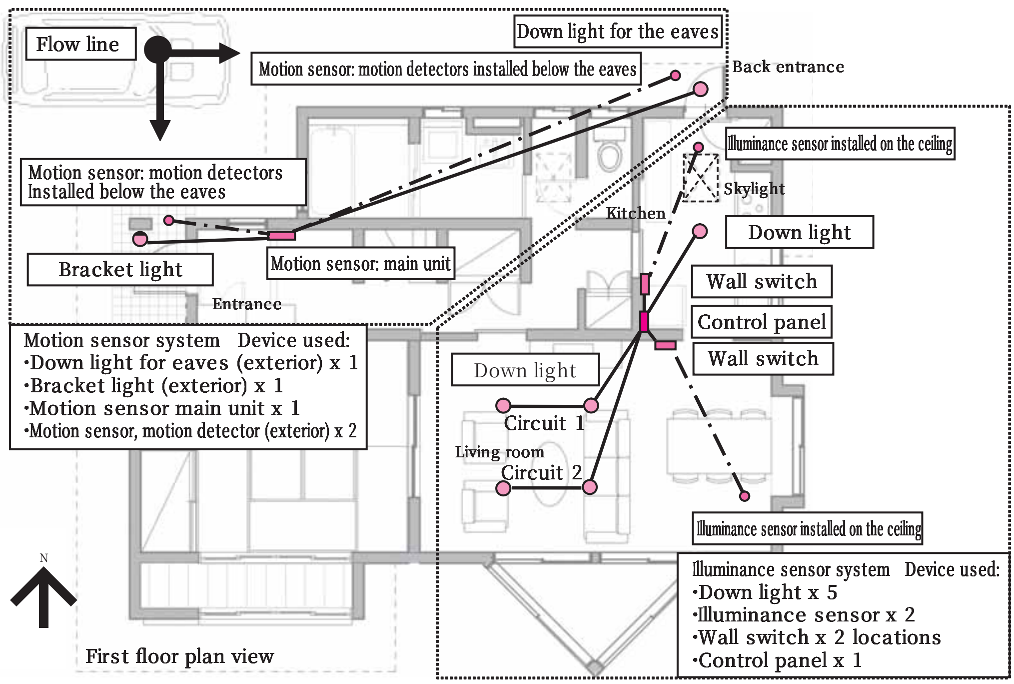


Fig. 6 Energy saving design example using motion sensors and illuminance sensors

Points of caution
The desired functioning of lighting devices can only be obtained when the detection range of motion sensors is appropriately adjusted.

Points of caution
Set up illuminance sensors where they are not affected by direct sunlight or other illuminance devices.

Method 3 : Method using design

Using either the one-light-per-room or the distributed multiple lighting system depending on the purpose or the actions that take place in the room is an effective way of saving energy as well as enhancing the light environment. As mentioned previously, the one-light-per-room lighting system is the conventional method that places one lighting device near the center of the ceiling while the distributed multiple lighting system spreads multiple lighting devices around the room with detailed settings determining the lighting pattern.

The advantages and effects of adopting the distributed multiple lighting system are as follows.

- The amount of artificial lighting required varies between the daytime and the evening and is also dependent on the actions that take place in the space. In a function-based room such as the bathroom and the toilet, the one-light-per-room lighting system is the norm, as actions that take place in the space do not vary. In a room such as the living room and bedrooms, however, actions can vary and adopting the distributed multiple lighting system may be necessary, as it allows multiple lighting patterns.
- By adopting the distributed multiple lighting system, wasteful lighting in locations and time periods can be reduced, which is extremely effective from the energy efficiency point of view. Furthermore, the quality of the light environment may also be improved, as it is easier to create the most appropriate light environment depending on the action.
- When using the distributed multiple lighting system, the occupants are required to select a lighting pattern for each action. This may create a situation, if the occupants are not overly concerned about being careful, in which most of the lights are almost always on without making use of the different lighting patterns. When using the system with many lighting devices, the range of the energy saving effect will therefore be very wide depending on how it is operated. The more lighting devices are used, the wider the range of this effect will be. It is thus essential for you to carefully discuss this with the occupants and be responsible in recommending a detailed lighting schedule according to their lifestyle. Ensure also, when planning, that the maximum power consumption (the total wattage of all lighting devices) is not excessive (See “Comment” later in the chapter).
- See pp. 291 – 293 for the steps in designing.

The following are the results of an evaluation concerning the light environment as well as the energy saving effect of the one-light-per-room lighting system and the distributed multiple lighting system, based on design examples prepared for realistic living and dining rooms.

The design examples do not take daylight into consideration but rather attempt to improve the light environment using artificial lighting while being energy efficient. Note that the evaluation of the energy saving effect was based on the lighting schedule for five hours in the evening until bedtime (18:00 to 23:00). Table 4 shows the overview of each design example.

Table 4 Overview of design examples

Plan type	Lighting device	Power consumption ratio	Characteristics
Design example 1: One-light-per-room plan (one-light-per-room lighting system)	2 types/2 lights	100%	This is a conventional plan with one device placed near the center of the ceiling. Problematic for both the light environment and energy efficiency.
Design example 2: Simple distributed multiple lighting plan (distributed multiple lighting system 1)	3 types/5 lights	75 – 90%	This plan adds auxiliary lighting to the one-light-per-room plan. By using an energy-efficient device that allows dimming, energy saving effects can be expected. Auxiliary lighting also enhances the light environment.
Design example 3: Plan reducing ceiling lighting to minimum (distributed multiple lighting system 2)	4 types/7 lights	65 – 90%	This plan mainly uses indirect lighting and puts emphasis on creating an atmosphere. Although the quality of the light environment is enhanced, power consumption can be high depending on the way the system is operated.
Design example 4: Plan that allows for various moods (distributed multiple lighting system 3)	5 types/9 lights	65 – 90%	This plan spreads small lighting devices around and allows for various moods to be created. It allows the occupants to select the most appropriate light environment. However, if their awareness toward the light environment is minimal, it may cause power consumption to rise due to a possible increase in wasteful lighting.

Design example 1: One-light-per-room lighting system in living and dining rooms

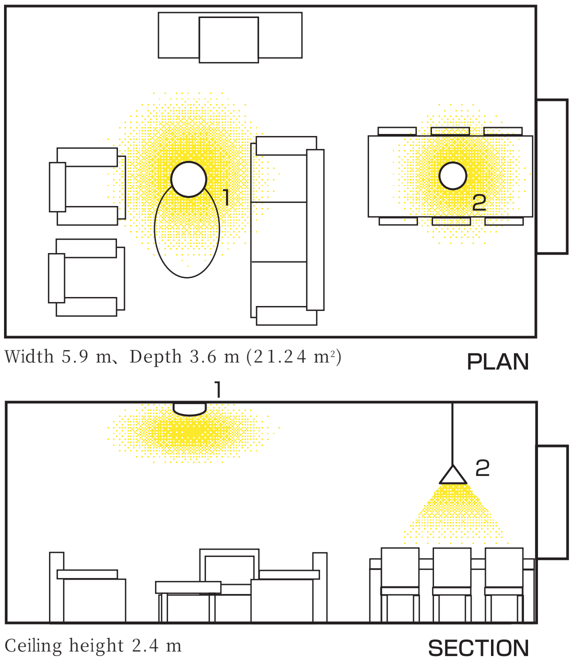
【One-light-per-room lighting plan】

With the one-light-per-room lighting system, it is most common to use a ceiling light in the living room and a pendant light in the dining room.

As the lighting devices are positioned in the center of the room, the impression of the room lacks contrast and appears rather flat. The light environment is strictly functional its quality is rather poor.

Furthermore, there is much wasteful lighting as areas where light is not needed are brightly lit and the ON/OFF-only control keeps the area bright until right up until bedtime.

The reason for the popularity of this lighting system is the ease of installation and exchange of lighting devices and light bulbs. It also does not require a detailed lighting design. This system, however, is problematic for both the light environment and the energy efficiency.



Disadvantages of one-light-per-room lightingsystem
・Some areas are lit unnecessarily.
・Wasteful lighting for some time periods.
・Cannot create appropriate light environment tailored to each room's purpose.

Actions likely to take place in the living room
・Family time, watching TV, listening to music, reading, entertaining guests, etc.
Actions likely to take place in the dining room
・Meals, family time, etc.

Table a　Light environment

	Characteristics	Device number
Functions	・Iluminance on table surface (200 lx)	1、2
	・Brightness on faces	1、2
Atmosphere	・Bright feel of the space	1
	・Cheerfulness	—
	・Calm	—
	・Sense of rhythm	—
	・Fun	—

Table b　Energy saving effect

Device	Lamp	No. of lights	Power consumption (W)	Total power consumption (Wh)	Power consumption ratio*
1 Ceiling	72W circular fluorescent lamp	1	70	280	
2 Pendant light	100W incandescent light bulb	1	90	90	
				370	100%

*See "How to calculate power consumption ratio" on p.309 for details on the total power consumption and the power consumption ratio.

Design example 2: Distributed multiple lighting system 1 in living and dining rooms

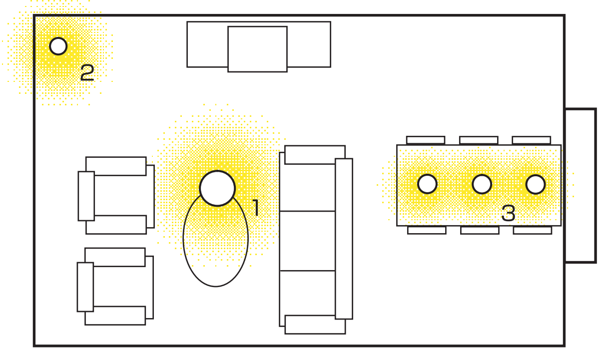
【Simple distributed multiple lighting plan】

A simple distributed multiple lighting system can be created, for example, by positioning a ceiling light at the center of the ceiling and adding some auxiliary lighting such as a floor lamp.

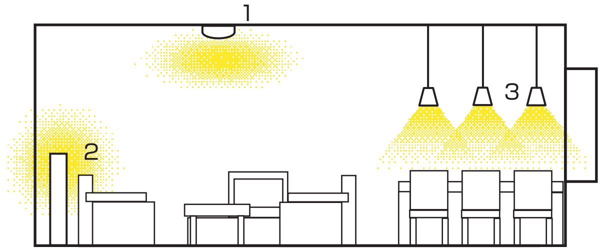
When doing so, it is important from the point of view of energy efficiency to either select a lower wattage for the ceiling light or lighting that allows dimming.

The quality of the light environment, however, is not excellent as the ceiling light at the center of the ceiling illuminates the table surface, providing even lighting and a flat impression to the whole space.

The dining pendant in this plan has several lights so as to allow for varied lighting patterns depending on the situation, which gives the space some contrast. Furthermore, low lighting such as a floor lamp can create a calm space.



Width 5.9 m、Depth 3.6 m (21.24 m²)　PLAN



Ceiling height 2.4 m　SECTION

Key points of distributed multiple lighting system
- Can provide necessary amount of brightness where it is needed.
- Can create moods appropriate for activities.
- Can reduce wasteful power consumption.

Mood example 1: All lights on

Mood example 2: Relaxing, etc.
(ceiling light 70% + floor lamp on low + 1 pendant on)

Table a　Light environment

	Characteristics	Device number
Functions	・Illuminance on table surface (200 lx)	1、3
	・Brightness on faces	1、3
Atmosphere	・Bright feel of the space	1
	・Cheerfulness	—
	・Calm	2
	・Sense of rhythm	3
	・Fun	—

Table b　Energy saving effect

Device	Lamp	No. of lights	Power consumption (W)	Total power consumption (Wh)	Power consumption ratio*
1 Ceiling	85W circular fluorescent lamp (dimmable)	1	77	250 ～ 273	Total power consumption in design example 2/Total power consumption in design example 1
2 Floor lamp	8W compact fluorescent lamps x2	1	16	8 ～ 36	
3 Pendant	8W compact fluorescent lamp	3	24	18 ～ 24	
				276 ～ 333	Approx. 75 – 90%

*See “How to calculate power consumption ratio” on p.309 for details on the total power consumption and the power consumption ratio.

Design example 3: Distributed multiple lighting system 2 in living and dining rooms

【Plan reducing ceiling lighting to minimum】

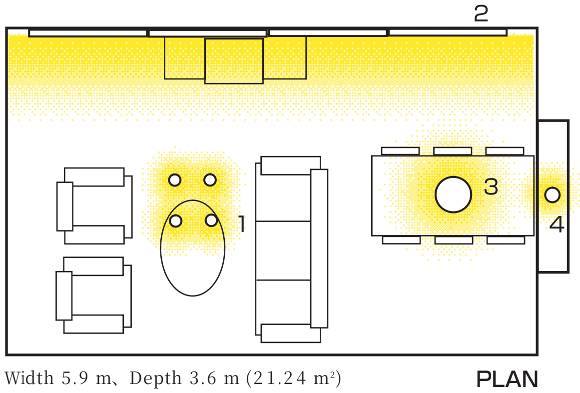
Besides multiplying the lighting from the ceiling, the distributed multiple lighting system can also disperse the light to the walls and floor.

Brightening up the walls, which can be done for example with indirect lighting, is especially effective in enhancing the overall brightness. When doing so, it is important to ensure that the wall surfaces are matt white in color with a high reflectance.

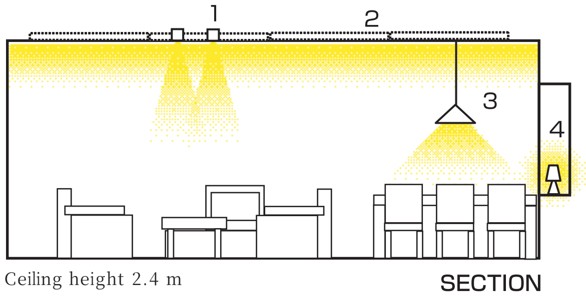
Using indirect lighting to obtain brightness on the table surface, however, can lead to more energy consumption. Selecting the type of indirect lighting that allows dimming is therefore recommended.

Furthermore, place down lighting and pendant lighting where brightness is needed.

Placing accent lighting such as a desk lamp can create a livelier atmosphere in the space where it tends to be flat.



Width 5.9 m、Depth 3.6 m (21.24 m²)



Ceiling height 2.4 m

Mood example 1: All lights on

Mood example 2: Watching a movie, etc.
(down light x 2 + indirect lighting 50%)

Key points of distributed multiple lighting system
- Functional lighting and atmosphere lighting are designed separately.
- Takes light balance into consideration.
- Also takes the interior (colors and materials) into consideration.
- Switches are placed clustered together.

Table a　Light environment

	Characteristics	Device number
Functions	・Iluminance on table surface (200 lx)	1、2、3
	・Brightness on faces	1、3
Atmosphere	・Bright feel of the space	2
	・Cheerfulness	—
	・Calm	—
	・Sense of rhythm	—
	・Fun	4

Table b　Energy saving effect

Device	Lamp	No. of lights	Power consumption (W)	Total power consumption (Wh)	Power consumption ratio*
1　Down light	8W Compact fluorescent lamp	4	32	95～112	Total power consumption in design example 2/Total power consumption in design example 1
2　Indirect lighting	LED Table lamp (dimmable)	1	80	120～208	
3　Pendant	22W compact fluorescent lamp	1	22	22	
4　Desk lamp	8W compact fluorescent lamp	1	8	4～8	
				241～350	Approx. 65 - 95%

*See “How to calculate power consumption ratio” on p.309 for details on the total power consumption and the power consumption ratio.

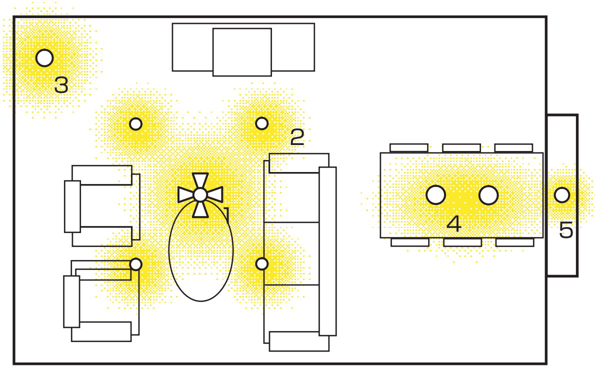
Design example 4: Distributed multiple lighting system 3 in living and dining rooms

【Plan that allows for various moods】

This plan allows the user to create various moods by turning on different combinations of lights.

Turning on the chandelier and the LED down light gives the room a cheerful atmosphere for special occasions such as when entertaining guests. Using the LED down light only can provide the room with an overall darkness as well as the minimum required light by dimming, which is suited for activities that take place in the dark such as watching a movie. Combining the LED down light and the floor lamp gives the space a calm atmosphere with enough local light, which is ideal for reading and other similar activities.

LED lamps enhance the attractiveness of the space by giving it a shimmering look. They also have a high light-harvesting performance and give the space a contrast. They are, in other words, effective in enhancing the quality of the light environment. They are however currently not commonly used due to their high prices, but this may come down as they become more popular.



Width 5.9 m、Depth 3.6 m (21.24 m²)　PLAN

Mood example 1: All lights on

Mood example 2: Family time, etc. (chandelier + pendant x 1)

Mood example 3: Watching a movie etc.
(down light 50% + floor lamp on low + desk lamp)

Key points of distributed multiple lighting system
- Ensure the total wattage is not excessive.
- Do not add too many different types of lamps.
- Discussion with the occupants is essential.

Table a Light environment

	Characteristics	Device number
Functions	・Illuminance on table surface (200 lx)	1、2、4
	・Brightness on faces	1、4
Atmosphere	・Bright feel of the space	1
	・Cheerfulness	1、2
	・Calm	3
	・Sense of rhythm	4
	・Fun	5

Table b　Energy saving effect

Device	Lamp	No. of lights	Power consumption (W)	Total power consumption (Wh)	Power consumption ratio*
1　Chandelier	13W compact fluorescent lamp x4	1	52	156～208	Total power consumption in design example 4/Total power consumption in design example 1
2　Down light	5W LED (dimmable)	4	20	32～52	
3　Floor lamp	8W compact fluorescent lamps x2	1	16	24～40	
4　Pendant	12W compact fluorescent lamp	2	24	24	
5　Desk lamp	8W compact fluorescent lamp	1	8	4～8	
				240～332	Approx. 65－90%

*See "How to calculate power consumption ratio" on p.309 for details on the total power consumption and the power consumption ratio.

Key Point

How to calculate power consumption ratio for design examples

- Power consumption ratio (%) expresses the ratio of power consumption planned for the distributed multiple lighting system compared with that of the conventional one-light-per-room lighting system.

$$\text{Power consumption ratio} = \frac{\text{Total Power consumption for distributed multiple lighting system}}{\text{Total power consumption for conventional one-light-per-room lighting system}}$$

- The total power consumption (Wh) is calculated using the following formula.

  Total power consumption = ∑ (power consumption of the single device x the switch-on ratio of the device)
- The switch-on ratio takes into consideration the hours the device was switched on as well as the dimming ratio, and is calculated using the following formula.

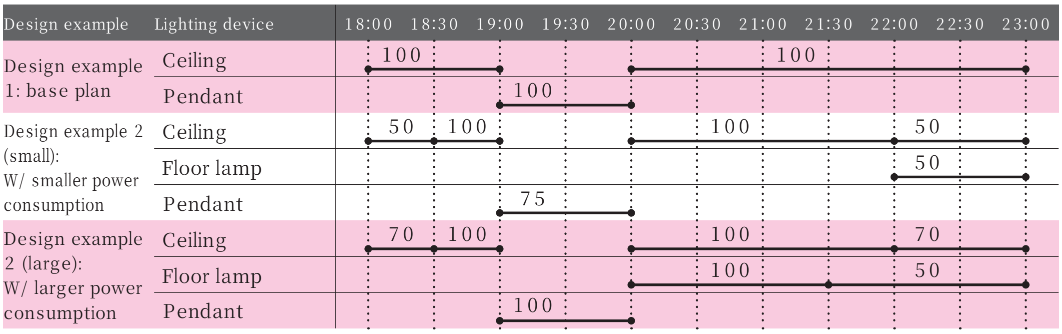
  Switch-on ratio = hours turned on x dimming ratio when on
- The dimming ratio also applies when using only some of identical multiple lighting devices or some of multiple lamps of one lighting device. For example, the dimming ratio when only two lamps of the three-lamp pendant light are used is 2/3=0.66=66%.

  The following is an example calculation for design example 2.

Table a Lighting devices used

Design example	Lighting device	Lamp	# of lamps	Power consumption (W)	Hours on (h) x dimming ratio
Design example 1: base plan	1. Ceiling	72W circular fluorescent lamp	1	70	4×1
	2. Pendant	100W incandescent light bulb	1	90	1×1
Design example 2 (small): W/ smaller power consumption	1. Ceiling	85W circular fluorescent lamp	1	77	2.5×1+1.5×0.5
	2. Floor lamp	8W compact fluorescent lamp X2	1	16	1×0.5
	3. Pendant	8W compact fluorescent lamp	3	24	1×0.75
Design example 2 (large): W/ larger power consumption	1. Ceiling	85W circular fluorescent lamp	1	77	2.5×1+1.5×0.7
	2. Floor lamp	8W compact fluorescent lamp X2	1	16	1.5×1+1.5×0.5
	3. Pendant	8W compact fluorescent lamp	3	24	1×1

Table b Switch-on schedule



Note: The solid line denotes that the device was turned on and the value above the line indicates the dimming ratio (%).

Comment ● How to plan distributed multiple lighting well

When planning distributed multiple lighting, if you start with the assumption of installing the lighting using a particular kind of scenario based on the total power consumption in watts, you may be so overwhelmed that you will be at a loss as to where to start.

Therefore, it will be helpful to fist bring down the wattage of the lighting device placed in the center of the room and then to distribute the wattage reduced to the down lights and lamps.

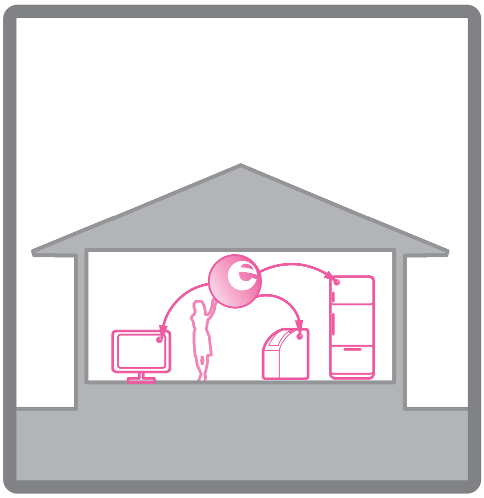
This way, in most households, a distributed multiple lighting can easily be achieved without increasing the power consumption of everyday life.

If the use of a ceiling light for a one-light-per-room system is to be retained, consideration should be given to adjusting the level of lighting lower and setting this as the norm; the wattage reduced should then be distributed to other lighting devices.

5

Chapter 5
Energy-efficient Equipment Technology (Elemental Technology Application Method 3)

5.6 Adopting High-efficiency Consumer Electronics



Although space cooling and heating along with lighting account for the majority of the power consumption in a household, approximately 30% of consumption is by consumer electronics such as televisions and refrigerators. These consumer electronics are becoming increasingly energy efficient to address society's demand for energy conservation. A significant improvement has thus been made on their energy performance while in use as well as when on standby.

Reducing the energy consumption of an entire household can be realized by gathering appropriate information when replacing consumer electronics.

5.6.1 Key Points for Adopting or Replacing High-efficiency Consumer Electronics

- When purchasing new or replacing old consumer electronics, in addition to the functions and the price, considering energy efficiency of the products will lead to energy conservation and reduced running costs.
- From the point of view of LCC and $LCCO_2$, purchasing new consumer electronics is not necessarily always recommended when the cost associated with replacing and the energy consumed for manufacturing the product are taken into account. However, in some cases, depending on the type and the age of the consumer electronics, the initial cost and the energy consumed by manufacturing process can be recovered in several years by replacing.
- When replacing consumer electronics, the cost effectiveness and energy benefit can vary greatly depending on the types of consumer electronics as well a their condition and how they are used. It is therefore important to estimate the reduction in running cost and the energy saving effect by perusing documents such as catalogs before making a decision.

Glossary: LCC and $LCCO_2$
The acronym LCC stands for "Life Cycle Cost", which is the total sum of cost required for the entire life process of industrial products and buildings, from the manufacturing and actual use of the product or building, right up to its disposal or demolition. LCC also includes all the costs associated with material procurement, construction, management, maintenance, repair, and scra-pping.
$LCCO_2$ stands for "Life Cycle Carbon Dioxide" and represents the amount of CO_2 emission during the above-mentioned process.

5.6.2 Energy Conservation Target Levels for Adopting High-efficiency Consumer Electronics

1. Definition of target levels

The levels for adopting high-efficiency consumer electronics are based on the energy consumption by consumer electronics found in an average household in 2000. The following table shows the reduction rates.

Level −1	:	Approx. 40% increase compared with typical energy consumption in 2000
Level 0	:	Typical energy consumption in 2000
Level 1	:	Approx. 20% reduction compared with typical energy consumption in 2000
Level 2	:	Approx. 40% reduction compared with typical energy consumption in 2000

All target levels can be achieved by taking energy saving measures such as replacing consumer electronics that have high energy consumption with high-efficiency ones.

Note
Some manufacturers of consumer electronics offer on their websites an application to calculate the estimated running costs.
http://panasonic.jp/eco/kaikae/

2. Requirements for achieving target levels

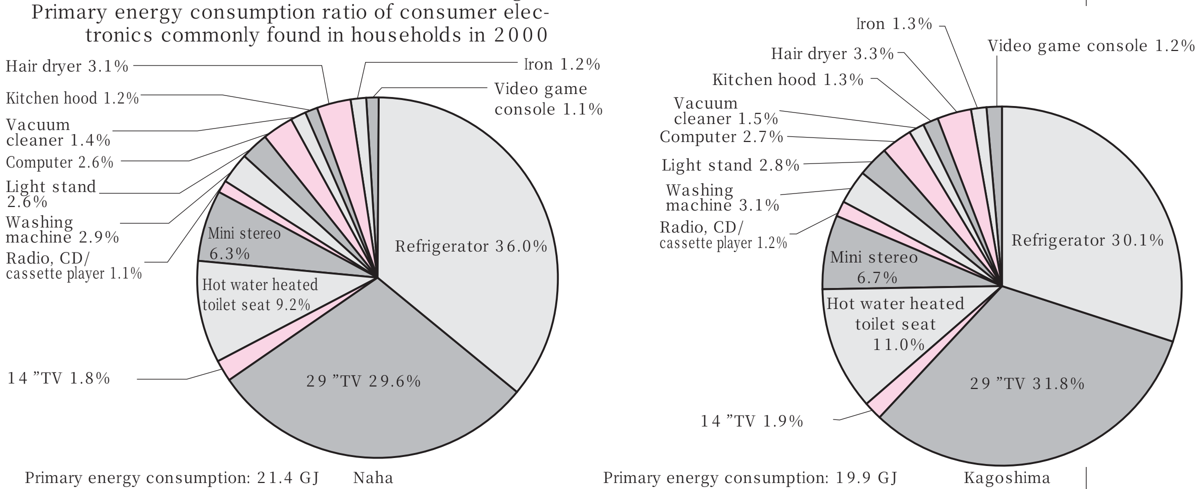
1) Facts about types of consumer electronics and energy consumption

Fig. 1 shows the breakdown of energy consumption by consumer electronics in a typical household (in Naha and Kagoshima). Power consumption is much greater for certain types of consumer electronics such as refrigerators and televisions (two televisions per household), each exceeding 30% (or 60% together) of the entire power consumption by consumer electronics. These two, along with hot water heated toilet seats and washing machines, account for nearly 80% of the total power consumption by consumer electronics.

Although appliances such as space cooling and heating devices and domestic hot water devices do consume electric power, it is important to carefully consider general consumer electronics, which account for roughly 30% of all energy consumption (or 40% of electric power consumption), in order to effectively achieve energy conservation. Consumer electronics that account for a high share of power consumption mentioned above need to be the first to be replaced with higher-efficiency models.

Fig. 2 (found on the next page) shows the power consumption by a conventional device as well as by an energy-efficient replacement and the reduction in power consumption for consumer electronics with high power consumption most common in households. The power consumption shown is the total annual power consumption (kWh per year) and the reduction is indicated using %. The reduction shown here is the result of comparing products from 1997 and 2003. Most energy-efficient technologies for devices such as refrigerators were well established by 2001 and the improvements thereafter have been minimal. Energy-efficient technologies in this area have been developed in discontinuous phases rather than small yearly increments and the timing of these phases differs depending on the kind of consumer electronics.

Fig. 1
Primary energy consumption ratio of consumer electronics commonly found in households in 2000



- These pie charts are based on the calculations using the energy consumption data obtained from conducting the validation experiment during which consumer electronics were actually operated. The weather conditions in Naha and Kagoshima were then taken into consideration.
- During the validation experiment, a full-scale test house (Kanto region) was used to recreate the life of an average four-person household including consumer electronics ownership, their daily schedules, and the use of these devices. It recreated energy consumption and heat generation that occur within the household throughout the year and measured the realistic energy consumption and the effects of energy saving methods.
- Some consumer electronics and their energy consumption can be affected by the outside conditions in hot humid regions. To calculate energy consumption for those devices, weather conditions in Naha or Kagoshima (Expanded AMeDAS Weather Data 1981 – 2000) were applied to the relational expression between various energy consumption figures and the outside air temperature, the room temperature, and the water temperature obtained through the validation experiment.

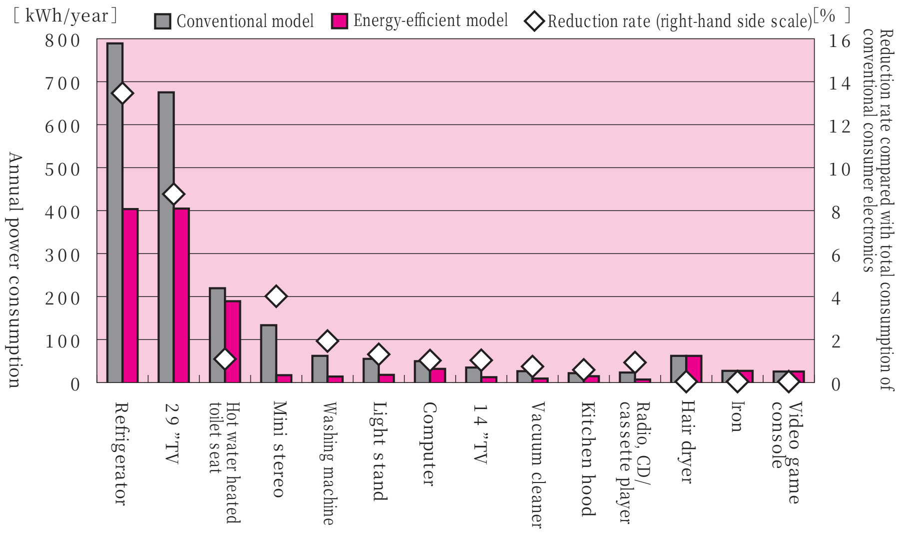


Fig. 2 Power consumption of conventional consumer electronics and reduction rate after adopting energy-efficient consumer electronics (Naha)

Conventional model = product with high market share in FY 1997.
Energy-efficient model = most energy-efficient product available in FY 2003.
In reality, the consumption pattern varies greatly from one household to another as products used for long periods of time consume more power.

- The validation experiment results shown above are for standard products selected from those available around 1997. Those with average efficiency were deemed appropriate after taking into consideration the consumer electronics ownership of an average household in 2000.
- The validation experiment results shown above for energy-efficient products in FY 2003 are for products with the best catalog energy performance of those sold in FY 2003.

2) Prime consumer electronics and priority consumer electronics

Of those general consumer electronics that account for a large percentage of the total energy consumption in a typical household, "prime consumer electronics" are defined as devices that are used for an extended period of time and tend to have high energy consumption. Refrigerators and televisions fall under this category. "Priority consumer electronics" are devices that can consume an unexpected amount of power depending on how they are used. Hot water heated toilet seats, electric hot water pots and washing machines fall under this category (Table 1).

Table 1 Prime consumer electronics and priority consumer electronics

Prime consumer electronics	1. Refrigerators 2. Televisions
Priority consumer electronics	3. Hot water heated toilet seats 4. Electric hot water pots 5. Washing machines

Furthermore, we have established the "energy-efficient device classification" based on the energy saving effect of the devices that fall under the categories of prime and priority consumer electronics. Energy-efficient device classification is divided into categories according to the year the device was manufactured, technologies, and power consumption. The classification also indicates the annual power consumption of the each category as well as the reduction in energy consumption when compared with a product manufactured in 2000 (See "1 Energy-efficient device classification for prime and priority consumer electronics and their characteristics" in Section 5.6.3 on p.316).

The most important factor in determining the energy saving effect achieved by replacing consumer electronics is the difference in performance between the product currently in use and the product that replaces it. The bigger the difference is between the two, the bigger the effect of replacing the current product.

However, as mentioned previously, the energy performance of consumer electronics does not improve in relation with time but rather tends to show drastic improvement when certain technologies are developed.

It is therefore crucial to determine whether the product was manufactured before or after the drastic improvement. As years and types of technologies that boosted the performance vary depending on the type of consumer electronics, consumers are encouraged to verify this information before making a decision.

Electric hot water pots, electric rice cookers, clothes dryers, and dishwashers also require a significant amount of power depending on how they are used. For example, an electric hot water pot, which is not insulated, consumes more than 80 W when keeping the water warm. This is comparable to the power consumption of a ventilation system for overall ventilation. Electric rice cookers also consume a lot of power when keeping the rice warm. In household where the family uses the “keep-warm” function for an extended period of time, it would be helpful to select an energy-efficient model. Although energy performance of clothes dryers cannot be simply compared as their drying methods differ from one dryer to another and no common index exists, small efforts such as using it less frequently or combining it with natural drying can reduce the power consumption. For dishwashers, selecting a water-saving model will limit the power required to supply hot water and conserve water resources.

Comment ● Energy consumption of hot water heated toilet seats in hot humid regions

Hot water heated toilet seats that are not energy efficient can consume an unexpected amount of energy in warm regions and are considered prime consumer electronics while they fall under priority consumer electronics in hot humid regions, reflecting the usage pattern in the area.

The figure below shows the comparison between the conventional hot water heated toilet seat and its energy-efficient counterpart. It can be surmised that the reason why conventional hot water heated toilet seats do not consume as much energy in hot humid regions is that the high temperature of both the air and the water supply make it less energy consuming to keep the toilet seat and washing water warm.

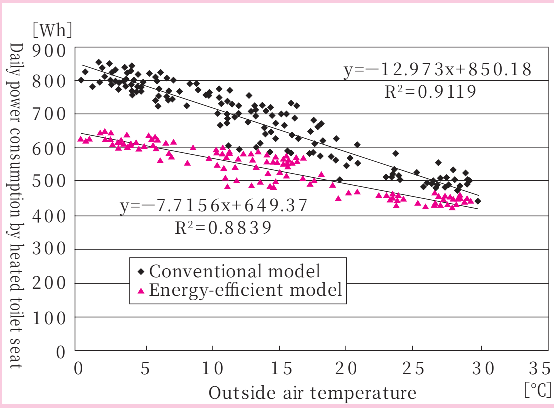


Fig.
Relationship between outside air temperature and daily power consumption by heated toilet seat

* When the outside air temperature is high, the energy saving effect is reduced.

3) Standby energy consumption

The consumer electronics device with the fourth largest power consumption is the mini stereo (See Fig. 1 on p.311); however, most of the power consumption occurs not when it is in use but as standby power. Standby power is consumed 24 hours a day and its amount greatly influences the power consumption of the device as a whole. For example, if a product consumes 1 W of standby power, the total consumption will be 8.76 kWh per year. Although the amount of standby power consumption varies greatly depending on the type of device and its rating, efforts have been made to minimize it as much as possible for most of the products sold after 2004. It should be noted, however, that some products that date back to the 1990s consume nearly 100 times more standby power than the current products.

Virtually all devices that remain plugged in consume standby power. Some examples other than prime and priority consumer electronics are mini stereos, stereos, tuners, DVD players, video cassette players, radio-CD-cassette players, computers, telephones, microwave ovens and video game consoles; especially those devices that come with remote controls, time display or AC adapters tend to consume a lot of power.

In most cases, the amount of standby power consumed is indicated on the device. Note that most products sold in recent years consume a minimal amount, approximately 0.1 W, of standby power. If a device consumes several watts of standby power, it would be wise to unplug is when it is not in use.

4) Devices that operate for extended periods of time

Similar to standby power consumption, if consumer electronics devices are used all day long or for extended periods of time, the total power consumption at the end of the day can be large even though the device is not high. Some examples of these devices are the increasingly popular network devices, air purifiers, and security devices.

At this point in time, it is difficult to find energy-efficiency measures for these consumer electronics as they are a new type of energy consumption born out of our new lifestyle in recent years. However, some basic rules such as not using devices unnecessarily and frequently turning them off when not in use do apply and being mindful as users remains important.

For reference purposes, Table 2 shows the amount of annual power consumption for products that are most common in recent years.

Table 2 Power consumption of consumer electronics used for extended periods of time

Device	Hours in use/year	Power consumption	Annual power consumption	Effect on power consumption of consumer electronics in 2000	Remarks
Wireless LAN, HUB, etc.	8,760	10 W	88 kWh	Increased 4.1	
Air purifier	500	12 W	6 kWh	Increased 0.3	In use for 4 hours/day, 125 days/year, 2.0 m3 /minute
Fire alarm	8,760	2 W	17.5 kWh	Increased 0.82	

3. How to achieve target levels

The energy conservation target levels for adopting high-efficiency consumer electronics are based on the power consumption by consumer electronics owned by a typical household in 2000 and indicate the reduction rate. Table 3 shows the reduction rate as well as the amount of energy reduced.

The amount of energy reduced for prime and priority consumer electronics is calculated by adding all the figures for energy reduction indicated for energy-efficient device classification (Table 4 – 8). Furthermore, Level 2 requires measures against standby power consumption.

Table 3 Target levels for adopting high-efficiency consumer electronics

Target level	Energy saving effect (consumer electronics energy reduction rate)	Amount of energy reduced	Device classification for prime and priority consumer electronics used (example)													
			Refrigerator				Television					Hot water heated toilet seat			Electric hot water pot	
			−1	0	1	2	−1	0	1	2	3	−1	0	1	0	1
Level −1	Up approx. 40%	Approx. −1,000 kWh (increase)	●					●					●		●	
Level 0	0	None		●				●					●		●	
Level 1	Approx. 20%	500 kWh or more			●				●				●		●	
Level 2	Approx. 40% or more	1,000 kWh or more + amount reduced by adopting devices with low standby power consumption				●					●			●		●

* It is assumed that mini stereos and microwave ovens, etc., are those with low standby power consumption available from 2003 or later (See p.314).

- Many different combinations of devices are possible to achieve each energy conservation level for consumer electronics.
- As televisions are increasingly bigger and information devices more common, energy consumption by consumer electronics appears to be increasing. It is thus preferable to select products that are more energy efficient after considering their functions and performance.
- Some consumer electronics such as hair dryers and irons are difficult to make energy efficient; however, even then, it is still important to make the effort to select highly-efficient products with low standby power consumption whenever possible.

5.6.3 Characteristics of Consumer Electronics and Points of Caution for Usage

1. Energy-efficient device classification for prime and priority consumer electronics and their characteristics

1) Refrigerators

Table 4 below shows the energy-efficient device classification for refrigerators (capacity of 400 L) using the power consumption of a product (inverter type) manufactured between 1995 and 2000 as the standard (Class 0).

Table 4 Energy-efficient device classification for refrigerators (400 L)

Device classification	Year manufactured	Technologies	Annual power consumption	Energy reduction	JIS indicated value of annual electricity consumption
Class −1	Models up to 1994	No energy-efficient design	1,800 kWh	−1,000 kWh (increase)	No display (800 kWh or more)
Class 0	1995 – 2000	Inverter	800 kWh	0 (Standard)	400 kWh
Class 1	2001 – 2006	High insulation performance (+ CFC free)	400 kWh	400 kWh	200 kWh
Class 2	Energy-efficient models in 2007	High insulation performance (+CFC free)	300 kWh	500 kWh	450 kWh (2006JIS)

* JIS indicated value of annual electricity consumption quotes figures indicated in catalogs (See "Key Point" on this page).
The figures for the annual power consumption as well as the energy reduction were obtained from the results of the validation experiment. (Based on a model manufactured in 1997: Class 1 is set at the values obtained through experiment using an energy-efficient model manufactured in 2003; the refrigerator door was never opened as per the condition of the validation experiment.)

- Class 0 (standard) is established using a model manufactured in 1997 with an annual power consumption of approximately 800 kWh.
- In terms of important energy-efficient technologies in refrigerators, the inverter compressor and the improved insulation performance have had a significant influence.
- Although energy consumption of refrigerators can vary depending on their capacity, generally speaking, the energy consumption increases in proportion with the capacity of the refrigerator. However, energy-efficient technologies tend to be implemented first in popular models that sell well. This means that a refrigerator with a smaller capacity may not be equipped with the energy-efficient technologies mentioned in the table above and its energy consumption may be larger.
- Power consumption of a refrigerator is closely linked to the temperature of its surroundings (ambient temperature), and the higher the temperature, the larger the power consumption. It is therefore advisable to avoid placing it at a location with direct sunlight. Good air circulation should also be ensured to efficiently eliminate the heat generated by the refrigerator.

Key Point

JIS indicated value of annual electricity consumption for refrigerator

- JIS revised its calculation standard for indicating annual power consumption for refrigerators on May 1, 2006. As shown on the figure below, when comparing the former indicated values to JIS2006 using models sold in FY 2006, all of them showed approximately 3.5 times more power consumption. Bear this in mind when comparing values between the former JIS and JIS2006. Note also that the difference in indicated values can vary depending on the size of the refrigerator since the indicated values for smaller models, unlike the larger models (400 L class), did not change much after the revision.
- Furthermore, when comparing the annual energy consumption indicated in catalogs and the results of the validation experiment, the difference was 2.1 times for the standard models manufactured in 1997 (380 kWh) and 2.2 times for energy-efficient models in 2003 (190 kWh). In other words, the estimated values for actual power consumption are approximately twice as much as the former JIS indicated values. Note that, among models with JIS2006 indicated values, the values for energy-efficient models (450 kWh) in 2007 were approximately 0.7 times greater than the results of the validation experiment. It is probable that this discrepancy is due to changes in measurement conditions and other factors.

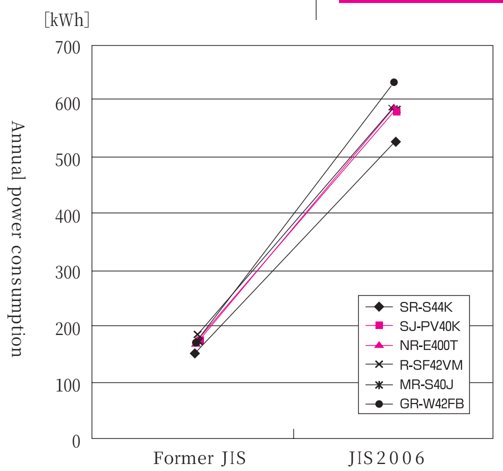


Fig. JIS indicated value for annual electricity consumption of refrigerators

2) Televisions

Televisions come in various types and sizes. Table 5 below shows the energy-efficient device classification based on measurements taken during the validation experiment using the power consumption of a CRT-based television manufactured in 1997 as the standard (Class 0).

Table 5 Energy-efficient device classification of televisions (28” and 37”, CRT-based, plasma, LCD)

Device classification	Type/size/year	Annual power consumption	Energy reduction
Class −1	37” plasma manufactured up to 2004	700 kWh (reference purposes)	−50 kWh (increase; reference purposes)
Class −1	37” plasma manufactured in 2007	900 kWh (reference purposes)	−250 kWh (increase; reference purposes)
Class 0	28” CRT-based manufactured up to 2000	650 kWh	Standard
Class 0	37” LCD manufactured up to 2004	650 kWh	0 kWh
Class 1	37” LCD manufactured in 2007	550 kWh	100 kWh
Class 2	28” LCD manufactured up to 2000	450 kWh	200 kWh
Class 3	28” LCD manufactured between 2001 and 2003	400 kWh	250 kWh
Class 3	28” LCD manufactured from 2004 onward	370 kWh	280 kWh

* Results for CRT-based TV were based on actual measurements estimating average of 8.3 hours of daily use.
As larger sizes are the norm for plasma TVs, the results for 37”-sized models were shown here for reference purposes. Those figures were calculated using catalogs and based on the JEITA standards with estimated 8.3 hours of daily use.
The results for the LCD TVs were based on actual measurements estimating an average of 8.3 hours of daily use.

- Energy-efficient technologies available for televisions include “minimizing standby power consumption”, “LCD TVs”, and reducing the power consumption of tuners. It is therefore preferable to select a product that is equipped with those technologies.
- In recent years, we are seeing an increasing number of large-size televisions. Bear in mind that, even if they are LCD TVs that consume a relatively small amount of energy, large televisions will consume much energy when in use.

Key Point

Changes in power consumption of televisions according to brightness of surroundings

- Wattage of televisions varies depending on the brightness setting of the screen (Fig.).
- The required brightness of the screen also varies depending on the condition of the surroundings and the program content. Making the surroundings as dark as possible can reduce the required brightness of the screen and lead to energy efficiency. In some cases, the reduction rate exceeds 50%.
- Many newer televisions are equipped with a function that automatically adjusts the brightness of the screen according to the brightness of the surroundings. Energy efficiency can be achieved by making use of such functions while taking into consideration the daylighting and lighting methods when watching the television.

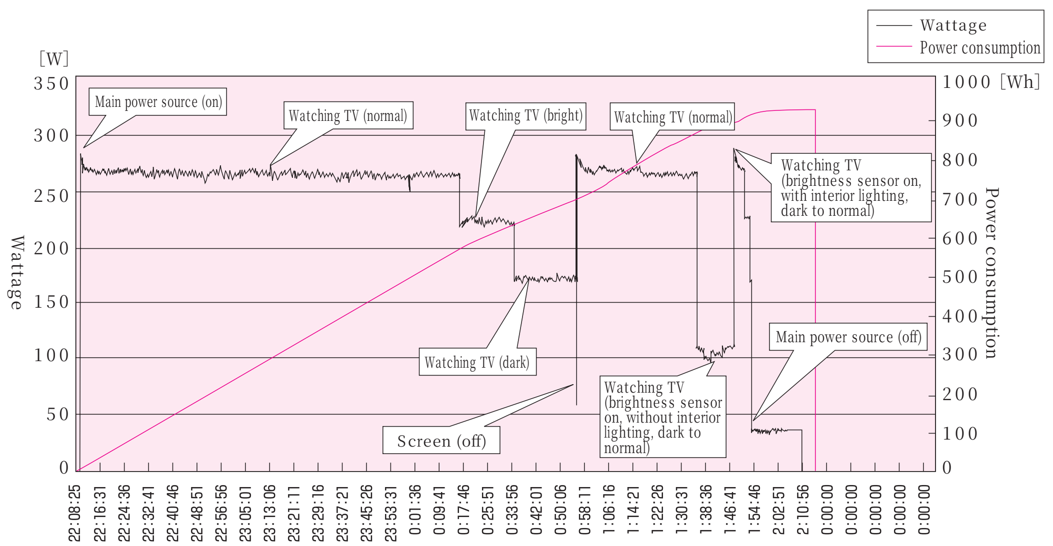


Fig. Changes in wattage of LCD TV (46”) according to brightness of surroundings
Year manufactured: 2006; rated wattage: 288 W; remote controller standby power consumption: 0.1 W

5

Chapter 5
Energy-efficient Equipment Technology (Elemental Technology Application Method 3)

3) Hot water heated toilet seats

Table 6 below shows the energy-efficient device classification for hot water heated toilet seats using the power consumption of the instant boiling type as the standard (Class 0).

Table 6 Energy-efficient device classification for hot water heated toilet seats

Device classification	Method	Annual power consumption	Energy reduction
Class −1	Hot water storage type	350 kWh or more	−100 kWh (increase)
Class 0	Instant boiling type	200 – 350 kWh	Standard
Class 1	Instant boiling type with timer	Less than 300 kWh	50 kWh

* Based on results of actual measurements conducted during validation experiment.

・Energy-efficient technologies available for hot water heated toilet seats include “instant toilet seat “keep-warm” function”, “instant warm washing water”, “energy-efficient timer”. The “energy-efficient timer” allows the user to set periods of time (such as late-night hours) when the device is not in use and automatically shuts off the heater for the toilet seat and the warm water, which leads to energy efficiency.

4) Electric hot water pots

Table 7 below shows the energy-efficient device classification for electric hot water pots using the power consumption of the regular boiling and “keep-warm” type as the standard (Class 0).

Table 7 Energy-efficient device classification for electric hot water

Device classification	Type	Annual power consumption	Energy reduction
Class 0	Regular	240 kWh	Standard
Class 1	No “keep-warm” function (consecutive boiling)	Approx. 70 kWh	170 kWh
Class 2	Thermos	Approx. 70 kW	170 kWh

* Based on catalog values with estimated average of 8 hours of daily use.

・Energy-efficient technologies available for electric hot water pots include “improved insulating performance “thermos” and “keep-warm function at a lower temperature”. It is also recommended to use a “consecutive boiling” type electric hot water pot without “keep-warm” function that boils only the required amount of water when necessary. Pots with high insulating performance, on the other hand, reduce energy consumption by keeping the water warmer longer and requiring less re-boiling.

5) Washing machines

Table 8 below shows the energy-efficient device classification for washing machines using the power consumption of a product manufactured in 1997 without inverter control as the standard (Class 0).

Table 8 Energy-efficient device classification for washing machines

Device classification	Type	Annual power consumption	Energy reduction
Class 0	No energy-efficient design	85 kWh	Standard
Class 1	Inverter	17.5 kWh	67.5 kWh

* Based on results of actual measurements conducted with average of 4 kg of daily washing.

・Energy-efficient technologies available for washing machines include “inverters” and “zero standby power consumption”.

2 Consumer electronics affected by room temperatures and other factors

Some consumer electronics such as televisions and videocassette players are not affected by the room temperature or the water temperature while others such as refrigerators and electric hot water pots are greatly affected by them (Table 8).

Using refrigerators as an example of a consumer electronics device affected by the room temperature, Table 3 shows the difference in the effect of the room temperature on energy-efficient refrigerators and standard-type refrigerators. Energy-efficient type refrigerators were shown to be somewhat resistant to the effect of the room temperature; however, its effect on standard-type refrigerators available in 2000 was significant as the difference in power consumption was 2.5 times greater between 20°C and 30°C.

Bear in mind that ways to minimize the effect of the room temperatures on consumer electronics are usually not presented in catalogs. Furthermore, the annual power consumption figures indicated in catalogs are generally calculated using the measurement standards established by JIS. The actual power consumption may vary depending on conditions such as how the device is used.

Table 9 Effect of temperatures and other factors on consumer electronics

Examples of devices affected by room temp. and other factors	Refrigerators, electric hot water pots, hot water heated toilet seats, dishwashers, and clothes dryers
Example of devices not affected by room temp. and other factors	TVs, videocassette players, DVD players, computers, vacuum cleaners, mini stereos, radio/CD and cassette players, kitchen hoods, and washing machines

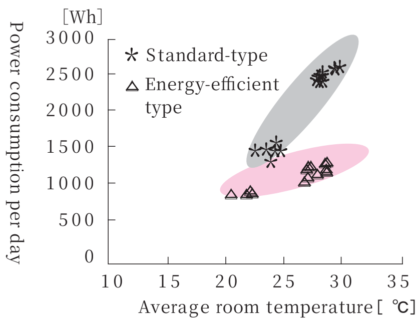


Fig. 3 Effect of room temperature on refrigerators (energy-efficient type and standard-type)

3. How to minimize effect of room temperature and other factors

Minimizing the effect of the room temperature on these consumer electronic devices can lead to energy efficiency.

1) Refrigerators

Refrigerators, one of the biggest sources of power consumption, should be placed at a location away from direct sunlight where air circulates freely. It is advisable to avoid placing a refrigerator near a stove where the air temperature tends to be high. It may also be effective to ensure air circulation by letting the outside air come in to keep the room temperature as low as possible when no one is home during the summer since the room temperature in such a situation tends to get extremely high.

Furthermore, when the door of the refrigerator is opened and closed, it lets in the warm air around the refrigerator. To minimize the effect of this, one should avoid opening the door unnecessarily. Generally speaking, even when the duration of the time that the door was open is the same, energy consumption increases when the door is opened more frequently.

2) Hot water heated toilet seat

When the room temperature of the bathroom is low, the power consumption by the hot water heated toilet seat increases. It is thus effective to improve the insulating performance of the house so as to increase the room temperature of an unheated bathroom.

3) Electric hot water pot

Similar to hot water heated toilet seats, the power consumption by electric hot water pots increases when the room temperature is low. In this case as well, it is effective to improve the insulating performance of the house so as to increase the room temperature.

Key Point

Comparison of annual power consumption by consumer electronics according to region

- A difference in annual power consumption by refrigerators and hot water heated toilet seats was found between the warm region and the cold region (Table).
- The table uses a standard-type device employed in a warm region (Ibaraki) as 100%.

Table: Comparison of annual power consumption by refrigerators and hot water heated toilet seats

Region	Annual average temp.	Refrigerators		Hot water heated toilet seat	
		Standard	Energy-efficient	Standard	Energy-efficient
Okinawa	22.7 °C	115.4%	60.5%	87.1%	74.4%
Ibaraki	15.3 °C	100.0%	54.5%	100.0%	82.4%
Aomori	10.3 °C	94.5%	51.2%	112.4%	89.4%

5.6.4 Estimating Running Cost of Adopting High-efficiency Consumer Electronics

For consumers, energy saving effects achieved by replacing their consumer electronics are understood in terms of saving in the running cost. By making it easier for them to become interested in the issue of running cost and to research on their own, we can create consumers who are more aware of energy efficiency and who will actually take action to improve energy efficiency. The following is a simple way to calculate running cost and how to interpret the results.

1. Calculating running cost

The formula for calculating the annual power consumption and running cost of consumer electronics when in use are as follows.

$$E = Er \times Tr + Es \times Ts$$

E: Annual power consumption (Wh)	
Er: Wattage when in use (W)	Determine using info in catalog
Es: Standby power consumption (W)	Determine using info in catalog
Tr: Hours in use per year (h)	Estimate based on lifestyle
Ts: Hours on standby per year (h)	Estimate based on lifestyle

$$C = E \times P$$

C: Annual running cost (yen)

P: Electricity price (yen/kWh) normally set at 21 yen/kWh (excluding tax)

To calculate the annual running cost accurately, it is necessary to first obtain power consumption by the season and the time of day, as the electricity price may vary according to the season or the time of day in some electricity contracts. However, if comparing two or more devices of the same type (e.g. comparing two televisions), the variance in the electricity price depending on the season or the time of day would also be the same. In this case, the standard price of 21 yen/kWh (excluding tax) can easily be used.

2. How to interpret cost reduction effect when replacing devices

The cost reduction effect for replacing consumer electronics is a combination of the initial cost and the running cost.

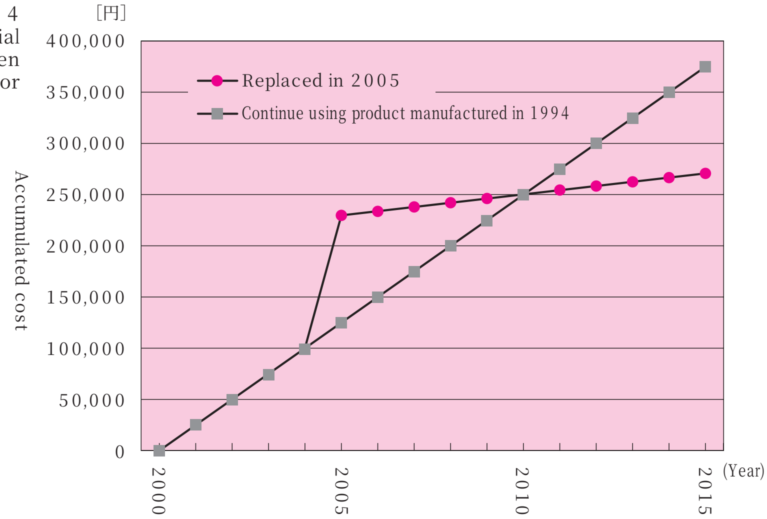
Table 4 shows the effect of replacing devices. When the device is not replaced, an electricity bill of 25,000 yen is incurred every year. In this example, if the device is replaced in 2005, although an initial cost of 100,000 yen is incurred, the electricity bill is reduced to 5,000 yen annually and the accumulated cost is reversed after 2010.

In this example, the initial cost was recouped in five years; however, the number of years it takes to recoup the initial cost would depend heavily on the amount of the initial cost and the difference in electricity bill afterwards. If the initial cost was high or the saving in annual electricity cost was small, the number of years to recover the cost will increase.

To maximize the effect of replacing devices, these two points need to be taken into consideration.

If comparing prime or priority consumer electronics, annual power consumption shown on energy-efficient device classification (Tables 4 – 8) can be used as a reference.

Fig. 4
Example of estimate for initial and running costs when replacing refrigerator



■Conditions for cost estimation when replacing 460 L refrigerator
(Electricity bill estimated when replacing product manufactured in 1994 with most energy-efficient product available in November 2004)
Estimated annual power consumption by product manufactured in 1994: 1,130 kWh
Estimated annual power consumption by product manufactured in 2004: 200 kWh
(Estimated results by the 13th Energy Conservation Awards (2002) for Home Electronics "Energy-efficient refrigerator")
Estimate based on power cost of 21 yen/kWh (excluding tax). Purchase cost was the suggested retail price at the time of purchase.

Comment ● Evaluation by public rating agencies as standard

Information regarding energy saving initiatives including the energy saving labeling system as well as product information can be found on the website of the Energy Conservation Center, Japan (http://www.eccj.or.jp/) along with consumer electronics manufacturers' websites. If detailed consideration of these data seems too daunting, one can still expect to achieve a certain degree of energy saving effect by selecting products based on the labeling system mentioned below and other similar tools.

The energy-efficiency labeling system was established in August 2000 mainly targeting air conditioners and refrigerators. As shown in Table below, as of February 2007, sixteen devices are displaying the label. All of the devices below are designated as "specified appliances" based on the Energy Conservation Law and account for a significant portion of household energy consumption.

Table Devices displaying labels (as of February 2007)

Air conditioners, refrigerators, freezers, fluorescent lighting devices, televisions, space heaters, gas cooking appliances, gas water heaters, oil water heaters, electric toilet seat, transformers, electric calculators, magnetic disk unit, rice cookers, microwave ovens, and DVD recorders.

Fig. Display logo for energy saving labeling system

The simple label above can be displayed on a device.

Cooling System Planning for Zone VI 5.6

5

Chapter 5
Energy-efficient
Equipment Technology
(Elemental Technology
Application Method 3)

5.7 Treatment and Efficient Use of Water and Kitchen Waste

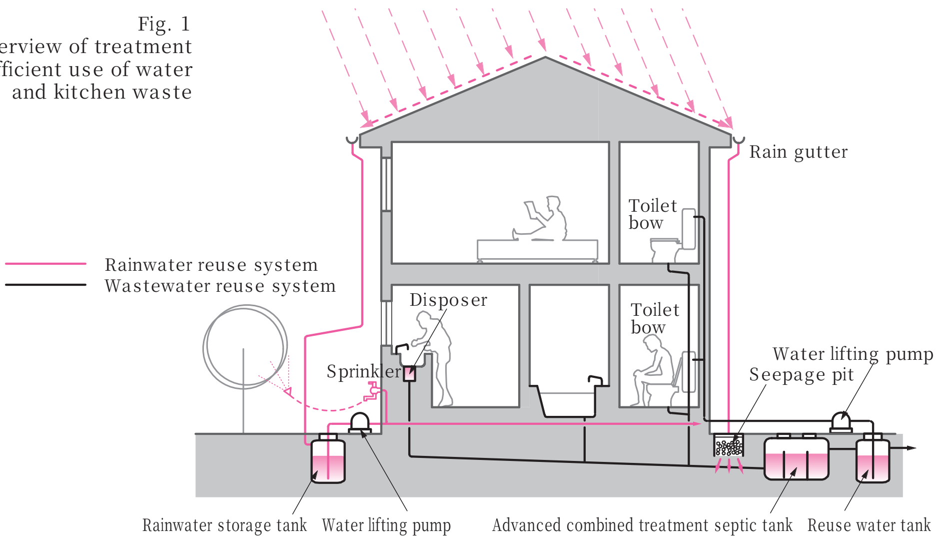
Effective use of water as well as efficient treatment technologies for wastewater and kitchen waste help us reduce waste and save water in cities and buildings. These also lead to the protection of our water resources.

Making efficient use of appropriate technologies according to the site conditions such as urban or suburban will help reduce the CO_2 emissions.

5.7.1 Purpose and Key Points of Treatment and Efficient Use of Water and Kitchen Waste

- Adopting water saving devices in rooms such as toilets, bathrooms, kitchens and washing rooms will reduce not only water usage, but also the energy required to treat, supply and heat the water.
- Using rainwater or reusing wastewater for watering plants or flush water can reduce water usage. Watering plants is especially effective as it can reduce the energy required for space cooling or can provide a cooling sensation by reducing the temperature of the surrounding area through the evaporation cooling effect.
- Adopting a rainwater seepage pit improves the habitat environment for the plants on site. It also reduces the concentration of drainage load into the public sewage system when torrential rain occurs, which helps minimize drainage flooding.
- In areas without public sewage systems, advanced wastewater treatment provided by an advanced combined treatment septic tank makes underground seepage of treated water possible, which reduces the impact on the aquatic environment.
- Adopting composting, kitchen waste disposers, and disposer wastewater treatment systems is effective in reducing the energy required for garbage collection, transport and incineration as it reduces the amount of kitchen waste produced. Reducing the amount of kitchen waste is also helpful in terms of the sanitary condition of the garbage collection site and other waste problems.

Fig. 1
Overview of treatment and efficient use of water and kitchen waste



5.7.2 Target Levels and Methods for Treatment and Efficient Use of Water and Kitchen Waste

- Methods for effective use of water and efficient treatment of wastewater and kitchen waste are: water saving devices, rainwater and wastewater reuse systems, rainwater seepage pits, advanced wastewater treatment technology in areas without public sewage systems, and efficient kitchen waste treatment technology.
- Among those methods mentioned above, only water saving devices have clearly set target levels at this point in time.
- Detailed explanations are provided for each method in “5.7.4 Methods of Treatment and Efficient Use of Water and Kitchen Waste”.

1. Using water saving devices (Method 1)

The four types of water saving devices presented here are toilet bowls, hardware for domestic cold and hot water faucets, showerheads, and washing machines. Note that the capacity of these devices varies greatly depending on the time period they were sold. Following target levels 1 and 2 were established based on the difference in water saving rate by the time period (Table 1).

The water saving rate is defined as follows

$$\text{Water saving rate} = \frac{\text{Water usage by device commercially available in 1990s} - \text{water usage by device of each level}}{\text{Water usage by device commercially available in 1990s}} \ (\%)$$

Table 1 Target levels for using water saving device

Target level	Time period when device was sold	Water saving rate
Level 0	Commercially available in 1990s	0
Level 1	Commercially available in 2000	10 – 20%
Level 2	Commercially available in 2004	30 – 40%

2. Other methods

There are no target levels established for rainwater and wastewater reuse systems, rainwater seepage pits, advanced wastewater treatment technology for areas without public sewage systems, or efficient kitchen waste treatment technology. The following section however provides a description of each method. Although qualitative in nature, their effectiveness has been confirmed. Adopting these methods as much as possible will therefore result in reducing energy consumption as well as environmental impact.

1) Adopting rainwater and wastewater reuse system (Method 2)

The issue associated with this system is the sanitation control within the rainwater and wastewater tank. Large buildings such as office buildings can adopt a cutting-edge system to deal with the issue; however, it is advisable to adopt this system for home use within a range that does not cause any sanitation problems. This document presents the following two types of this method (Table 2).

Table 2 Types of rainwater and wastewater reuse system

Type	Purpose	Description
Type 1	For watering plants	Install rainwater storage tank
Type 2	For watering plants + flush water for toilets	1. Rainwater storage tank + water lifting pump or 2. Rainwater storage tank + water lifting pump + advanced combined treatment septic tank

2) Adopting rainwater seepage pit (Method 3)

Using planting ground and paving on the site through which rainwater can seep reduces the temperature of the surroundings as well as the excessive wastewater load on the public sewage system during torrential rain. Moreover, adopting a rainwater seepage pit, into which the rainwater on the roof surface flow, will further enhance its effect. This document covers the following three types of this method (Table 3).

Table 3 Types of rainwater seepage pits

Type	Purpose	Description
Type 1	Rainwater treatment	• Allows rainwater to run off from roof surface. • Covers site with impermeable material.
Type 2		• Treats rainwater from roof surface by means of rainwater seepage pit. • Covers site with impermeable material.
Type 3		• Treats rainwater from roof surface by means of rainwater seepage pit. • Covers site with permeable material.

3) Adopting advanced wastewater treatment technology (Method 4)

In areas without public sewage systems, septic tanks play an important role in aquatic environmental protection. The appropriate treatment performance should be selected based on factors such as the condition of the area's aquatic environment, wastewater reuse, and whether or not underground seepage is required. This document discusses the following three types of this method (Table 4).

Glossary: BOD
BOD stands for "Biochemical Oxygen Demand", which is an index that expresses the degree of water contamination by organic matter.

Glossary: T-N and T-P
T-N and T-P express the amount of nutrient salts, total nitrogen and total phosphorous respectively. In a closed body of water, plankton and aquatic plants thrive when the amount of these nutrient salts increases. This will in turn cause problems such as algal bloom, red tide, and blue tide. Furthermore, nitrogen infiltrating into the underground water will cause contamination from sulfuric acid.

Table 4 Method of advanced wastewater treatment technology

Type	Purpose	Description
Type 1	Wastewater BOD treatment	• Combined treatment septic tank • BOD in treated water: 20 mg/L or less
Type 2	Wastewater BOD treatment, wastewater nitrogen treatment	• Advanced combined treatment septic tank • BOD and T-N in treated water: 20 mg/L or less
Type 3	Wastewater BOD treatment, advanced nitrogen (and phosphorous if necessary) treatment	• Advanced combined treatment septic tank • BOD and T-N in treated water: 10 mg/L or less • Using additional devices, T-P: 1 mg/L or less

4) Adopting efficient kitchen waste treatment technology (Method 5)

The appropriate method to reduce and recycle the kitchen waste a household produces can be selected from among several options according to the site condition and the family lifestyle. This document presents the following three types of this method (Table 5).

Table 5 Types of efficient kitchen waste treatment technology

Type	Purpose	Description
Type 1	Kitchen waste recycling and reduction	Composting
Type 2		Kitchen waste disposer for home use
Type 3		Disposer wastewater treatment system

5.7.3 Steps for Considering Treatment and Efficient Use Technology for Water and Kitchen Waste

1. Steps to consider for treatment and efficient use technology for water

- Verify whether or not any water saving devices have been installed where either clean water or reuse water is used.
- Select the appropriate system for reusing rainwater and wastewater so as not to run the system at an unreasonable capacity.
- Verify by-laws and consider the influence on the soil when adopting a rainwater seepage pit.

Step 1 Verifying and considering lifestyle and area conditions

1) Consider where to place water saving devices (convenience and effectiveness)
2) Consider the possibility of the stored water freezing and where to place the tank.
3) Verify whether or not the area has a public sewage system.
4) If there is no public sewage system, verify whether or not removal of nitrogen or phosphorous is required for the protection of the water source area or closed bodies of water and other water-related areas. Verify also whether or not underground seepage of wastewater is required.
5) Calculate the amount of rainwater based on the area of the roof.
6) Calculate the required amount of water for watering plants and toilet flush water.
7) Consider whether or not a rainwater seepage pit is required or its installation possible (in accordance with by-laws and other ordinances).

▼

Step 2 Determining system to adopt

1) Determine the water saving devices to adopt.
2) Determine the capacity of the storage tank and its installation location.
3) Determine the location and other aspects of the reuse water faucets.
4) Determine the specifications and the location of the rainwater seepage pit.
5) If there is no public sewage system, determine the treatment performance of the septic tank and the intended use for the treated water.

2. Steps to consider for treatment and efficient use technology for kitchen waste

- Consider which type of system to adopt from among composting, kitchen waste disposers for home, and the disposer wastewater treatment system.

Step 1 Verifying and considering lifestyle and area conditions

1) Verify whether or not the area has a public sewage system. (Especially, if the area has a public sewage system, verify whether or not installation of a disposer wastewater treatment system is permitted.)
2) Verify the size of the garden and the conditions of use. (Verify whether or not it is possible to adopt composting.)
3) Consider whether or not compost can be used. (Verify whether or not it is possible to adopt composting.)

▼

Step 2 Determining system to adopt

1) Make a provisional decision based on the conditions in Step 1.
2) Consider factors such as power consumption after adopting the system. (The condition for adopting kitchen waste disposer.)
3) Verify the user-friendliness of the system and whether or not local authorities offer subsidies.
4) Verify that the system is suited for the intention (user-friendliness) of the occupants or the contractor.
5) Determine the system to adopt.

5.7.4 Methods of Treatment and Efficient Use for Water and Kitchen Waste

Method 1 : Using water saving devices

- Water saving devices are easy to adopt as they can be effective even when used on their own. Note that effects vary greatly from one device to another, so care is required when selecting one.
- Four water saving devices are presented here: toilet bowls, hardware for domestic cold and hot water faucets, showerheads, and washing machines. Table 6 shows the capacity (water usage and other characteristics) and the specifications of each device by target levels and rooms.

Table 6 Setting levels for water saving devices

Device	Toilet bowls	Hardware for domestic cold and hot water		Showerheads	Washing machines
Room	Toilet	Bathroom	Washing room/Kitchen	Bathroom/ Washing room	Various locations
Evaluation index	Quantity of flush water (L)	Water saving function/ temperature adjustment	Water saving function/ temperature adjustment	Water saving function	Quantity of washing water (L)
Level 0	13	Two-valve mixer faucet	Two-valve mixer faucet	No water saving function	200
Level 1	12 – 9	Thermostatic mixer faucet	Single-lever mixer faucet	Shower head w/ shut-off	150
Level 2	8 – 6		Automatic faucet		80

* Values indicated for each level are to be used as reference since the way devices are used by occupants influences them considerably in real life.

1. Toilet bowls

Toilet bowls are categorized as shown in Table 7 based on their flush method and the quantity of flush water. The table shows the JIS standards and the standard values for Quality Housing Components Certification (BL-standards) by the Center for Better Living. From the point of view of water saving, ones that require less flush water were deemed superior.

However, it is important to design the system to smoothly eliminate waste and toilet paper by ensuring that enough flush water is provided and establishing an appropriate piping slope (See Table 12 on p.334).

In recent years, models with no low tank or super water saving toilet bowls with roughly 6 L of flush water have become increasingly popular; however, before adopting these types of toilet bowls, it is necessary to secure enough water pressure (dynamic water pressure) for the former and to ensure that an appropriate length of piping and number of bends in the piping are in place for the latter.

Table 7 Types of toilet bowls and standards for quantity of flush water

Types of toilet bowls	Quantity of flush water (L)	
	JIS Standards	BL-standards
Washout toilets and washdown toilets	11	N/A
Washout toilets (water saving) and washdown toilets (water saving)	8	≤9.5
Washdown toilets (super water saving)	N/A	Large flush ≤6.5, small flush ≤5
Siphon toilets and siphon jet toilets	13	≤13
Siphon toilets (water saving)	9	N/A
Siphon vortex toilets	N/A	≤18

2 Hardware for domestic cold and hot water faucet

Compared with two-valve mixer faucets, thermostatic mixer faucets waste less water as they allow the user to set or adjust the temperature, which in turn further enhances the energy saving effect.

Automatic faucets detect approaching hands by their sensor and open and close the tap, which reduces the amount of wasted water when the tap is inadvertently left open. Furthermore, this type is more sanitary as hands do not touch the faucet.

Fig. 2
Hardware for domestic cold and hot water

Thermostatic mixer faucet　　Two-valve mixer faucet

3. Showerheads

Recently, new types of showerheads with verified water saving effect have become commercially available. These showerheads are equipped with a shut-off mechanism (shut-off type) that allows the user to shut off the water at the showerhead. Fig. 4 shows the water usage per shower by this type of device. The shut-off type is shown to have high water saving effect regardless of the season.

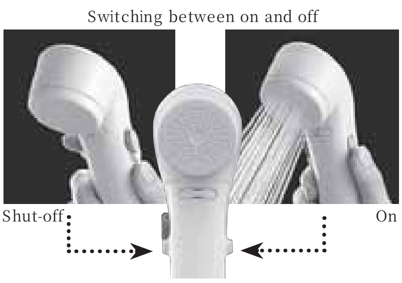


Fig. 3 Example of showerhead with shut-off mechanism

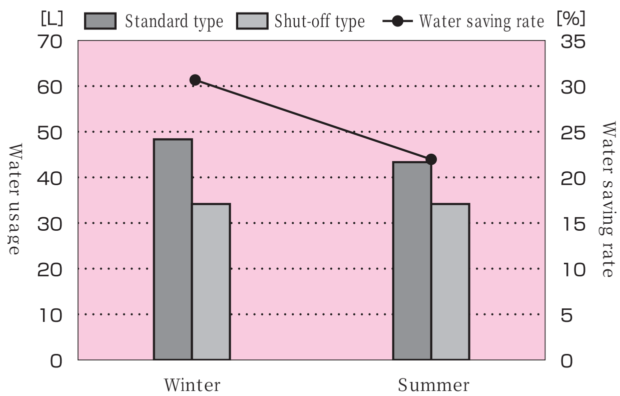


Fig. 4 Example of water usage experiment results (amount of water used per shower) using standard and shut-off type showerheads

4. Washing machines

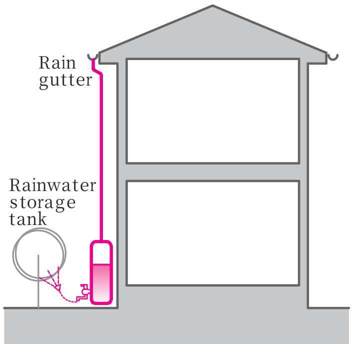
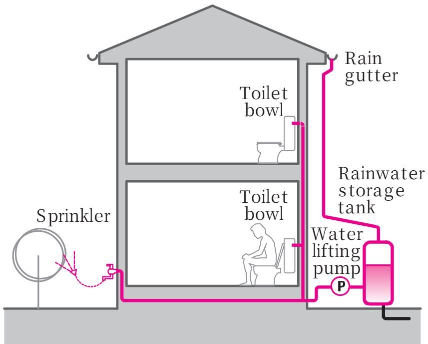
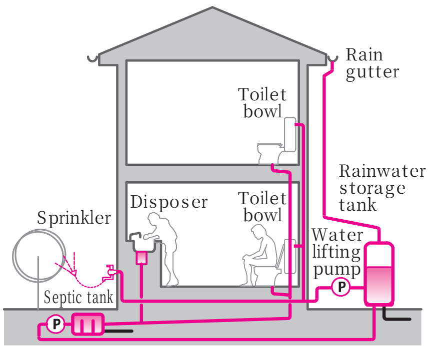
There are two types of water saving function with which washing machines may be equipped: that which uses the remaining hot water from a bath, and that which saves water when washing. Virtually all manufacturers' washing machines are compatible with the former; however, note that the remaining hot water should not be used if it appears dirty and the bathtub needs to be kept clean after each use.

Water saving technologies available for washing machines include "high-concentration detergent circulation" and "water-saving beat wash"; however, each manufacturer has come up with their own unique methods. Comparing water usage is difficult as it varies depending on how the washing has been done with each option; nevertheless, note that one product saved 60% of water when performing 8 kg of washing on the regular setting.

Method 2 : Adopting rainwater and wastewater reuse system

- Reusing rainwater and wastewater requires a storage tank for rainwater and reuse water. Furthermore, the use for reuse water is rather limited due to its water quality. The effect of this system also depends heavily on the site conditions. It is therefore essential to select a type that is suitable for these conditions.
- There are several types of rainwater and wastewater reuse systems. One is equipped with a simple rainwater tank to be used for watering plants and other similar tasks while another is equipped with an advanced combined treatment septic tank to provide the treated water to be used as toilet flush water. Table 8 shows an overview of some of these systems.

Table 8 Rainwater and wastewater reuse systems and their characteristics

Type	Diagram	Type	Characteristics
Type 1		Rain gutter + rainwater storage tank	• Power is not required for waste supply. • Easy maintenance. • Low cost.
Type 2		Rain gutter + rainwater storage tank + water lifting pump	• Requires water lifting pump. • Can frequently run out of rainwater. Add clean water to tank when this occurs.
		Rain gutter + rainwater storage tank + water lifting pump + advanced combined treatment septic tank	• Requires water lifting pump. • Efficient use by combining rainwater and wastewater. • Can be combined with disposer wastewater system. • Almost never runs out of water. Excess reclaimed wastewater is discharged. The excess is also suitable for underground seepage thanks to its advanced treatment.

Key Point

Points of caution for reusing rainwater and wastewater

1) Although the water should not cause any health problems as it goes through chlorine cleaning, the water quality may deteriorate due to lack of maintenance. Ensure that children do not accidentally swallow or inhale spray water while playing with it.
2) If storing water in the rainwater storage tank, sterilize it with chlorine (add a disinfectant agent). Check the water quality when necessary.
3) Perform maintenance on the suction opening of the water lifting pump to prevent sediment from clogging it. The screen also requires frequent cleaning.

Comment ● Wastewater reuse

Generally speaking, reclaimed wastewater is used for purposes for water quality 4 or lower indicated on the table below. In a home, those activities include toilet flush water and watering the garden. When using reclaimed wastewater, a water quality check should be performed when necessary. If using chlorine disinfectant, check to ensure that the system has not run out of the disinfecting agent.

Furthermore, if using reclaimed wastewater for watering the garden, ensure that people do not inhale the water's spray to prevent the spread of Legionella.

Table: Types of water use and water quality

Water quality level		Purposes of use	Remarks
High	1	Drinking and cooking	Sustenance, oral contact
	2	Washing hands and face, bathing, pools	Maintaining sanitation and comfort, occasional oral contact, skin contact (direct)
	3	Washing clothes	Maintaining sanitation and comfort, bodily contact (indirect), hand contact
	4	Cleaning, washing cars, fire prevention, extinguishing fire (individual cooling)	Maintaining sanitation, comfort and safety, hand contact
Low	5	Toilet flushing, sprinkling the garden, ponds, fountains	Maintaining sanitation and comfort, hand contact, seeing, hearing

Comment ● Water saving effect of rainwater storage tank

Figure on the right shows the changes in reuse rate according to the capacity of rainwater storage tank based on the rainfall in Tsukuba City in 2004. The reuse rate is shown to be 40% using a mere 0.1m3 storage tank. Although the amount of rainfall varies greatly depending on the region or the year, it can be said that this system can provide a certain degree of effect.

■Calculation conditions
Water collection area: 71.2 m2
Amount of toilet flush water: 104 L/day

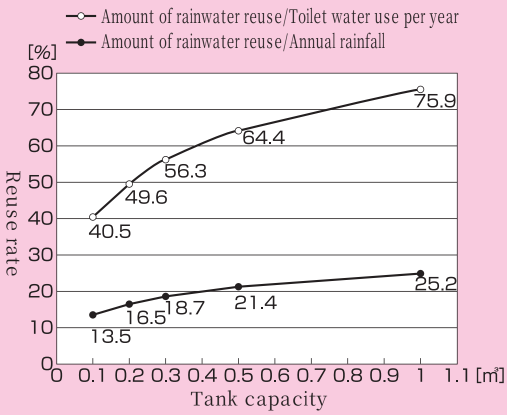


Fig. Capacity of rainwater storage tank and rainwater reuse rate

Treatment and Efficient Use of Water and Kitchen Waste 5.7

Method 3 : Adopting rainwater seepage pit

- Excessive load on a public sewage system during torrential rain can be reduced by filtering it through rainwater-permeable pavement and planting soil. The effect can also be further enhanced by letting the rain from the roof surface filter through a rainwater seepage pit or infiltration trench (Fig. 5).
- One of the advantages of this method is that it prevents landslides by increasing the amount of rainwater seeping underground and providing extra water for trees lining the sidewalk and other green spaces to encourage growth. It also contributes to the natural recovery of the city's ecosystem and improves our living environment. Some other likely benefits of this method are securing underground water, reviving spring water, reducing the impact of salination of underground water, and preventing subsidence.
- Although there are some initial costs associated with the method, some local authorities provide subsidies. It is preferable therefore to enquire before making a decision whether or not to adopt the system.

- However, this system is not suitable for areas where underground water is located close to the surface or in cold regions, and may also be banned under by-laws in certain areas. It is therefore necessary to confirm the suitability with the local authorities before adopting this system.
- The capacity of the system also depends heavily on the soil's infiltration characteristics. Verify them during the ground survey so that an effective seepage pit can be installed.

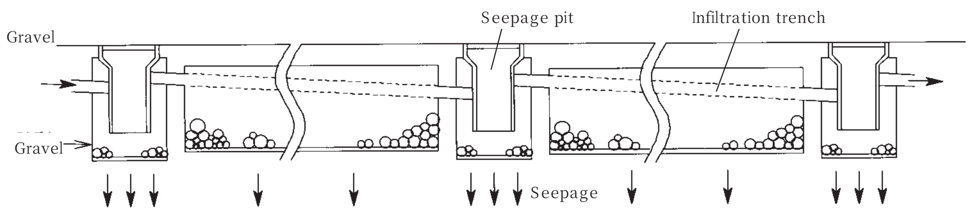


Fig. 5 Example of rainwater seepage pit on residential lot

Glossary: Infiltration rate
It expresses the amount of rainwater (mm) that can filter through per hour.

Comment ● Effect of rainwater seepage

What would the required infiltration rate be when filtering rainwater through rainwater-permeable pavement or planting soil?

It is accepted that a site with a capacity to filter 5 mm of rainwater per hour can filter approximately 80% of the rainfall. An example of a site with this capacity is shown below.

The areas into which rainwater can seep are (1) and (2) only, which can secure an infiltration rate of 5 mm/hr. Although the infiltration rate of the soil can vary depending on the type of soil, even soil with a low infiltration rate was able to fulfill the above condition.

A single-family home can use rainwater seeping pavement for the garage and planting soil for the garden to achieve similar effect. Doing so will also help create cool breeze during the summer or in-between seasons and improve the living environment.

■Example of site with capacity to filter roughly 5 mm of rainwater/hr

Site area: 2,682 m^2、Building area: 1,175 m^2 (multi-family complex)
(1) Planting ground area: 536 m^2 (20% of site area)
(2) Parking area: 700 m^2 using water-permeable asphalt concrete
(3) Other: 271 m^2 (bicycle rack area, garbage disposal area and building entrance)

Method 4 : Adopting advanced wastewater treatment technology

- In areas without public sewage systems, septic tanks play an important role in protecting the aquatic environment. In these areas, it is prohibited to install single treatment septic tanks and the use of combined treatment septic tanks is mandatory. Especially in water source areas and near closed bodies of water, removal of organic pollution load expressed by BOD (Biochemical Oxygen Demand) as well as nitrogen (T-N) and phosphorous (T-P) is required. To do so, installing an advanced combined treatment septic tank equipped with sophisticated nitrogen and phosphorous removal capabilities is necessary.
- Furthermore, if the treated water from the septic tank does not have a specific effluent destination and infiltrates into the underground water, nitrogen in the treated water needs to be sufficiently removed to protect the underground water from pollution. This scenario also requires an advanced combined treatment septic tank.
- Table 9 shows the types of advanced wastewater treatment technology and their characteristics.

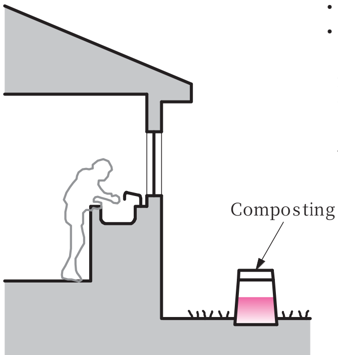
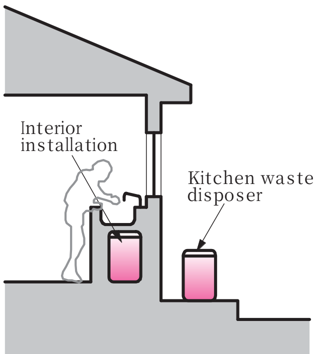
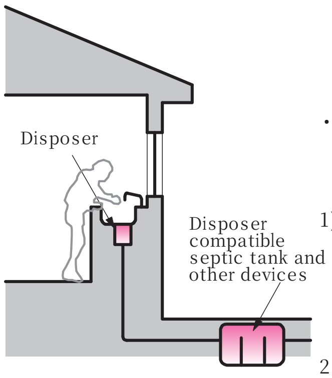
Table 9 Types of advanced wastewater treatment technology and their characteristics

Type	Description	Characteristics
Type 1	Combined treatment septic tank	• BOD in treated water 20 mg/L or less • Not suitable near closed bodies of water or water sources • Treated water not suitable for seeping into underground water
Type 2	Combined treatment septic tank for nitrogen removal	• BOD and T-N in treated water 20 mg/L or less • Effective as measure to prevent pollution near closed bodies of water and water sources • Treated water not suitable for seeping into underground water
Type 3	Advanced combined treatment septic tank	• BOD and T-N in treated water 10 mg/L or less. If necessary, T-P should be 1 mg/L or less (done w/ additional devices) • Effective as measure to prevent pollution near closed bodies of water and water sources • Treated water suitable for seeping into underground water

Method 5 : Adopting efficient kitchen waste treatment technology

- When considering kitchen waste treatment technology for home use, important factors need to be verified such as the occupants' lifestyle, the site conditions (especially how complete the sewage system is), and how frequently the generated compost will be used. Additionally, consider the convenience and the initial as well as the running cost of the system equipment to determine whether to adopt the system or not.
- Table 10 shows the types of kitchen waste treatment for home use and their characteristics.

Fig. 10 Types of kitchen waste treatment and characteristics

Type	Description	Image	Conditions for adopting system	Characteristics
Type 1	Composting		• Compost can be used. • Can secure installation location where issues such as odor or unsanitary pest infestations can be dealt with if they occur.	• Least expensive. • Some local authorities provide subsidies. • Producing compost is time-consuming and labor-intensive. Depending on how frequently compost is used, two or three containers may be needed. • Requires soil for installation location.
Type 2	Kitchen waste dispose		• Can secure installation location for kitchen waste disposer where odor is not issue. • Requires power supply.	• Some local authorities provide subsidies. • Requires ventilation for odor produced by treatment. • Install at location where odor does not blow back. • Final product can either be compost or dry waste. • Incurs power consumption of roughly 7,500 yen per year.
Type 3	Disposer wastewater treatment system		• In areas with public sewage systems, approval from system manager is required for installation of disposer wastewater treatment system. • In areas without public sewage systems, one of the following must apply: 1) Treated water from disposer wastewater treatment system flows into advanced combined treatment septic tank; 2) Disposer-compatible septic tank is installed.	• Comprising of disposer, wastewater piping and wastewater treatment device. • Confirm approval of and instruction from local authorities when adopting system. • Requires sludge treatment and possibly other cleaning of wastewater treatment device. • Requires installation space and some construction work for wastewater treatment device.

1. Composting

- When adopting composting, certain factors need to be taken into consideration. In other words, the site where the compost produced will be used, its environment and the occupants' lifestyle all need to be suitable for composting.
- It is preferable to secure a sufficiently large space (soil) for installing two or three compost containers. Furthermore, careful attention must be paid to the environment of the surrounding area of the installation site since issues such as odor and unsanitary pest infestations may arise during the advanced stage of fermentation.
- As compost containers are installed outside, some degree of inconvenience is expected when disposing kitchen waste. It is preferable, therefore, to secure a safe pathway for doing so.
- Some local authorities provide subsidies for waste reduction measures. Inquire regarding the amount provided and the application process at local offices.

2. Kitchen waste disposer for home use

- There are generally two types of kitchen waste disposers for home use. One called the "dry-type" produces dried waste to be disposed of and the other, the "bio-type", produces compost (Table 11). Careful consideration is required when adopting a disposer as power consumption varies even among disposers of the same type.
- When adopting a kitchen waste disposer for home use, before determining the installation location, consider the factors such as the flow line from the kitchen, the size of the kitchen waste disposer, the position of the electric plug, and different specifications for indoor and outdoor unit. Furthermore, ventilation needs to be considered carefully even if the unit is equipped with an odor removal function.
- The method of maintenance varies from one type to another. Factors such as labor-intensity therefore need to be taken into account before making a decision.
- Similar to the compost containers, some local authorities provide subsidies for kitchen waste disposers.

Table 11　Types of kitchen waste disposers for home use and their characteristics

Treatment type	Characteristics
Dry-type	This type of disposer removes moisture in kitchen waste via evaporation through heating by means of hot air or heater. This process reduces mass of kitchen waste and prevents putrefaction. Dried residue is periodically disposed of as waste; however, it can in some cases be reused as fertilizer. Its power consumption is higher than bio-type; however, it performs treatment in short period of time and requires no material to be added such as sawdust or microorganisms.
Bio-type	This type of disposer makes use of purification function of microorganisms that decompose organic matter in kitchen waste. This process reduces mass of kitchen waste and prevents putrefaction. Residue is usually reused as fertilizer or compost. It requires user to periodically add microorganisms as well as sawdust or woodchips to maintain microorganisms.

3. Disposer wastewater treatment system

・A disposer wastewater treatment system comprises a disposer that crushes the kitchen waste, a piping system that transports the debris and a treatment device that treats the wastewater containing the debris. The following key points need to be taken into consideration when planning and designing a disposer wastewater system.

1) Condition of public sewage system

If the public sewage system is fully complete, an exclusive wastewater treatment system can be installed to treat the water before releasing it into the public sewage system. In areas without public sewage systems, one of the following two scenarios must apply when adopting a disposer wastewater system.

(1) A disposer-compatible septic tank is installed to treat all wastewater.

(2) An exclusive wastewater treatment device and an advanced combined treatment septic tank are installed so that the disposer wastewater treated by the exclusive wastewater treatment device is then further treated by the advanced combined treatment septic tank.

2) Installation location for septic tanks and other devices

When adopting a disposer, it is necessary to first confirm that there is enough space to install a disposer-compatible septic tank and an exclusive wastewater treatment device. If underground work is required, the installation location must be determined after considering the workability of the excavation work.

The space required by a septic tank used for a one- to five-person household is approximately 900 mm (depth) x 1,200 mm (width) x 1,400 mm (height) if using a kitchen-exclusive type with a disposer, and 1,300 mm (depth) x 2,500 mm (width) x 1,800 mm (height) if using a general wastewater type.

3) Piping

When planning and designing the piping, it is necessary to ensure that there is a drainage piping slope from the disposer to the disposer-compatible septic tank and then to the exclusive wastewater treatment device. Pipes may clog if the piping slope is not properly set up. As a rule, design must follow the minimum slope by pipe diameter shown in Table 12.

The wastewater pit must be an inverted pit . If the piping system is connected to a trap pit , problems such as blockage or foul odor blowing back indoors due to a broken trap may occur. (This scenario does not only apply to disposers; however, the likelihood of problems occurring is increased by the use of a disposer.)

Table 12 Slope for horizontal wastewater pipes (from SHASE-S206-2000)

Pipe diameter (mm)	Slope (minimum)
65 or less	1/50
75 and 100	1/100
125	1/150
150, 200, 250, and 300	1/200

4) Points of caution for adopting treatment device

If a mechanical solid-liquid separator is used to separate the kitchen waste to be treated, verify that the structure of the device ensures that the exhaust from the device does not have a negative impact. Shooting the exhaust from the device into the wastewater pipe will cause inconvenience to the neighbors as well as major sanitary problems due to a broken trap, foul odor blowing back indoors, and foul odor escaping from the sewage pipes. The exhaust from the device therefore needs to be released directly to the outside air so as not to cause problems resulting from foul odors.

5.7.5 Estimating Effects of Using Water Saving Devices

Table 13 shows estimates of the water saving effect as well as the energy reduction effect. The result was obtained based on the use of a water saving device (method 1) under the conditions indicated in A.

A. Trial conditions

1) Location: Tokyo
2) Family composition: Four (husband, wife and two children)
   Husband (company employee); wife (homemaker); daughter (university student);
   son (high school student)
3) Daily schedule
   (1) Toilet: large flush once per person
   small flush three times per person
   (2) Bathing: 150 L
   (3) Shower: once per person
   (4) Kitchen: three times
   (5) Washing machine: once
4) Water heater: conventional gas water heater

B. Estimation result of water saving and energy reduction effect

Table 13 Example of estimate of water saving and energy reduction effect by using water saving device

Room/Device		Device used before	Water saving device	Water saving amount/rate		Energy reduction amount/rate	
Toilet	Toilet bowl	Flush water = 13 L/flush	W/ large and small flush function (Quantity of flush water) Large flush = 8 L/flush Small flush = 6 L/flush	76 m³ – 38 m³ = 38 m³ saved	50% less	N/A	N/A
Bathroom	Showerhead/ faucet hardware	Regular shower w/ no shut-off, two-valve mixer faucet	Water saving shower w/ manual shut-off, thermostatic mixer faucet	89 m³ – 58 m³ = 31 m³ saved	35% less	Gas 257 m³ – 168 m³ = 89 m³ saved	35% less
	Bathtub	No shut-off at set water level (Quantity of water) Wasted water = 4.5 m³/year Bathtub = 150 L	W/ shut-off at set water level (Quantity of water) Waste water = 0 Bathtub = 150 L	59 m³ – 54 m³ = 5 m³ saved	8% less	Gas 170 m³ – 157 m³ = 13 m³ saved	8% less
Total				224 m³ – 150 m³ = 74 m³ saved	33% less	Gas 427 m³ – 325 m³ = 102 m³ saved	24% less

■Conditions for conversion of gas consumption by domestic hot water
1.065 x 10-4 Nm3/kcal
Domestic hot water was provided by gas heater. Gas consumption was established using heat efficiency of common gas water heater.

In order to achieve LEHVE design, it is extremely important to quantitatively and comprehensively determine the effectiveness of individual technologies described above. This chapter provides methods for estimating the energy saving effects and costs that can be utilized for determining the effectiveness of these technologies under such prerequisites as occupant lifestyle, types of housing and local conditions. Please use these as tools for predicting the effectiveness of your design plans.

6

Chapter 6 : Energy Saving Effect Evaluation and its Utilization in Design

6

Chapter 6
Energy Saving Effect
Evaluation and its Utilization
in Design

6.1 Energy Saving Effect Using Elemental Technologies and Calculation Method

6.1.1 Summary of Energy Saving Effect Using Elemental Technologies

1. Necessity of information on energy saving effect and its quantification

Information on energy reduction effects is extremely important not only for those who practice housing construction but also homeowners and occupants, manufactures who provide technologies in the form of products, parties engaged in the energy business, national and local governments about to implement measures to prevent global warming, and other public agencies when making decisions on various matters. Now that the Kyoto Protocol's commitment period for reducing green house gas emissions has started, neutral yet trustworthy information on energy saving effects is needed since it provides guidelines when determining what the truly effective energy saving measures are and which method of which elemental technology should the limited funds be used for. In addition, we can say that such information has not been made available despite the fact that it has been eagerly demanded by society since the oil crisis of 1973. The lack of trustworthy information on reduction effects means that the reduction of utility costs through energy saving measures, i.e. economic benefits, is not clear. This also means that the acceptable degree of the increase in initial costs that occurs during the energy saving measures has been unclear to this date. The information on the reduction effect listed in this document is not necessarily complete. We are required to continue research that offers a wider range of application with improved precision.

Unlike roads and dams, most of buildings are built by the private sector, as is equipment used for buildings. However, most of the technologies, which are related to energy performance (low carbon performance) and are required for future buildings (including non-residential buildings), can be shared as public technologies by the private sector. Even if the construction of each building is a private activity, technologies used for energy performance can be recognized as public technologies. This also applies to earthquake resistance and fire protection capacity performance, the improvement of which is made compulsory by the Building Standards Act. With regard to the evaluation of elemental technologies related to energy conservation, which can be considered as public technology, it is necessary to implement it under certain rules from now on.

2. Elemental technologies and energy saving effect through their use

Chapter 1 in this document talked about the definition of low energy housing with validated effectiveness and why its design guidelines are necessary, and Chapter 2 described the flow of design method and matters to consider. Chapter 3 onward focused on the 13 elemental technologies for energy conservation (Table 1) and presented estimated values, using reduction rates (%), for how much energy saving effect can be achieved through the use of methods related to each elemental technology. In this chapter, we will describe the details of Step iv. Analyzing design models and verifying their effectiveness (Fig. 1 Design flow of low energy housing with validated effectiveness in Chapter 2 on p.021), which uses quantitative information related to energy saving effect.

Table 1 Elemental technologies discussed in this document

		Field of thermal environment	Field of air environment	Field of light environment	Other
Natural energy application technology	Technology that replaces fuel energy with natural energy such as wind, solar heat, sunlight	Use of solar radiation heat (Solar heat utilization 1) Solar water heating (Solar heat utilization 2)	Use/control of wind	Daylight utilization (Sunlight utilization 1) Photovoltaic power generation (Sunlight utilization 2)	
Heat control technology of building envelopes	Technology that controls heat transfer and maintains an appropriate indoor environment using architectural solutions for building envelopes including insulation and solar shading	Insulated building envelope planning Solar shading method			
Energy-efficient equipment technology	Technology that uses select energy efficient equipment and systems, reduces energy, and increases comfort	Cooling/heating system planning Domestic hot water system planning	Ventilation system planning	Lighting system planning	Introduction of high-efficiency consumer electronics Treatment and efficient use of water and kitchen waste

The reduction rates listed in Chapter 3, 4 and 5 are based on average design details as of 2000 (design details indicated as “level 0” in sections of each elemental technology) as well as on energy consumption that occurs in the lifestyle pattern considered as most typical. The following are the two major reasons for having hardly any opportunities for information related to energy saving effects as presented in this document as presented in this document: a lack of sufficient knowledge on factors that cause a large influence on energy consumption in buildings including houses, and the possibility that energy saving effects vary under different lifestyle pattern conditions. While knowledge has accumulated thanks to the advancement of field studies on energy consumption and lifestyle and the implementation of validation experiments, the disadvantages of avoiding the presentation of energy saving effects, with the latter reason as an excuse, have been increasing seriously. Therefore, the “Design Guidelines for Low Energy Housing with Validated Effectiveness” set given conditions for housing forms and living pattern and put together design methods and elemental technologies, of which effectiveness is expressed by energy consumption reduction rates.

Design methods based on numerical values under such given conditions also have disadvantages. To put it simply, there may be large errors in energy saving effects under conditions other than the given conditions. For example, if the number of family members is different or the hours for being at home are long, it is expected that there will be some difference in the degree of energy consumption and energy saving effects among elemental technologies compared to those for a family of four, a given condition set in this document. However, if asked whether there is such a thing as quantitative information that takes into consideration all design conditions, the answer is “No”. While so-called simulation allows us to do a lot of calculation on paper by assuming various cases, it is not easy to accurately reflect the actual performance of specific equipment at this point.

Table 2 shows assumed numerical values based on “average design details as of 2000 and energy consumption that occurs in the lifestyle pattern considered as most typical” mentioned earlier. Total consumption based on primary energy conversion and composition by use are determined according to the results of field studies and validation experiments. In this document, we call these numerical values “reference energy consumption”. Reference energy consumption varies depending on regions and heating and cooling system types.

Table 2　Reference energy consumption as of 2000

Use of energy	Zone VI (Naha)		Zone V (Kagoshima)			
			Partial intermittent heating and cooling		Whole-building continuous heating and cooling	
Cooling	10.3 GJ	(15.5%)	5.7 GJ	(8.3%)	27.1 GJ	(27.0%)
Heating	0 GJ	(0.0%)	5.0 GJ	(7.3%)	13.4 GJ	(13.3%)
Ventilation	3.1 GJ	(4.7%)	3.1 GJ	(4.5%)	4.7 GJ	(4.7%)
Domestic hot water	13.8 GJ	(20.7%)	19.2 GJ	(28.0%)	19.2 GJ	(19.1%)
Lighting	13.6 GJ	(20.4%)	11.3 GJ	(16.5%)	11.3 GJ	(11.2%)
Consumer electronics	21.4 GJ	(32.1%)	19.9 GJ	(29.0%)	20.4 GJ	(20.3%)
Cooking	4.4 GJ	(6.6%)	4.4 GJ	(6.4%)	4.4 GJ	(4.4%)
Total	66.6 GJ	(100%)	68.6 GJ	(100%)	100.5 GJ	(100%)

* Reference energy consumption for “ventilation” indicates values in a duct system. As for the values in a through-the-wall system, see Table 3 on p.340 and Table 4 on p.341.

In the meantime, with regard to the energy consumption reduction effect gained through the use of various elemental technologies for energy conservation and related methods, Table 3 and Table 4 show the summary of what was described in Chapter 3, 4 and 5. However, the numerical values indicating energy saving effect in Table 3 and Table 4 are presented in the form of "energy consumption ratio", which has a simple relationship with reduction rate as shown in the following formula, so that calculation of energy consumption after reduction becomes easier. In addition, as for photovoltaic power generation, instead of using rates, we convert power generation that corresponds to the capacity of solar cells installed in a house into primary energy. Values obtained through this are subtracted from the entire energy consumption of the house.

$$\text{Energy consumption ratio} = (100 - \text{energy consumption reduction rate (\%)}) \times 1/100$$

Table 3 Energy reduction effect through use of elemental technologies (Zone VI: Naha)

Usage	Reference energy consumption	Elemental technology		Energy consumption ratio (Reference value considered to be 1.0) Level 1	Level 2	Level 3	Level 4
Cooling	11.0GJ	Use and control of wind		0.96	0.91	0.88	
		Solar shading method		0.9	0.8	0.75	0.7
		Cooling system planning		0.9	0.8	0.75	0.65
Ventilation	3.1GJ*1	Ventilation system planning	Duct type1	0.7	0.5		
	2.8GJ*2		Through-the-wall2	0.8			
Domestic hot water	13.8GJ	Solar water heating		0.9	0.7	0.5	0.3
		Hot water system planning		0.9	0.8	—	0.6
Lighting	13.6GJ	Daylight utilization		0.97 ~ 0.98	0.95	0.9	
		Lighting system planning		0.85	0.8	0.7	
Consumer electronics	21.4GJ	Introducing high-efficiency consumer electronics		0.8	0.6		
Other (cooking)	4.4GJ	—					
Total	66.6GJ	—					
	66.3GJ						

Power		Photovoltaic power generation	33.7GJ reduction	45.0GJ reduction

■Special Comments
- Reference energy consumption and the energy consumption ratio are set according to ventilation system types. The values in the upper cells (1) in the ventilation" and total" sections are for duct systems, and the values in the lower cells (2) are for through-the-wall ventilation systems.
- In regard to energy consumption in other (cooking)", since there are no significant differences among devices, only reference energy consumption is set.
- Power" is indicated in the form of amount of annual primary energy consumption reduction (power generation) that is estimated based on the capacity of solar cells installed. Values in the table above are the estimated values in Naha (See Section 3.3 Photovoltaic Power Generation).
- Section 5.7 Treatment and Efficient Use of Water and Kitchen Waste discussed in Chapter 5 are not included in this table.

Table 4 Energy reduction effect through use of elemental technologies (Zone V: Kagoshima)

Usage	Reference energy consumption	Elemental technology		Energy consumption ratio (Reference value considered to be 1.0) Level 1	Level 2	Level 3	Level 4
Cooling	5.7GJ (27.1GJ)	Use and control of wind		0.95	0.88	0.82	
		Solar shading method	South-facing	0.85	0.7	0.55	
			Southeast/ southwest-facing	0.8	0.75	0.65	
			East/west-facing	0.8	0.75	0.65	
		Heating and cooling system planning (cooling)	Partial intermittent cooling	0.95	0.9 ¦ 0.85	0.8 ¦ 0.75	0.7 ¦ 0.65
			Whole-building continuous cooling	0.75	0.6		
Heating	5.0GJ (13.4GJ)	Insulated building envelope planning	Partial intermittent heating	0.7	0.5	0.45	0.35
			Whole-building continuous heating	0.6	0.5	0.4	0.3
		Use of solar radiation heat (requires insulated building envelope planning of at least Level 3)		0.95	0.9	0.8	0.6
		Heating and cooling system planning (heating)	Partial intermittent heating	0.95	0.9 ¦ 0.85	0.8 ¦ 0.75	0.7
			Whole-building continuous heating	0.8	0.55		
Ventilation	3.1GJ*[1] (4.7 GJ)	Ventilation system planning	Duct type[1]	0.7	0.5		
	1.0GJ*[2]		Through-the-wall[2]	0.8			
Domestic hot water	19.2GJ	Solar water heating		0.9	0.7	0.5	0.3
		Hot water system planning		0.9	0.8	0.7	0.6
Lighting	11.3GJ	Daylight utilization		0.97 ~ 0.98	0.95	0.9	
		Lighting system planning		0.7	0.6	0.5	
Consumer electronics	19.9GJ (20.4GJ)	Introducing high-efficiency consumer electronics		0.8	0.6		
Other (cooking)	4.4GJ	—					
Total	68.6GJ (100.5GJ)	—					
	66.5GJ						

Power		Photovoltaic power generation	32.7GJ reduction	43.6GJ reduction

■Special Comments

- For the reference energy consumption in heating", cooling", ventilation" and consumer electronics", two types of values are listed according to heating and cooling operation systems. The values in the upper cells correspond to the consumption under the partial intermittent heating and cooling system, and the values in brackets in the lower cells correspond to the consumption under the whole-building continuous heating and cooling system.
- For the insulated building envelope planning, energy consumption ratios are set to correspond to heating and cooling operations systems.
- For solar heat utilization aimed at space heating, in order to adopt Level 1 or higher, it is necessary that the level of the insulated building envelope planning is 3 or higher.
- The partial intermittent heating and cooling system in the table above shows values for air conditioners only. For air conditioners for cooling, level 2^{-} (energy consumption ratio: 0.9), level 3^{-} (0.8) and level 4^{-} (0.7) are set. Level 2^{-} (0.9) and level 3^{-} (0.8) are set for air conditioners for heating.
- For ventilation", reference energy consumption and energy consumption ratio are set according to ventilation system types. The values in the upper cells (1) in the ventilation" and total" sections are for duct systems, and the values in the lower cells (2) are for through-the-wall ventilation systems.
- In regard to energy consumption in other (cooking)", since there are no significant differences among devices, only reference energy consumption is set.
- Power" is indicated in the form of amount of annual primary energy consumption reduction (power generation) that is estimated based on the capacity of solar cells installed. Values in the table above are the estimated values in Kagoshima (See Section 3.3 Photovoltaic Power Generation).
- Section 5.7 Treatment and Efficient Use of Water and Kitchen Waste discussed in Chapter 5 are not included in this table.

6.1.2 Given Conditions Related to Determination of Energy Saving Effect

Information on energy saving effect, which is a basis for the method of designing LEHVE, is the result of evaluation implemented under certain given conditions. Such given conditions are set while considering the factors listed in Table 5.

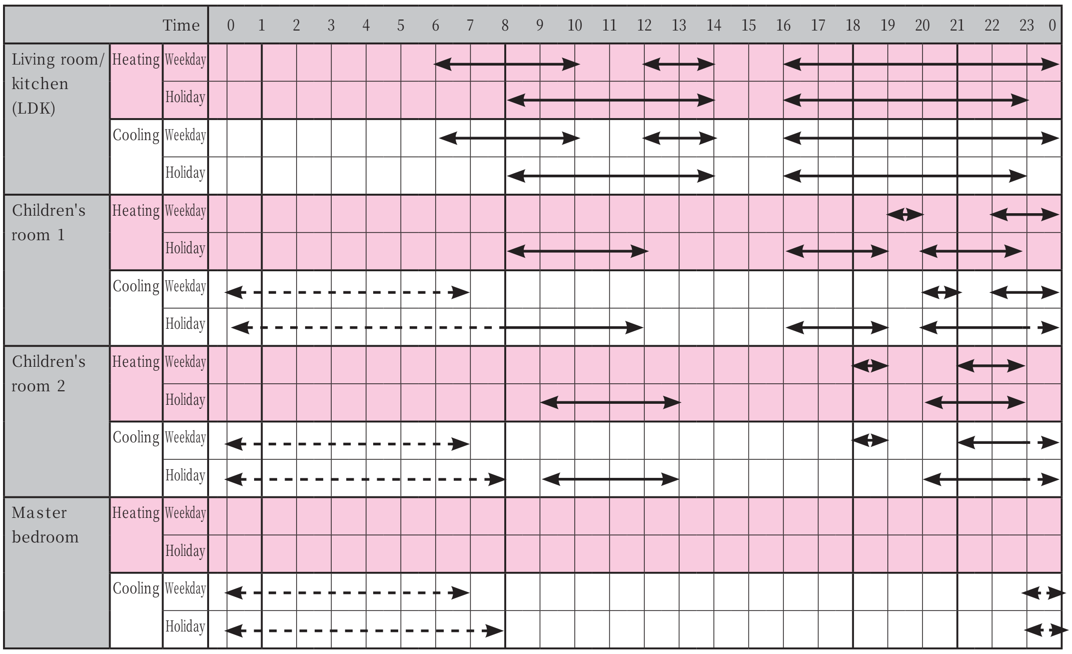
Table 5 Given conditions common to all evaluations

Items		Conditions	
		Zone VI	Zone V
Construction site region		Naha (suburb)	Kagoshima (suburb)
Building site size		430 m² (4,628 ft²)	210 m² (2,260 ft²)
Building conditions	Structure	Reinforced concrete	Post-and-beam construction
	Number of stories	One-storey house	Two-storey house
	Exterior finish	Roof: Concrete with paint finish Exterior wall: Same as above Opening: Aluminum sash	Roof: Metal sheet roofing Exterior wall: Cement siding Opening: Aluminum sash
	Interior finish	Roof/wall: Plaster board with cloth finish Floor: Flooring/partial *tatami* mat finish	Roof/wall: Plasterboard/vinyl clothing Floor: Flooring/partial *tatami* mat finish
Living conditions	Family structure	4 people (husband and wife with two children) Householder: 45-year old (company employee) Wife: 42-year old (full-time homemaker) Daughter: 17-year old (high school student) Son: 15-year old (junior high school student)	Same as left
	Life style	Assume average use of time according to nationwide survey	Same as left
	Indoor set temperature	28°C during summer (while cooling is used)	28°C during summer and 18°C during winter (while cooling and heating is used)
	Heating and cooling usage time slot	See Table 5; Supplementary Fig. 1	Same as left
	Hot water usage amount	Table b and figure in Section 5.4 Domestic Hot Water System Planning on p.273 .	Same as left
	Use of lighting device	See Table 5; Supplementary Table 1	Same as left
	Use of consumer electronics	See Table 5; Supplementary Table 2	Same as left

In addition, most of the evaluations were conducted by using a model house plan established under the given conditions listed above.

The model house plan will be described in the next chapter onward. Two types, a general model (Type A) and a model that pays some consideration to the use of natural energy (Type B), are set up for both Zone VI and Zone V.

Table 5; Supplementary Fig 1 Conditions for heating and cooling usage time slot (Partial intermittent heating and cooling)



Legend ←→ Heating and cooling operation time slot (waking hours), ←- - -→ Heating and cooling operation time slot (sleeping hours)

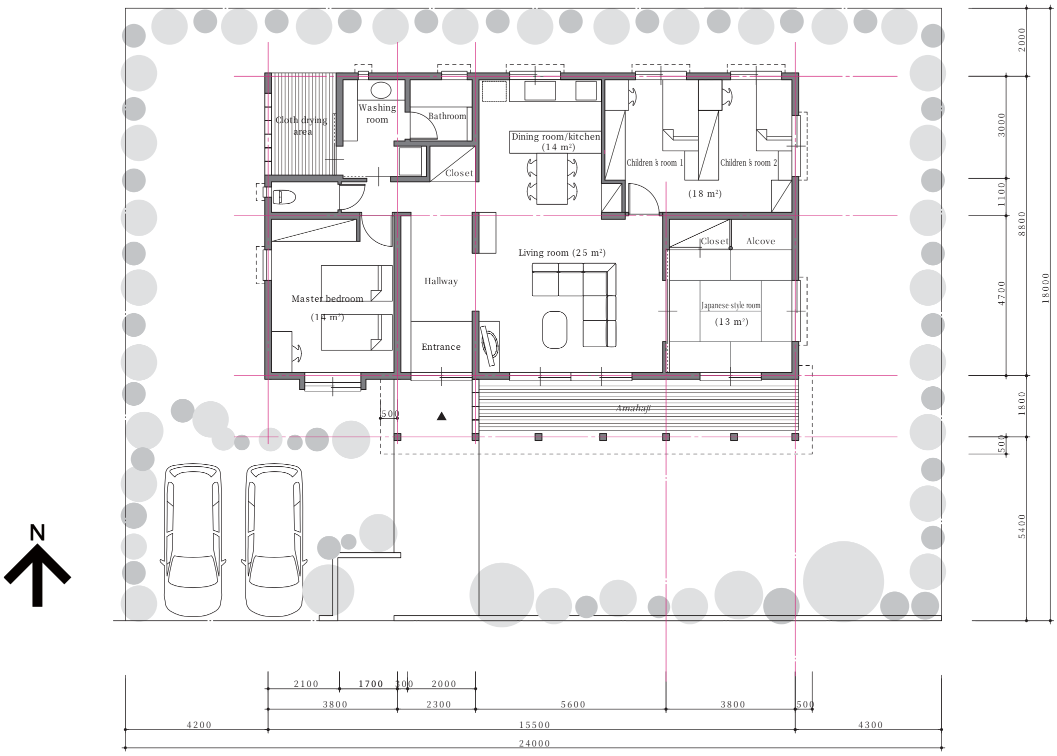
Table 5; Supplementary Table 1 Conditions for use of lighting device (Energy saving method not applied)

Usage location	Types of devices/lamps		Quantity (unit)	Wattage (W/unit)	Weekday Switch-on time (time/day)	Weekday Power consumption (kWh/day)	Holiday (staying home) Switch-on time (time/day)	Holiday (staying home) Power consumption (kWh/day)	Holiday (away from home) Switch-on time (time/day)	Holiday (away from home) Power consumption (kWh/day)
Entrance porch	Ceiling	Mini krypton bulb	1	54	2.250	0.122	0.5	0.027	1	0.054
Hallway, corridor	Ceiling	Ring FL	1	27	0.333	0.009	1.25	0.034	0.5	0.014
	Down light	Mini krypton bulb	2	54	7.500	0.810	2	0.216	2.75	0.297
First floor toilet	Down light	Mini krypton bulb	1	54	1.417	0.077	3	0.162	1.5	0.081
Washing room	Ceiling	Ring FL	1	27	2.000	0.054	2.5	0.068	2.75	0.074
	Bracket	Straight FL	1	19	2.500	0.048	1.5	0.029	2.75	0.052
Bathroom	Bracket	Standard light bulb	2	54	0.750	0.081	1.25	0.135	1.25	0.135
Kitchen	Ceiling	Straight FL	1	46	3.000	0.138	2.75	0.127	0.75	0.035
	Under-cabinet light	Straight FL	1	21	2.500	0.053	2.75	0.058	0.75	0.016
Living/ dining room	Ceiling	Ring FL	2	70	10.250	1.435	10.75	1.505	5	0.700
	Pendant	Standard light bulb	1	90	3.500	0.315	2	0.180	0.25	0.023
Japanese-style room	Ceiling	Ring FL	1	74	2.917	0.216	1.25	0.093	3	0.222
	Bracket	Straight FL	1	22	2.917	0.064	1.25	0.028	3	0.066
Master bedroom	Ceiling	Ring FL	1	74	0.667	0.049	1.25	0.093	1	0.074
	Bracket	Mini krypton bulb	1	54	0.500	0.027	1.25	0.068	1	0.054
Children's room 1	Ceiling	Ring FL	1	59	3.250	0.192	7.75	0.457	1.75	0.103
	Desk lamp	Compact FL	1	21	2.750	0.058	5	0.105	1	0.021
Children's room 2	Ceiling	Ring FL	1	59	2.750	0.162	7.25	0.428	2.5	0.148
	Desk lamp	Compact FL	1	21	1.500	0.032	3.25	0.068	0	0.000
Total (kWh/day)						3.94		3.88		2.17

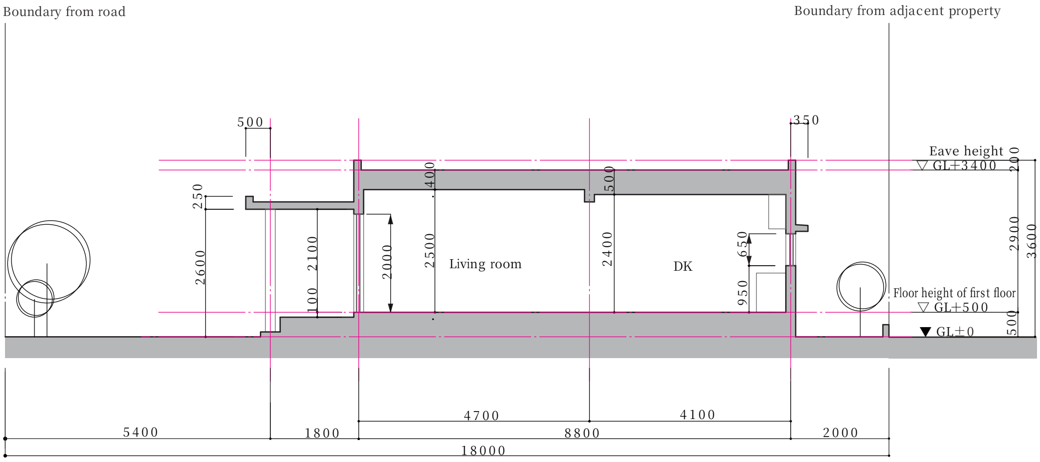
Table 5; Supplementary Table 2
Conditions for use of consumer electronics

Type	Annual operation time (h)	Annual operation time (h)
Refrigerator	8760.0	0.0
29-inch TV	3048.0	5712.0
14-inch TV	505.3	8254.8
Hot water heated toilet seat	8760.0	0.0
MD player	800.3	7959.8
CD radio-cassette recorder	157.8	8602.3
Washing machine	200.5	8559.5
Desk light	896.5	0.0
PC	373.5	0.0
Vacuum	60.8	0.0
Kitchen hood fan	456.5	8303.5
Hair dryer	135.3	0.0
Iron	42.7	0.0
Computer game	505.3	8254.8

◆Zone VI: Model house (Type A)



■Plan view

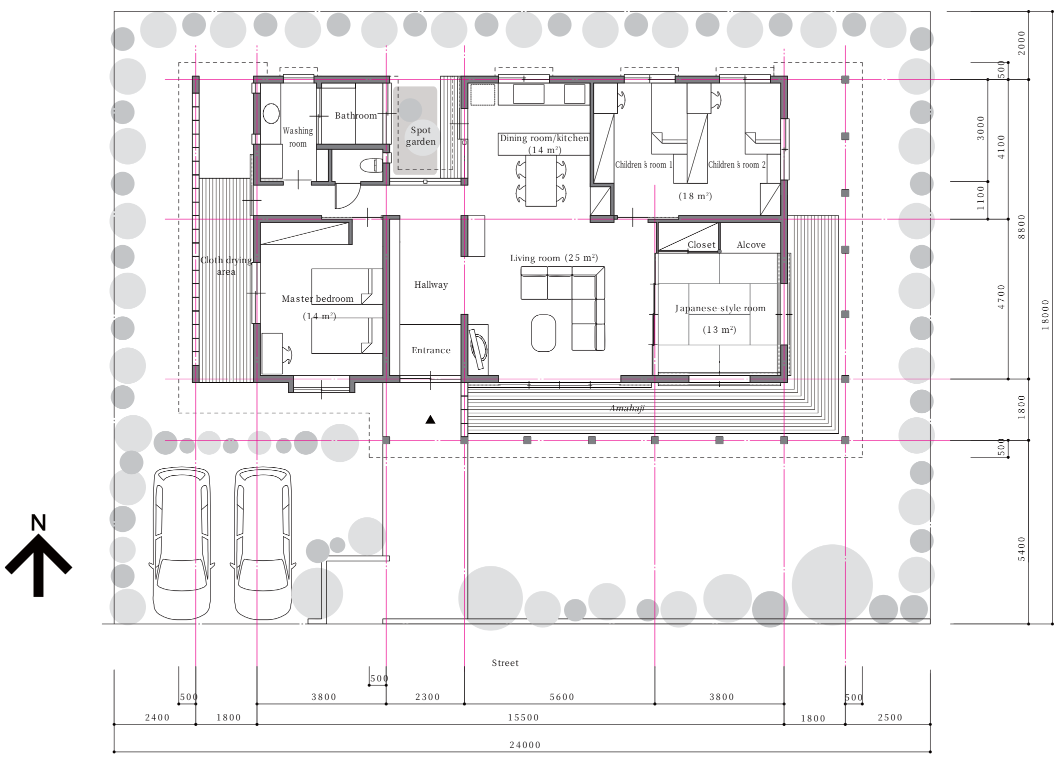


■Cross-section drawing

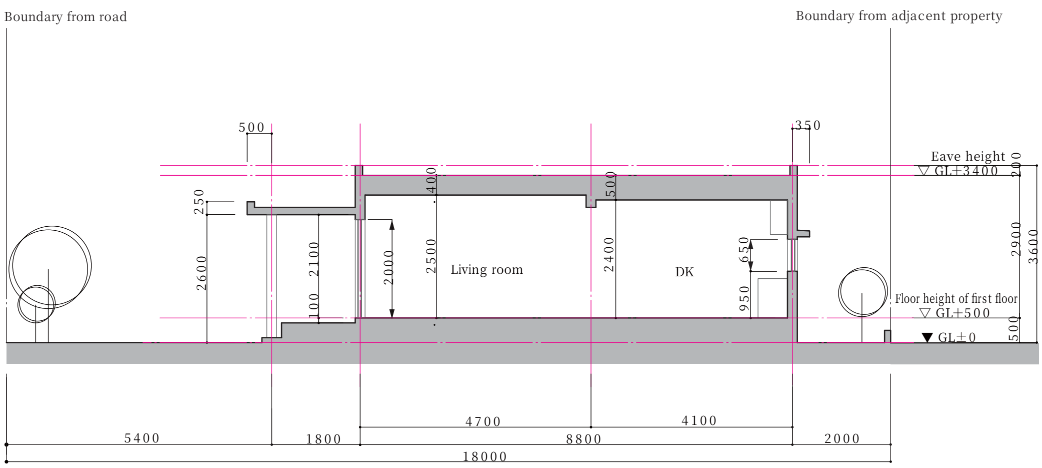
■Design specifications

Structure:	Reinforced concrete
Number of stories:	One-storey house
Site area:	432.0 m² (4,650 ft²)
Building area:	185.5 m² (1,996.7 ft²)
Total floor area:	145.3 m² (1,564 ft²)
Family structure:	Husband and wife with two children

◆Zone VI: Model house (Type B)



■First floor plan view

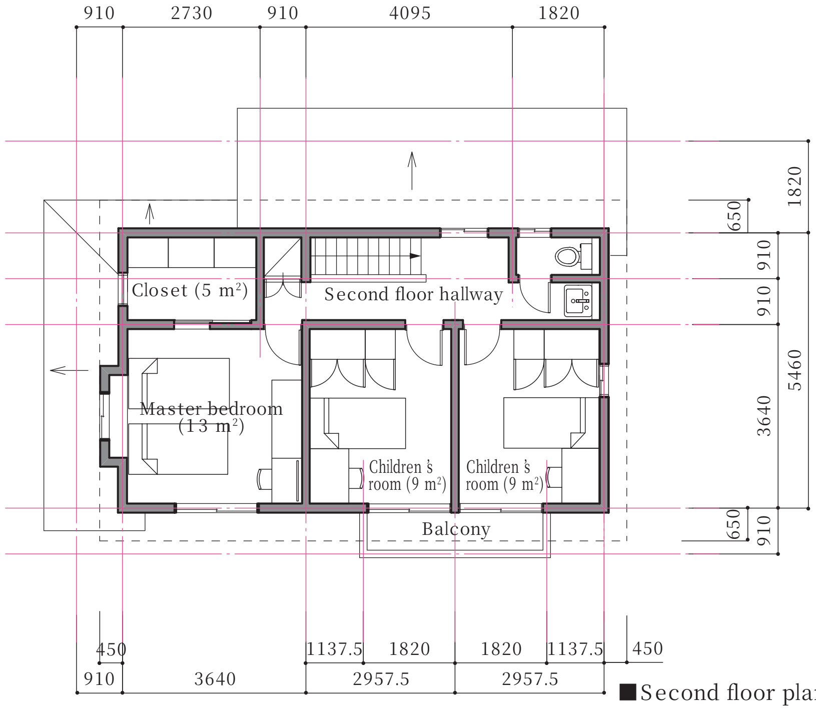


■Cross-section drawing

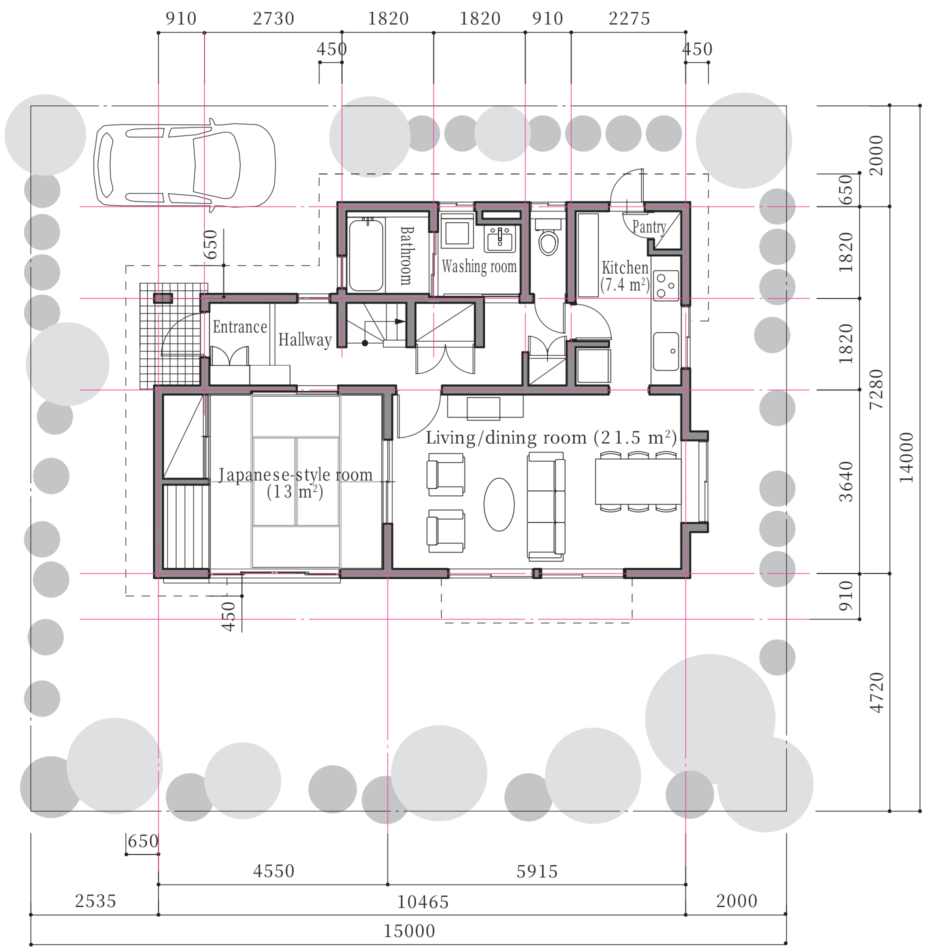
■Design specifications

Structure:	Reinforced concrete
Number of stories:	One-storey house
Site area:	432.0 m² (4,650 ft²)
Building area:	185.5 m² (1,996.7 ft²)
Total floor area:	145.3 m² (1,564 ft²)
Family structure:	Husband and wife with two children

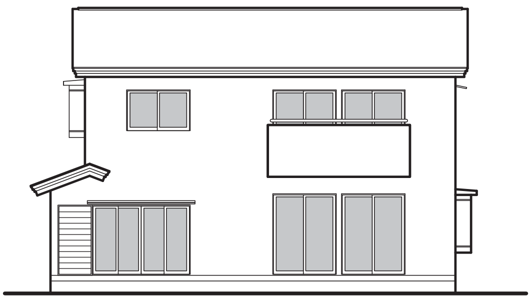
◆Zone V: Model house (Type A)



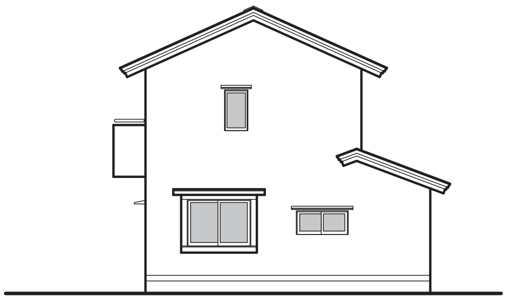
■Second floor plan vie



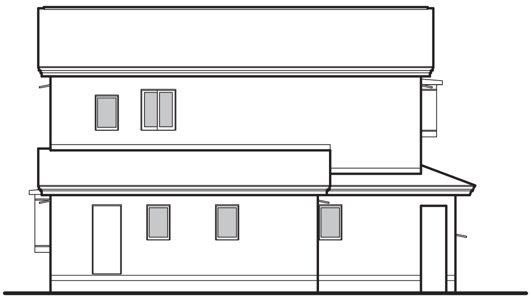
■First floor plan view



■South elevation view

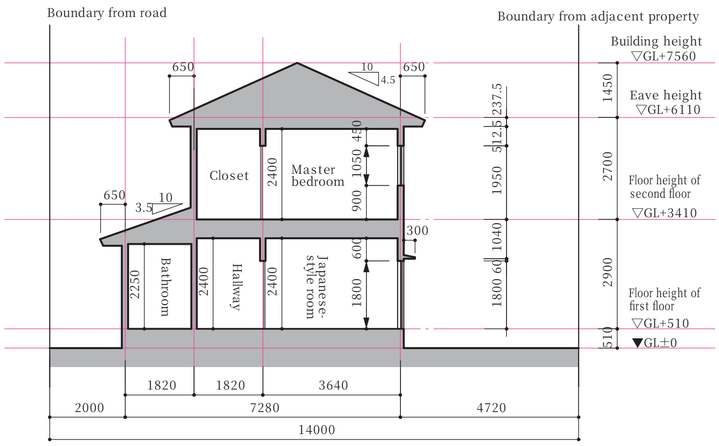


■East elevation view

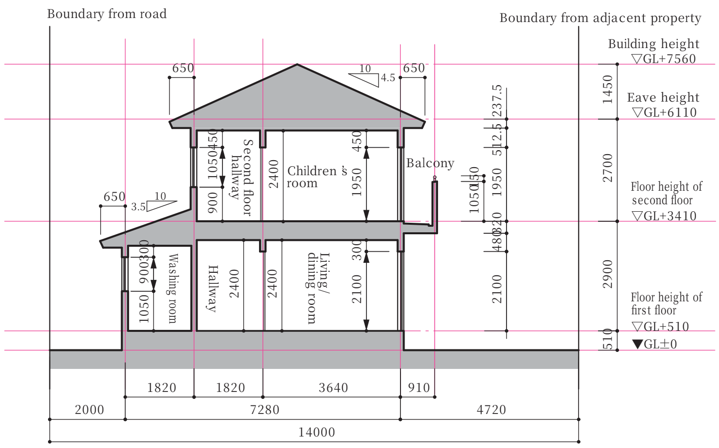


■North elevation view

■West elevation view



■Cross-section drawing 1



■Cross-section drawing 2

■Design specifications

Structure : Wooden

Number of stories : Two-storey house

Site area : 210.00 m² (2,260.42 ft²)

Building area : 69.56 m² (748.74 ft²)

Total floor area:

-Second floor : 57.14 m² (615.05 ft²)

- First floor : 62.93 m² (677.37 ft²)

- Total : 120.07 m² (1,292.42 ft²)

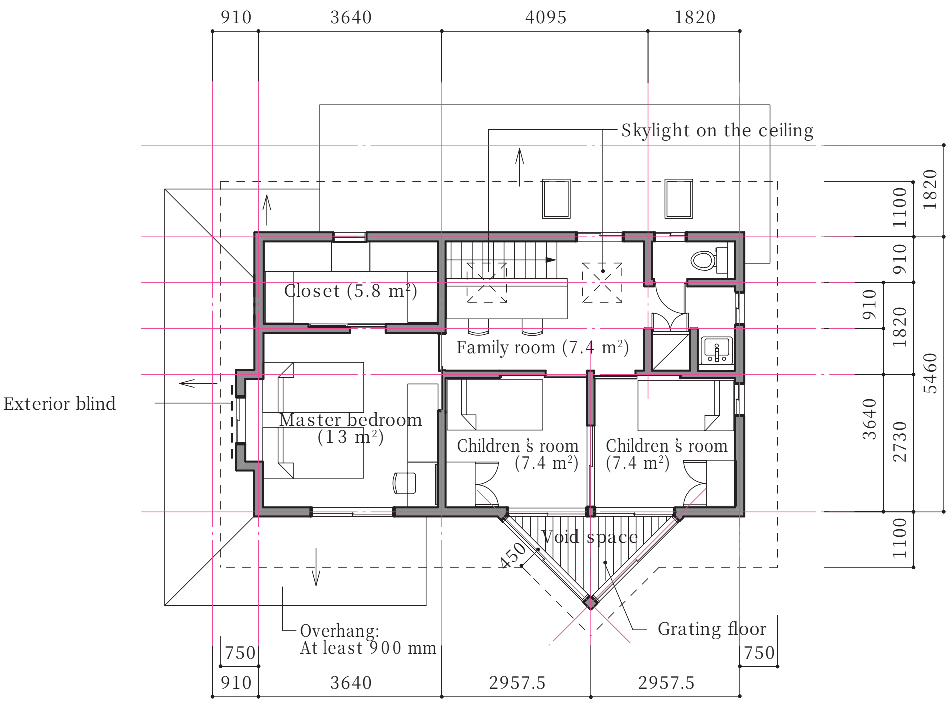
Window area: 27.92 m²

Window area against total area : 23.25%

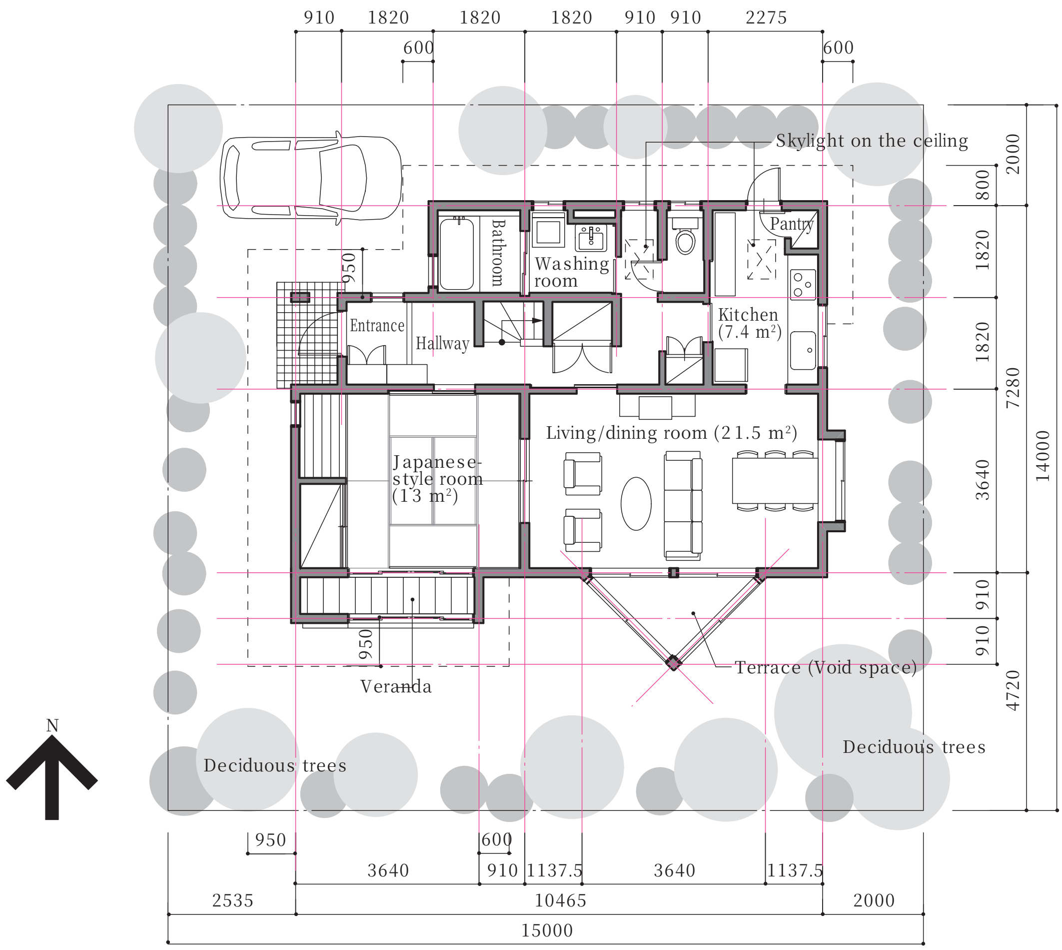
(Window area does not include entrance and door for shoe area)

Family structure : Husband and wife with two children

◆Zone V: Model house (Type B)

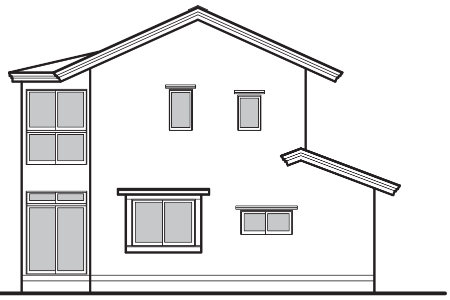


■Second floor plan view

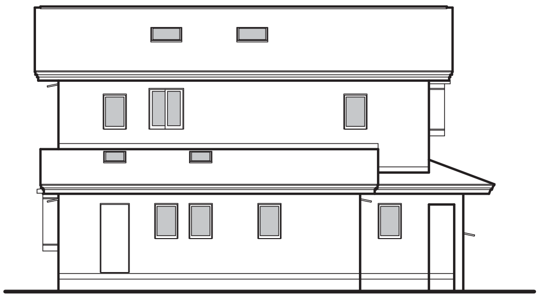


■First floor plan view

■South elevation view

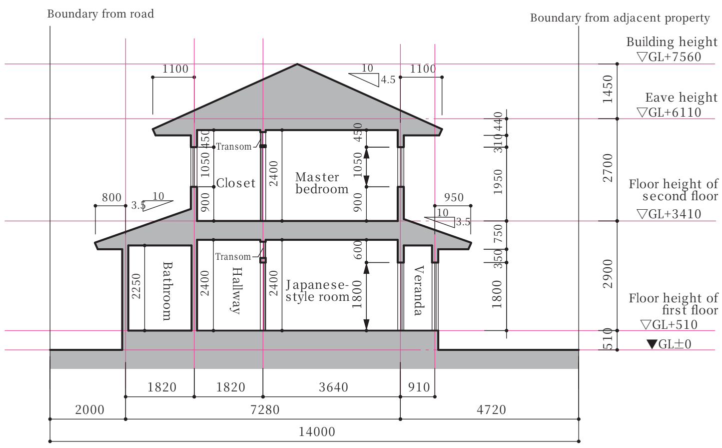


■East elevation view

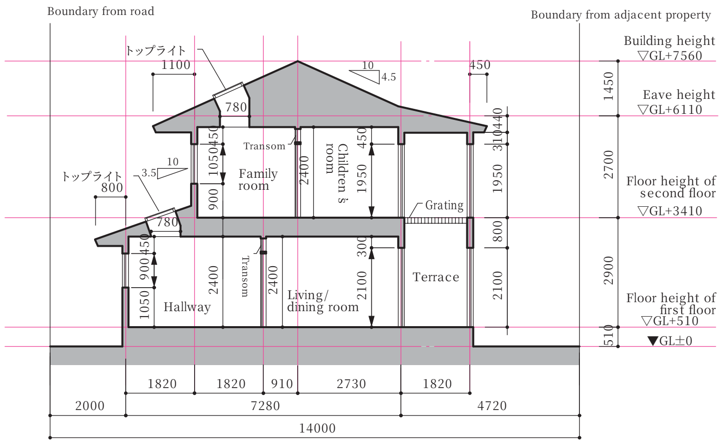


■North elevation view

■West elevation view



■Cross-section drawing 1



■Cross-section drawing 2

■Design specifications

Structure : Wooden

Number of stories : Two-storey house

Site area : 210.00 m² (2,260.42 ft²)

Building area : 77.83 m² (837.76 ft²)

Total floor area :

- Second floor: 57.14 m² (615.05 ft²)
- First floor: 71.21 m² (766.50 ft²)
- Total: 128.35 m² (1,381.55 ft²)

Window area : 29.47 m²

Window area against total area : 22.96%

(Window area does not include skylight, entrance and door for shoe area)

Family structure : Husband and wife with two children

6.1.3 Basis for Calculation Determination of Energy Saving Effect

1. Background that made energy saving effect evaluation difficult

One of the reasons why it was conventionally difficult to obtain numerical values related to the effect of various energy saving methods for buildings is the difficulty in judging the effect of various energy saving methods through field studies. In other words, when comparing energy saving method A applied to one building and method B applied to another building, or when evaluating the effect of energy saving method A by comparing the building using energy saving method A and another building that does not use this method, it is necessary not only that the two buildings enjoy the same weather conditions but also that conditions other than the method are as similar as possible. In addition, while the buildings are required to offer the same way of living, even if the number of family members and family attributes are the same on the surface, it is almost impossible to match the factors that have a strong influence on energy consumption, such as the number of hours being at home, how equipment is used, and the opening and shutting of windows. For these reasons, we have been facing a difficult situation whereby only vague effects can be distinguished when comparisons are made through field studies.

Given this, in the study that serves as the basis of this document, we used a method that mechanically recreates the occupant's life to quantify the energy saving effect. In this method, we assumed one family's living hours, method of using equipment, and method of closing and opening windows and curtains based on statistics and existing field study results. In the test house for the study, equipment was operated and windows were opened and closed mechanically or electronically as if the family lived there. With regard to various types of equipment used in the experiment for quantifying the effect, actual units (products that are actually sold on the market) were the target of evaluation. It is important to evaluate the performance of equipment purchased and used commonly, not that which has been specially prepared for the experiment, by actually using it. The performance of actual units cannot be understood if only a part of the equipment's operation mechanism is evaluated.

Table 6 Matters to keep in mind when evaluating actual effect of energy saving methods

System devices wherein control method is critical	Electric water heater with natural refrigerant heat pump
System devices wherein operating environment is critical	Heating and cooling system (efficiency varies depending on heating load) Refrigerator (room temperature) Hot water heated toilet seat (room temperature)
System devices wherein performance of auxiliary components (other than devices for core mechanism) is critical	System devices located outside (antifreezing heater) Solar heat system (supportive devices including circulating pump, etc.)

2. Overview of validation experiment methods

Validation experiments can be divided roughly into the following; comprehensive experiments that recreate the occupant's life and energy consumption phenomena as a whole, and individual experiments where each machine is individually evaluated.

The comprehensive experiments used test buildings like the ones shown in Photo 1 , and the devices shown in Photo 2 were used to operate equipment and open and close windows automatically according to a schedule. In the meantime, individual experiments were implemented when many tests were needed to be conducted under diversified conditions by artificially changing weather conditions. An artificial climate chamber was used. Photo 3 shows the measuring of air conditioner efficiency under various conditions provided by changing the test outside air temperatures inside the artificial climate chamber.

Exterior of multi-family type test building

Exterior of detached house type test building

Interior of multi-family type test building (living room)

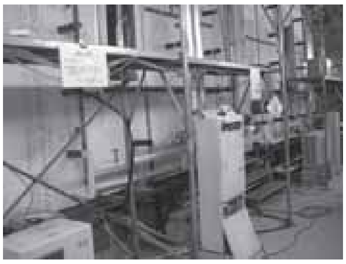
Photo 1　Test buildings

Control room (control panel, PC for control)

Internal heat generation/humidification simulator (human body, consumer electronics, etc.)

Group of domestic hot water systems placed in the hallway of multi-family type test building

Photo 2　Test devices



House/equipment inside artificial weather chamber

Measuring of air conditioner load efficiency

Photo 3　Artificial weather climate

3.　Use of simulation

Simulation is a method that virtually recreates the behaviours of the target phenomena under discussion on a computer after theoretically clarifying the phenomena. For example, heat that enters and exits through walls and windows is calculated while outside conditions, such as outside air temperature and solar radiation, as well as heat quantity generated inside the building, are taken into consideration. The advantage of doing a simulation on a computer is that it is possible to carry out a forecast evaluation on a huge number of conditions related to a phenomenon (e.g.: several hundred patterns). Simulations enable what cannot be realized by experiments, because they take too long or cost too much. However, the program used for a simulation must offer calculation results with fully verified accuracy, and it is also necessary that a fully experienced person operates the program so that no mistakes occur when entering calculation conditions.

In the creation of this document we used the following simulation programs: three types (SimHeat, SMASH and Passwork) for heat phenomena, one type (VentSim) for ventilation and cross ventilation phenomena, and one type (Inspirer) for light-related phenomena.

6.1.4 Methods of Calculating Energy Consumption, CO_2 Emissions, and Costs

1. Elemental technology evaluation scale

In this document, energy consumption is the main index used to evaluate the effect of elemental technologies and related methods. In this chapter, however, we added two more indices, CO_2 emissions and economic efficiency (cost).

The reason why we consider CO_2 emissions to be important is obviously because CO_2 emissions caused by energy consumption have worsened the state of global warming. As for economic efficiency, every designer worries about it when selecting elemental technologies and methods during the designing process. Trying to spread energy saving technology without considering economic efficiency would be impossible. In regard to design technology that can be used by many designers for a long time, it is desirable that it allows the increase in initial costs to be recovered as soon as possible through the reduction in running costs. In addition, this document offers guidelines regarding the limit for the extent of increase in initial costs (information for main suppliers of elemental technologies and methods) and how much reduction (support) in initial costs through public subsidies is called for (information for national and local governments) in order to recover the money after a period of, say, 15 years.

Supplementary explanation on the three indices is given below.

Glossary: GJ
GJ is pronounced as "gigajoule", and joule (J) is a unit of energy amount. Since giga means one billion, 1 GJ is 1 billion joules.

1) Energy efficiency: Annual energy consumption (primary energy in GJ/year)

- When evaluating energy efficiency, the evaluation of electric power energy uses a conversion factor (9,760 kg/kWh*) provided in energy conservation standards for buildings, i.e. "Criteria for Judgment by Owners Regarding the Rationalization of Energy Use Related to Buildings" (Notification No.1 in 2003 by the Ministry of Economy, Trade and Industry and the Ministry of Land, Infrastructure, Transport and Tourism and Notification No.5 in 2006 by the Ministry of Economy, Trade and Industry and the Ministry of Land, Infrastructure, Transport and Tourism as the latest version). In other words, the evaluation uniformly uses primary energy conversion values.

  * When different conversion factors for night and daytime are used, the values of 9,280 kJ/kWh and 9,970 kJ/kWh can be used for night electricity (receiving electricity supply from 22:00 and 8:00 the next day) and for daytime electricity (receiving electricity supply from 8:00 to 22:00), respectively.
- Primary energy conversion values of processed natural gas, LPG and kerosene are as follows.
  Processed natural gas (13A): 46,046 (kJ/Nm3) ※ See Table 7 on the next page for Okinawa Gas.
  LPG: 50,200 (kJ/kg)
  Kerosene: 37,000 (kJ/L)

2) Global warming impact: Annual CO_2 emissions (in kg-CO_2/year)

- In order to prevent global warming, the Kyoto Protocol, which requires developed countries to reduce greenhouse gas emissions, came into effect as of February 16, 2005. With regard to greenhouse gas emissions between 2008 and 2012, the Kyoto Protocol obliges developed countries as a whole to achieve 5.2% reductions compared to 1990 levels, with Japan to achieve 6% reductions. If reduction targets are not met, there is likely to be a penalty within a new framework starting 2013. Based on such circumstances, this document positions "CO_2 emissions" as a main axis of evaluating global warming impact from the perspective of preventing global warming.
- The method of calculating CO_2 emissions is based on the "Ordinance Regarding the Calculation of Greenhouse Gas Emissions That Occur During the Business Activities of Specific Producers" (Ordinance No. 3 by the Ministry of Economy, Trade and Industry and the Ministry of the Environment issued on March 29, 2006) which was provided based on the "Order for the Enforcement of the Act on the Promotion of Global Warming Prevention" (Ordinance No. 143 in 1999, Ordinance No. 195 finalized on June 13, 2008)

Table 7 Coefficient for calculating CO_2 emissions

Types of fuel, etc.	Unit	Coefficient
Processed natural gas	Megajoule (MJ; generated heat amount)	Okinawa Gas Nihon Gas (Kagoshima) Shikoku Gas (Kochi City) (13A zone) (5B zone)
Liquefied petroleum gas (LPG)	Kilogram (kg)	3.00 kg-CO_2/ kg
Kerosene	Liter (L)	2.489 kg-CO_2/ L
Electricity	Kilowatt-hour (kWh)	See Table 8

Table 8 Coefficients applied to electric utility companies under which Zone V and Zone VI fall (actual values in 2007)

Electric utility company	Coefficient (kg-CO_2/ KWh) in 2007	Coefficient in 2008	Adjusted Coefficient in 2008
Tokyo Electric Power Company	0.425	0.418	0.322
Chubu Electric Power	0.470	0.455	0.424
Kansai Electric Power Co., Inc	0.366	0.355	0.299
Chugoku Electric Power Co., Inc.	0.677	0.674	0.501
Shikoku Electric Power Co., Inc.	0.392	0.378	0.326
Kyushu Electric Power Co., Inc.	0.387	0.374	0.348
Okinawa Electric Power Company, Incorporated	0.934	0.946	0.946

* The values in the left column are those announced by the Ministry of Environment, except for the values for Chugoku Electric Power Co., Inc. and Okinawa Electric Power Co., Inc., which are announced by themselves. The values in the center and right columns are the newest values announced in December 2009. ("Adjusted Coefficient" is the one reflecting, the amount of the Kyoto Mechanism Credit acquired by electric power companies and transferred to the state.) However, the values in the left column (Coefficient in 2007) are adopted for the calculation of the CO_2 emissions in this guidelines. Refer to the homepage of the Ministry of Environment, if the latest values are necessary, because the coefficients are being revised every year.

established in order to enforce the "Act on the Promotion of Global Warming Prevention". With regard to each fuel and electricity, Table 7 shows coefficients for calculating CO_2 emissions based on their consumption taken from the Ordinance in question. However, as for electricity, the numerical values (Table 8) which were announced by the Ministry of Environment according to the Ordinance Article 10.2 or by electric utility companies shall be used.

- In addition, when calculating CO_2 emissions to be reduced in cases where a certain technology or a designing method is used, coefficients to be used may be different from the ones listed in Table 8. For example, the "Progress of Kyoto Protocol Target Achievement Plan" (July 29, 2008) by the headquarters for promoting the prevention of global warming uses 0.6 kg-CO_2/kWh as a coefficient for calculating the emissions caused by thermal power generation, in a part of calculating the reduction effects.

3) Economic efficiency: Initial cost, annual energy cost (running cost), simple payback time

- The initial costs discussed in this document are roughly estimated values based on regular prices. However, the open prices of equipment are based on market price research results.
- The annual energy cost of domestic hot water is based on the pricing system of electric power companies and gas companies in the regions concerned. The electric bills of other consumer electronics and air conditioners were calculated based on the "new electric power reference price (22 yen excluding tax/kWh).
- Simple payback time indicates how many years it takes to recover the increase in initial costs through energy cost reduction; it can be calculated based on the following formula.

Simple payback time [years]
= Increase in initial cost [yen] / annual energy cost reduction [yen/year]

6.2 Evaluation of Energy Performance, Global Warming Impact, and Cost through Application of Elemental Technologies

6.2.1 Evaluation Results in Zone VI

1. Energy performance

- The results of evaluating energy performance (annual energy consumption) are shown in Table 9.
- For each elemental technology, the Table shows the results of calculating annual energy consumption at each level, energy consumption reduction rates compared to level 0, and applied methods.

Table 9 Energy efficiency evaluation results <Zone VI>

Use	Elemental technology		Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	Cooling system planning		10.3 GJ 0 AC COP3	8.6 GJ ▲16.4% AC COP4	8.2 (7.6) GJ ▲20.5(▲25.9)% AC COP3 + electric fan/ceiling fan (or COP5)	7.0 GJ ▲31.4% AC COP4 + electric fan/ceiling fan	6.4 GJ ▲37.6% AC COP5 + electric fan/ceiling fan
Ventilation	Ventilation system planning	Duct type	3.1 GJ 0 Normal-efficiency fan (AC motor)	2.0 GJ ▲36.3% Normal-efficiency fan (AC motor) Increased duct diameter	1.5 GJ ▲52.9% High-efficiency fan (DC motor) Increased duct diameter		
		Through-the-wall type	2.8 GJ 0 Turbofan Outside air terminal: regular hood	2.2 GJ ▲16.6% Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning		13.8 GJ 0 Conventional gas water heater	12.0 GJ ▲13.0% Latent heat recovery gas water heater	11.0GJ ▲20%～	9.7GJ ▲30%～	6.9GJ ▲50%～
			(An example other than above) 13.1 GJ ▲5.1% Conventional oil water heater	11.8 GJ ▲14.5% Latent heat recovery oil water heater	9.9 GJ ▲28.3% Latent heat recovery gas water heater + piping method/hot water saving devices		7.7 GJ ▲44.2% Electric water heater with a natural refrigerant heat pump (energy-efficient mode)
					9.8 GJ ▲29.0% Latent heat recovery oil water heater + piping method/hot water saving devices		6.3 GJ ▲54.3% Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/hot water saving devices
					8.9 GJ ▲35.5% Electric water heater with a natural refrigerant heat pump (medium boiling mode)		5.2 GJ ▲62.3% Solar water heating (solar water heating: flat plate type) + conventional gas water heater
Lighting	Lighting system planning		13.6 GJ 0 Conventional device + continuous lighting while staying in the room or on/off lighting + one-light-per-room system	11.0 GJ ▲18.8% High-efficiency device + on-off lighting + one-light-per-room system	10.6 GJ ▲22.0% High-efficiency device + lighting adjustment + one-light-per-room system	9.4 GJ ▲30.6% High-efficiency device + lighting adjustment + distributed multiple system (simplified)	
Consumer electronics	High-efficiency consumer electronics		21.4 GJ 0 Conventional consumer electronics (made in 1997)	17.1 GJ ▲20% Energy-efficient products (500 kWh decrease)	12.8 GJ ▲40% Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices		4.4 GJ Cooking stove or induction heating (IH) cooking heater (values are according to the results from a survey on cooking stove)				
Overall			66.6 GJ* 0	55.1 GJ - 39.7 GJ ▲17.3% – ▲40.4%			

Note 1: Upper values indicate annual primary energy consumption; lower values indicate energy consumption reduction rate (▲: reduction, +: increase).

Note 2: With regard to domestic hot water, energy saving effects shown in the table (second row onward at level 0 as well as level 1 to 4) were confirmed for the types of machines used for validation experiments.

* When the duct system is used in the ventilation system planning.

2. Global warming impact

- The results of evaluating global warming impact (annual CO² emissions) are shown in Table 10.
- For each elemental technology, the Table shows the results of calculating annual CO² emissions at each level, CO² emissions reduction rates compared to level 0, and applied methods.

Table 10 Global warming impact evaluation results <Zone VI>

Use	Elemental technology	Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	Cooling system planning	983 kg 0 AC COP3	821 kg ▲16.4% AC COP4	781 (728) kg ▲20.5 (▲25.9)% AC COP3 + electric fan/ceiling fan (or COP5)	674 kg ▲31.4% AC COP4 + electric fan/ceiling fan	613 kg ▲37.6% AC COP5 + electric fan/ceiling fan
Ventilation	Ventilation system planning — Duct type	295 kg 0 Normal-efficiency fan (AC motor)	188 kg ▲36.3% Normal-efficiency fan (AC motor) Increased duct diameter	139 kg ▲52.9% High-efficiency fan (DC motor) Increased duct diameter		
	Through-the-wall type	265 kg 0 Turbofan Outside air terminal: regular hood	221 kg ▲16.6% Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning	713kg (processed natural gas) 0 835 kg (LPG) +17.1% Conventional gas water heater (An example other than above) 893 kg +25.2% Conventional oil water heater	632 kg (processed natural gas) ▲11.4% 737 kg (LPG) ▲3.4% Latent heat recovery gas water heater	527 kg ▲26.1% Latent heat recovery gas water heater + piping method/hot water saving devices		774 kg +8.6% Electric water heater with a natural refrigerant heat pump (energy-efficient mode)
			809 kg +13.5% Latent heat recovery oil water heater	670 kg ▲6.0% Latent heat recovery oil water heater + piping method/hot water saving devices		632 kg ▲11.4% Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/hot water saving devices
				895 kg +25.5% Electric water heater with a natural refrigerant heat pump (medium boiling mode)		278 kg ▲61.0% Solar water heating (solar water heater: flat plate type) + conventional gas water heater
Lighting	Lighting system planning	1,301 kg 0 Conventional device + continuous lighting while staying in the room + one-light-per-room system	1,057 kg ▲17.0% High-efficiency device + on/off lighting + one-light-per-room system	1,016 kg ▲20.3% High-efficiency device + lighting adjustment + one-light-per-room system	903 kg ▲29.1% High-efficiency device + lighting adjustment + distributed multiple system (simplified)	
Consumer electronics	High-efficiency consumer electronics	2,048 kg 0 Conventional consumer electronics (made in 1997)	1,636 kg ▲20% Energy-efficient products (500 kWh decrease)	1,225 kg ▲40% Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices	223 kg (processed natural gas) Cooking stove or IH cooking heater				
Overall		5,563 kg* 0	4,734 kg – 3,381 kg ▲14.9% – ▲39.2%			

Note 1: Upper values indicate annual CO_2 emissions (kg-CO_2); lower values indicate CO_2 emissions reduction rate (▲: reduction, +: increase).
Note 2: With regard to domestic hot water, CO2 emissions were calculated based on the energy consumption of the types of machines used for validation experiments by using conversion factors listed in Table 7 and Table 8 on p.346 (value provided by Okinawa Gas was used for the CO2 emission coefficient).
* When the duct system is used in the ventilation system planning.

3. Economic efficiency

1) Initial cos

・The results of evaluating initial costs are shown in Table 11.

・For each elemental technology, the Table shows the results of calculating initial costs needed when methods at each level were applied, changes compared to the initial cost at level 0, and applied methods.

Table 11 Initial cost evaluation results <Zone VI>

Use	Elemental technology	Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	Cooling system planning	417,000 yen 0 AC COP3	461 ,000 yen + 44,000 yen AC COP4	429 (608),000 yen + 12(+191),000 yen AC COP3 + electric fan/ceiling fan (or COP5)	473,000 yen + 56,000 yen AC COP4 + electric fan/ceiling fan	620,000 yen + 203,000 yen AC COP5 + electric fan/ceiling fan
Ventilation	Ventilation system planning / Duct type	276,000 yen 0 Normal-efficiency fan (AC motor)	277,000 yen + 1,000 yen Normal-efficiency fan (AC motor) Increased duct diameter	365,000 yen + 89,000 yen High-efficiency fan (DC motor) Increased duct diameter		
	Through-the-wall type	117,000 yen 0 Turbofan Outside air terminal: regular hood	117,000 yen ± 0,000 yen Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning	483,000 yen 0 Conventional gas water heater (An example other than above) 528,000 yen + 45,000 yen Conventional oil water heater	544,000 yen + 61,000 yen Latent heat recovery gas water heater	601,000 yen + 118,000 yen Latent heat recovery gas water heater + piping method/ hot water saving devices		916,000 yen + 433,000 yen Electric water heater with a natural refrigerant heat pump (energy-efficient mode)
			580,000 yen + 97,000 yen Latent heat recovery oil water heater	637,000 yen + 154,000 yen Latent heat recovery oil water heater + piping method/ hot water saving devices		973,000 yen + 490,000 yen Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/ hot water saving devices
				916,000 yen + 433,000 yen Electric water heater with a natural refrigerant heat pump (medium boiling mode)		917,000 yen + 434,000 yen Solar water heating (solar water heater: flat plate type) + conventional gas water heater
Lighting	Lighting system planning	407,000 yen 0 Conventional device + continuous lighting while staying in the room or on/off lighting + one-light-per-room system	543,000 yen + 136,000 yen High-efficiency device + on/off lighting + one-light-per-room system	580,000 yen +173,000 yen High-efficiency device + lighting adjustment + one-light-per-room system	675,000 yen +268,000 yen High-efficiency device + lighting adjustment + distributed multiple system (simplified)	
Consumer electronics	High-efficiency consumer electronics	— Conventional consumer electronics (made in 1997)	— Energy-efficient products (500 kWh decrease)	— Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices	— Cooking stove or IH cooking heater				
Electricity	Photovoltaic power generation	0 0 Do not introduce	2,753,000 yen + 2,753,000 yen Approx. 3 kW	3,486,000 yen + 3,486,000 yen Approx. 4 kW		

Note: Upper values indicate initial cost (unit-price-based).
Lower values indicate increase or decrease in initial costs when the initial cost at level 0 is considered 0.

2) Annual energy cost (running cost)

- The results of evaluating annual energy costs are shown in Table 12.
- For each elemental technology, the Table shows the results of calculating annual energy costs needed when methods at each level were applied, changes compared to the energy cost at level 0, and applied methods.

Table 12 Annual energy cost evaluation results <Zone VI>

Use	Elemental technology		Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	Cooling system planning		23,000 yen/year 0 AC COP3	19,000 yen/year − 4,000 yen/year AC COP4	18(17),000 yen/year − 5(−6),000 yen/year AC COP3 + electric fan/ceiling fan (or COP5)	16,000 yen/year − 7,000 yen/year AC COP4 + electric fan/ceiling fan	14,000 yen/year − 9,000 yen AC COP5 + electric fan/ceiling fan
Ventilation	Ventilation system planning	Duct type	7,000 yen/year 0 Normal-efficiency fan (AC motor)	4,000 yen/year − 3,000 yen/year Normal-efficiency fan (AC motor) Increased duct diameter	3,000 yen/year − 4,000 yen/year High-efficiency fan (DC motor) Increased duct diameter		
		Through-the-wall type	6,000 yen/year 0 Turbofan Outside air terminal: regular hood	5,000 yen/year −1,000 yen/year Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning		82,000 yen/year 0 Conventional gas water heater (An example other than above) 44,000 yen/year − 38,000 yen/year Conventional oil water heater	72,000 yen/year − 10,000 yen/year Latent heat recovery gas water heater	62,000 yen/year − 20,000 yen/year Latent heat recovery gas water heater + piping method/hot water saving devices		8,000 yen/year − 74,000 yen/year Electric water heater with a natural refrigerant heat pump (energy-efficient mode)
				40,000 yen/year − 42,000 yen/year Latent heat recovery oil water heater	33,000 yen/year − 49,000 yen/year Latent heat recovery oil water heater + piping method/hot water saving devices		6,000 yen/year − 76,000 yen/year Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/hot water saving devices
					9,000 yen/year − 73,000 yen/year Electric water heater with a natural refrigerant heat pump (medium boiling mode)		38,000 yen/year − 44,000 yen/year Solar water heating (solar water heater: flat plate type) + conventional gas water heater
Lighting	Lighting system planning		31,000 yen/year 0 Conventional device + continuous lighting while staying in the room + one-light-per-room system	25,000 yen/year − 6,000 yen/year High-efficiency device + on/off lighting + one-light-per-room system	24,000 yen/year − 7,000 yen/year High-efficiency device + lighting adjustment + one-light-per-room system	21,000 yen/year − 10,000 yen/year High-efficiency device + lighting adjustment + distributed multiple system (simplified)	
Consumer electronics	High-efficiency consumer electronics		48,000 yen/year Conventional consumer electronics (made in 1997)	39,000 yen/year Energy-efficient products (500 kWh decrease)	29,000 yen/year Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices		— Cooking stove or IH cooking heater				

Note: Upper values indicate annual energy cost.
Lower values indicate reduction in annual energy costs when the annual energy cost at level 0 is considered 0 (increase: +; decrease: -).

■Conditions for initial cost test calculation (Zone VI)

①Cooling

- Market prices of air conditioners were calculated based on the research results on the websites below (October, 2008).
  (1) img.yamada-denkiweb.com/item/list.php/special/2ct28/tm002/?lorder=1&ltype=1&Current_Page=1
  (2) www.yodobashi.com/enjoy/more/productslist/cat_162_539_9560938/moid_542185/sr_nm/9560884.html
- The number of air conditioners installed for each room and their capacities are as follows (See 3.1 on p.064).
  Living and dining rooms: 5 kW × 1 unit、Master bedroom: 2.8 kW × 1 unit、Children's room: 3.6 kW × 1 unit
- Prices are all special prices listed on websites (including tax).
- With regard to air conditioner installation fees, we checked local consumer electronics stores and used the following prices (basic installation fee only, including tax).
  Capacity 2.8 kW or lower: 15,000 yen per unit, 2.9 kW or higher: 20,000 yen per unit
- As for electric fans, we checked local consumer electronics stores and used the price at 4,000 yen (including tax) per unit.

Table 11 Supplementary Tables: Air conditioner prices and COP that corresponds to solar shading method levels

Supplementary Table 1: Price range (Unit: yen)

Solar shading method levels	6 *tatami* mats (10 m²)	8 *tatami* mats (13 m²)	10 *tatami* mats (16 m²)	14 *tatami* mats (22 m²)
Level 0	144,800			
Level 1	84,100	175,900		
Level 2	89,400	112,300 – 119,200	179,600	221,700
Level 3		79,200		203,600
Level 4		89,400	103,100 – 132,800	147,500

Supplementary Table 2: Air conditioner COP

Solar shading method levels	6 *tatami* mats (10 m²)	8 *tatami* mats (13 m²)	10 *tatami* mats (16 m²)	14 *tatami* mats (22 m²)
Level 0	5.8			
Level 1	5.1	5.5		
Level 2	4.9	5.1 – 5.4	5.4	4.8
Level 3		4.8		4.6
Level 4		5.1	4.6 – 5.3	3.7

The air conditioner prices in Table 11 (Initial cost evaluation results on p.356) were the ones surveyed on the assumption that the air conditioner is required to provide the maximum cooling capacity when the solar shading ability of building envelope is at level 0. Meanwhile, the maximum cooling capacity required becomes lower when the building envelope ' s solar shading ability is improved, making it possible to lower the initial costs since a smaller air conditioner is adequate in this case.

Supplementary Table 1 of Table 11 shows the results of surveyed prices of air conditioners that meet the requirements of the maximum cooling capacity for each room size according to the level of solar shading methods. When the room size is definitely the same, the cost of installing an air conditioner clearly tends to become lower as the solar shading performance improves. For example, in the case of an 8-tatami-mat room, the price is approximately 176,000 yen when the solar shading method is at level 0. However, at level 4, the air conditioner installation cost is reduced almost by half, being approximately 89,000 yen.

Incidentally, Supplementary Table 2 of Table 11 lists the energy efficiency of corresponding types. Although types with a smaller maximum cooling capacity tend to offer lower energy efficiency, they are considered to have few problems from the viewpoint of substantial energy conservation.

②Ventilation

- Regular prices listed in manufacturers' catalogues are used as unit prices, and local labor costs for the region in question are used for other prices (October, 2008).
- As for cut lengths (flexible pipes), converted unit prices for each unit of length were used.
- As for cost per man-hour, labor costs (electrical work) in the region in question are used for each specialist.
- With regard to the man-hours for labor costs, we assumed numbers within the bounds of common sense of equipment installation for a new detached house.
- Expenses regarding expendable supplies and miscellaneous materials, transportation cost and other expenses are not included.
- Prices do not include tax.

③Domestic hot water

- Regular prices listed in manufacturers' catalogues are used as unit prices, and local labor costs for the region in question are used for other prices (October, 2008).
- The range of estimates includes the water heater itself (including necessary items separately sold such as a remote controller and a circulation adaptor), piping around the water heater (water pipes, hot water pipes, gas pipes), piping and devices inside the building (kitchen faucets, bathroom shower faucets).
- As for cut lengths (each pipe), converted unit prices for each unit of length were used.
- As for cost per man-hour, labor costs (plumbing work, electrical work) in the region in question are used for each specialist.
- With regard to the man-hours for labor costs, we assumed numbers within the bounds of common sense of equipment installation for a new detached house.
- Expenses regarding expendable supplies and miscellaneous materials, transportation cost and other expenses are not included.
- Prices do not include tax.

④Lighting

- Regular prices listed in manufacturers' catalogues are used as unit prices (January, 2009).
- As for switches, their prices were calculated based on the cost component percentages listed in the existing "Design Guidelines for Low Energy Housing with Validated Effectiveness" (published in June, 2005).
- As for costs per man-hour, labor costs in the region in question are used for each specialist (October, 2008).
- Expenses regarding expendable supplies and miscellaneous materials, transportation cost and other expenses are not included.
- Prices do not include tax.

⑤Photovoltaic power generation

- The range of estimates includes costs of photovoltaic power generation system components, costs of wiring, processing and system installation, costs of electricity application and inspection, and other expenses. The same temporary scaffolding as that used when constructing the building is assumed to be used for the installation of the system.
- Prices do not include tax.

■Conditions for annual energy cost (running cost) test calculation (Zone VI)

①Processed natural gas cost

- Processed natural gas costs were calculated based on the list of rates provided by Okinawa Gas (http://www.okinawagas.co.jp/). See Table.

  Note 1: Calorific value: 61.954 MJ/Nm3

  Note 2: Rate category B was applied.

  Note 3: Basic rates were proportionally divided according to the composition ratio of each energy use listed in the reference energy consumption in Zone VI (Naha). See Table 2 on p.339.

Table: List of rates provided by Okinawa Gas (Applicable period: Gas rates between April 2008 Unit: Yen (including tax)

Fee classification	Usage per month	Basic rate per month	Reconciliation unit price* per m^3	Base unit price per m^3
A	Up to 18 m3	796.95	350.2	340.158
B	Up to 19 m3 to 152 m3	1,438.50	314.56	304.521
C	Over 152 m3	8,400.00	268.76	258.72

Note 1: Unit price adjusted based on raw material costs; increase by 10.0464 yen/m2 (unit price adjusted every six months according to changes in raw material costs).
Note 2: Gas rate = basic rate + (quantity consumed × reconciliation unit price).
* Reconciliation unit price = basic unit price + unit price adjusted based on raw material costs (Note 1); unit price used for calculating actual prices

②Kerosene cost

- Kerosene costs were calculated based on the price information provided by the Oil Information Center (http://oil-info.ieej.or.jp/).

* Research results in October 2008 were applied.

Retail price of kerosene at a gas station (Okinawa): 2,264 yen/18 L

③Electricity cost

- Electricity costs for devices other than night heat storage devices were calculated based on the reference unit price of electric charges (22 yen/kWh including tax). Therefore, if there is a need to calculate the precise electricity energy cost, it is necessary to covert reference unit price provided by each electric power company.

* Reference unit price of electric charges: This is used for indicating electric charges specified in the manufacturing business display rules by the Home Electric Appliances Fair Trade Conference (http://www.eftc.or.jp/).

- Electricity costs for night heat storage devices were calculated based on “Ee Life”, a seasonal and hourly rate lighting service offered by the Okinawa Electric Power Company (Table).

  Note 1: Basic rates were proportionally divided according to the composition ratio of each energy use listed in the reference energy consumption in Zone VI (Naha). See Table 2 on p.339.

  Note 2: A power distribution control discount for an electric water heater with a natural refrigerant heat pump (device capacity: 2 kVA) can be applied.

Table: Ee Life unit price table (Electric charges for meter reading in Sep. 2008; unit price adjusted based on fuel costs is 0 yen)

Classification			Unit	Unit price (yen, including tax)
Basic charge	–		1 contract	1,575.00
Electricity charge	Daytime	Summer	1 kWh	38.37
		Other seasons	1 kWh	35.04
	Active hours		1 kWh	26.22
	Nighttime		1 kWh	11.46
Discount for 5-hour rechargeable devices			1 kW	210
Discount for recharge control type/nighttime heat storage type devices			1 kW	157.5
Ee plan discount (discount for all-electric homes)			–	Discount target abount x 10%

Notes:
1. “Summer” is the season between July 1 and September 30; “Other seasons” means the rest of the year.
2. “Daytime” means the period of time between 10:00 and 17:00 on weekdays (from Monday to Saturday).
3. “Living hours” mean the period of time between 7:00 and 10:00 and between 17:00 and 23:00 on weekdays and from 7:00 till 23:00 on holidays specified by the optional provisions.
4. “Nighttime” means the period of time other than “Daytime” and “Living hours”.
5. “Amount subject to discount” is a total of basic rate and electric energy charges.
6. The maximum Ee Plan discount is 3,150 yen per month (including tax) for each contract.
7. “All-electric home” means that electricity provides the heat source for the entire house.

6.2.2 Evaluation Results in Zone V

1. Energy performance

- The results of evaluating energy performance (annual energy consumption) are shown in Table 13.
- For each elemental technology, the Table shows the results of calculating annual energy consumption at each level, energy consumption reduction rates compared to level 0, and applied methods.

Table 13 Energy efficiency evaluation results <Zone V>

Use	Elemental technology	Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	Heating and cooling system planning (Cooling through air conditioner)	5.7 GJ 0 (Living/Dining room and kitchen) Cooling COP3 (Other habitable rooms) Cooling COP3	5.4 GJ ▲5 % (Living/Dining room and kitchen) Cooling COP4 (Other habitable rooms) Cooling COP3	4.8 GJ ▲15 % (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan (Other habitable rooms) Cooling COP3	4.3 GJ ▲25 % (Living/Dining room and kitchen) Cooling COP4 + electric fan/ceiling fan *Appropriate device capacity setting (Other habitable rooms) Cooling COP3	3.7 GJ ▲35 % (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan *Appropriate device capacity setting (Other habitable rooms) Cooling COP3
Heating	Heating and cooling system planning (Heating through air conditioner)	5.0 GJ 0 (Living/Dining room and kitchen) Heating COP4.14 (Master bedroom) Heating COP5.72 (Children ' s room) Heating COP5.65 <Heating level 0>	4.8 GJ ▲5 % (Living/Dining room and kitchen) Heating COP5.20 (Master bedroom) Heating COP5.72 (Children ' s room) Heating COP5.65 <Heating level 1>	4.8 GJ ▲5 % (Living/Dining room and kitchen) Heating COP5.20 (Master bedroom) Heating COP5.72 (Children ' s room) Heating COP5.65 <Heating level 1>	3.5 GJ ▲30 % (Living/Dining room and kitchen) Heating COP6.22 (Master bedroom) Heating COP5.72 (Children ' s room) Heating COP5.65 <Heating level 4>	3.5 GJ ▲30 % (Living/Dining room and kitchen) Heating COP6.22 (Master bedroom) Heating COP5.72 (Children ' s room) Heating COP5.65 <Heating level 4>
Ventilation	Ventilation system planning – Duct type	3.1 GJ 0 Normal-efficiency fan (AC motor)	2.0 GJ ▲36.1% Normal-efficiency fan (AC motor) Increased duct diameter	1.5 GJ ▲52.5% High-efficiency fan (DC motor) Increased duct diameter		
Ventilation	Ventilation system planning – Through-the-wall type	1.0 GJ 0 Turbofan Outside air terminal: regular hood	0.8 GJ ▲17.1% Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning	19.2 GJ 0 Conventional gas water heater	16.3 GJ ▲15.1% Latent heat recovery gas water heater	13.5 GJ ▲29.7% Latent heat recovery gas water heater + piping method/hot water saving devices	12.1 GJ ▲37.0% Electric water heater with a natural refrigerant heat pump (energy-efficient mode)	9.9 GJ ▲48.4% Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/hot water saving devices
Domestic hot water		(An example other than above) 18.1 GJ ▲5.7% Conventional oil water heater	16.3 GJ ▲15.1% Latent heat recovery oil water heater	13.4 GJ ▲30.2% Latent heat recovery oil water heater + piping method/hot water saving devices		10.0 GJ ▲47.9% Solar water heating (solar water heating: flat plate type) + conventional gas water heater
Domestic hot water			15.3 GJ ▲20.3% Electric water heater with a natural refrigerant heat pump (medium boiling mode)			
Lighting	Lighting system planning	11.3 GJ 0 Conventional device + continuous lighting while staying in the room + one-light-per-room system	7.4 GJ ▲34.5% High-efficiency device + on-off lighting + one-light-per-room system	6.1 GJ ▲46.1% High-efficiency device + lighting adjustment + one-light-per-room system	5.8 GJ ▲48.8% High-efficiency device + lighting adjustment + distributed multiple system (simplified/complete)	
Consumer electronics	High-efficiency consumer electronics	19.9 GJ 0 Conventional consumer electronics (made in 1997)	15.9 GJ ▲20% Energy-efficient products (500 kWh decrease)	11.9 GJ ▲40% Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices	4.4 GJ Cooking stove or induction heating (IH) cooking heater (values are according to the results from a survey on cooking stove)				
Overall		68.6 GJ* 0	56.3. GJ – 40.7 GJ ▲17.9% – ▲40.7%			

Note 1: Upper values indicate annual primary energy consumption; lower values indicate energy consumption reduction rate (▲: reduction, +: increase).
Note 2: As for heating (heat pump air conditioner), the table shows primary energy consumption determined by the capacity of cooling (air conditioner) devices.
Note 3: With regard to domestic hot water, energy saving effects shown in the table (second row onward at level 0 as well as level 1 to 4) were confirmed for the types of machines used for validation experiments.
* When the duct system is used in the ventilation system planning.

2. Global warming impact

- The results of evaluating global warming impact (annual CO_2 emissions) are shown in Table 14.
- For each elemental technology, the Table shows the results of calculating annual CO_2 emissions at each level, CO_2 emissions reduction rates compared to level 0, and applied methods.

Table 14 Global warming impact evaluation results <Zone V>

Use	Elemental technology	Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	Heating and cooling system planning (Cooling through air conditioner)	226 kg 0 (Living/Dining room and kitchen) Cooling COP3 (Other habitable rooms) Cooling COP3	215 kg ▲5% (Living/Dining room and kitchen) Cooling COP4 (Other habitable rooms) Cooling COP3	192 kg ▲15% (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan (Other habitable rooms) Cooling COP3	170 kg ▲25% (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan *Appropriate device capacity setting (Other habitable rooms) Cooling COP3	147 kg ▲30% (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan *Appropriate device capacity setting (Other habitable rooms) Cooling COP3
Heating	Heating and cooling system planning (Heating through air conditioner)	198 kg 0 (Living/Dining room and kitchen) Heating COP4.14 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 0>	188 kg ▲5 % (Living/Dining room and kitchen) Heating COP5.20 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 1>	188 kg ▲5 % (Living/Dining room and kitchen) Heating COP5.20 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 1>	139 kg ▲30 % (Living/Dining room and kitchen) Heating COP6.22 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 4>	139 kg ▲30 % (Living/Dining room and kitchen) Heating COP6.22 (Master bedroom) Heating COP5.72 (Children ' s room) Heating COP5.65 <Heating level 4>
Ventilation	Ventilation system planning — Duct type	122 kg 0 Normal-efficiency fan (AC motor)	78 kg ▲36.1% Normal-efficiency fan (AC motor) Increased duct diameter	58 kg ▲52.5% High-efficiency fan (DC motor) Increased duct diameter		
Ventilation	Ventilation system planning — Through-the-wall type	41 kg 0 Turbofan Outside air terminal: regular hood	34 kg ▲17.1% Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning	966 kg (processed natural gas) 0 1138 kg (LPG) +17.8% Conventional gas water heater	819 kg (processed natural gas) ▲15.2% 963 kg (LPG) ▲0.3% Latent heat recovery gas water heater	675 kg (processed natural gas) ▲30.1% Latent heat recovery gas water heater + piping method/hot water saving devices	503 kg +47.9% Electric water heater with a natural refrigerant heat pump (energy-efficient mode)	411 kg ▲57.5% Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/hot water saving devices
		(An example other than above) 1211 GJ +25.4% Conventional oil water heater	1086 kg +12.4% Latent heat recovery oil water heater	893 kg ▲7.6% Latent heat recovery oil water heater + piping method/hot water saving devices		499 kg ▲48.3% Solar water heating (solar water heater: flat plate type) + conventional gas water heater
			637 kg ▲34.1% Electric water heater with a natural refrigerant heat pump (medium boiling mode)			
Lighting	Lighting system planning	448 kg 0 Conventional device + continuous lighting while staying in the room + one-light-per-room system	294 kg ▲34.5% High-efficiency device +on/off lighting + one-light-per-room system	241 kg ▲46.1% High-efficiency device + lighting adjustment + one-light-per-room system	229 kg ▲48.8% High-efficiency device + lighting adjustment + distributed multiple system (simplified/complete)	
Consumer electronics	High-efficiency consumer electronics	789 kg 0 Conventional consumer electronics (made in 1997)	631 kg ▲20% Energy-efficient products (500 kWh decrease)	473 kg ▲40% Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices	223 kg (processed natural gas) Cooking stove or IH cooking heater				
Overall		2,972 kg * 0	2,715 kg – 1,680 kg ▲8.6% – ▲43.5%			

Note 1: Upper values indicate annual CO_2 emissions (kg-CO_2); lower values indicate CO_2 emissions reduction rate (▲: reduction, +: increase).
Note 2: As for heating (heat pump air conditioner), the table shows CO_2 emissions determined by the capacity of cooling (air conditioner) devices.
Note 3: With regard to domestic hot water, CO_2 emissions were calculated based on the energy consumption of the types of machines used for validation experiments by using conversion factors listed in Table 7 and Table 8 on p.353. (value provided by Kyushu Electric Power Co., was used for the CO_2 emission coefficient)
* When the duct system is used in the ventilation system planning.

3. Economic efficiency

1) Initial cost

- The results of evaluating initial costs are shown in Table 15.
- For each elemental technology, the Table shows the results of calculating initial costs needed when methods at each level were applied, changes compared to the initial cost at level 0, and applied methods.

Table 15 Initial cost evaluation results <Zone V>

Use	Elemental technology	Level 0	Level 1	Level 2	Level 3	Level 4
Cooling Heating	Heating and cooling system planning (Air conditioner)	417,000 yen 0 (Living/Dining room and kitchen) Cooling COP3 (Other habitable rooms) Cooling COP3	461,000 yen + 44,000 yen (Living/Dining room and kitchen) Cooling COP4 (Other habitable rooms) Cooling COP3	477,000 yen + 60,000 yen (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan (Other habitable rooms) Cooling COP3	477,000 yen + 60,000 yen (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan * Appropriate device capacity setting (Other habitable rooms) Cooling COP3	477,000 yen + 60,000 yen (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan * Appropriate device capacity setting (Other habitable rooms) Cooling COP3
Ventilation	Ventilation system planning — Duct type	284,000 yen 0 Normal-efficiency fan (AC motor)	298,000 yen + 14,000 yen Normal-efficiency fan (AC motor) Increased duct diameter	386,000 yen + 102,000 yen High-efficiency fan (DC motor) Increased duct diameter		
Ventilation	Ventilation system planning — Through-the-wall type	109,000 yen 0 Turbofan Outside air terminal: regular hood	109,000 yen ± 0,000 yen Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning	483,000 yen 0 Conventional gas water heater (An example other than above) 528,000 yen + 45,000 yen Conventional oil water heater	544,000 yen + 61,000 yen Latent heat recovery gas water heater	601,000 yen + 118,000 yen Latent heat recovery gas water heater + piping method/hot water saving devices	916,000 yen + 433,000 yen Electric water heater with a natural refrigerant heat pump (medium boiling mode)	973,000 yen + 490,000 yen Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/hot water saving devices
			580,000 yen + 97,000 yen Latent heat recovery oil water heater	637,000 yen + 154,000 yen Latent heat recovery oil water heater + piping method/hot water saving devices		
			916,000 yen + 433,000 yen Electric water heater with a natural refrigerant heat pump (medium boiling mode)			917,000 yen + 434,000 yen Solar water heating (solar water heater: flat plate type) + conventional gas water heater
Lighting	Lighting system planning	484,000 yen 0 Conventional device + continuous lighting while staying in the room or on/off lighting + one-light-per-room system	539,000 yen + 55,000 yen High-efficiency device + on/off lighting + one-light-per-room system	574,000 yen +90,000 yen High-efficiency device + lighting adjustment + one-light-per-room system	734,000 yen +250,000 yen High-efficiency device + lighting adjustment + distributed multiple system (simplified)	
Consumer electronics	High-efficiency consumer electronics	— Conventional consumer electronics (made in 1997)	— Energy-efficient products (500 kWh decrease)	— Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices	— Cooking stove or IH cooking heater				

Electricity	Photovoltaic power generation	0 0 Do not introduce	2,546,000 yen + 2,546,000 yen Approx. 3 kW	3,209,000 yen + 3,209,000 yen Approx. 4 kW

Note 1: Upper values indicate initial cost (unit-price-based).
Lower values indicate increase or decrease in initial costs when the initial cost at level 0 is considered 0.
Note 2: As for cooling/heating (air conditioner), the table shows initial costs determined by the capacity of cooling devices.

2) Annual energy cost (running cost)

- The results of evaluating annual energy costs are shown in Table 16.
- For each elemental technology, the Table shows the results of calculating annual energy costs needed when methods at each level were applied, changes compared to the energy cost at level 0, and applied methods.

Table 16 Annual energy cost evaluation results <Zone V>

Use	Elemental technology	Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	Heating and cooling system planning (Cooling through air conditioner)	12,800 yen/year 0 (Living/Dining room and kitchen) Cooling COP3 (Other habitable rooms) Cooling COP3	12,200 yen/year − 600 yen/year (Living/Dining room and kitchen) Cooling COP4 (Other habitable rooms) Cooling COP3	10,900 yen/year − 1,900 yen/year (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan (Other habitable rooms) Cooling COP3	9,600 yen/year − 3,200 yen/year (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan * Appropriate device capacity setting (Other habitable rooms) Cooling COP3	8,400 yen/year − 4,400 yen (Living/Dining room and kitchen) Cooling COP5 + electric fan/ceiling fan * Appropriate device capacity setting (Other habitable rooms) Cooling COP3
Heating	Heating and cooling system planning (Heating through air conditioner)	11,300 yen/year 0 (Living/Dining room and kitchen) Heating COP4.14 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 0>	10,700 yen/year − 600 yen/year (Living/Dining room and kitchen) Heating COP5.20 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 1>	10,700 yen/year − 600 yen/year (Living/Dining room and kitchen) Heating COP5.20 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 1>	7,900 yen/year − 3,400 yen/year (Living/Dining room and kitchen) Heating COP6.22 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 4>	7,900 yen/year − 3,400 yen/year (Living/Dining room and kitchen) Heating COP6.22 (Master bedroom) Heating COP5.72 (Children's room) Heating COP5.65 <Heating level 4>
Ventilation	Ventilation system planning Duct type	6,900 yen/year 0 Normal-efficiency fan (AC motor)	4,400 yen/year − 2,500 yen/year Normal-efficiency fan (AC motor) Increased duct diameter	3,300 yen/year − 3,600 yen/year High-efficiency fan (DC motor) Increased duct diameter		
	Through-the-wall type	2,300 yen/year 0 Turbofan Outside air terminal: regular hood	1,900 yen/year − 400 yen/year Turbofan Outside air terminal: Manufacturer verifies the combination			
Domestic hot water	Solar water heating Domestic hot water planning	103,000 yen/year 0 Conventional gas water heater (An example than above) 36,000 yen/year − 67,000 yen/year Conventional oil water heater	91,000 yen/year − 12,000 yen/year Latent heat recovery gas water heater	78,000 yen/year − 25,000 yen/year Latent heat recovery gas water heater + piping method/hot water saving devices	13,000 yen/year − 90,000 yen/year Electric water heater with a natural refrigerant heat pump (energy-efficient mode)	10,000 yen/year − 93,000 yen/year Electric water heater with a natural refrigerant heat pump (energy-efficient mode) + piping method/hot water saving devices
			33,000 yen/year − 70,000 yen/year Latent heat recovery oil water heater	27,000 yen/year − 76,000 yen/year Latent heat recovery oil water heater + piping method/hot water saving devices		
			16,000 yen/year − 92,000 yen/year Electric water heater with a natural refrigerant heat pump (medium boiling mode)			64,000 yen/year − 39,000 yen/year Solar water heating (solar water heater: flat plate type) + conventional gas water heater
Lighting	Lighting system planning	25,000 yen/year 0 Conventional device + continuous lighting while staying in the room or on/off lighting + one-light-per-room system	17,000 yen/year − 8,000 yen/year High-efficiency device + on/off lighting + one-light-per-room system	14,000 yen/year − 11,000 yen/year High-efficiency device + lighting adjustment + one-light-per-room system	13,000 yen/year − 12,000 yen/year High-efficiency device + lighting adjustment + distributed multiple system (simplified)	
Consumer electronics	High-efficiency consumer electronics	— Conventional consumer electronics (made in 1997)	— Energy-efficient products (500 kWh decrease)	— Energy-efficient products (1,000 kWh decrease)		
Cooking	Cooking devices	— Cooking stove or IH cooking heater				

Note 1: Upper values indicate annual energy cost.
Lower values indicate reduction in annual energy costs when the annual energy cost at level 0 is considered 0.
Note 2: As for heating (heat pump air conditioner), the table shows annual energy costs determined by the capacity of cooling (air conditioner) devices.

■Conditions for initial cost test calculation (Zone V)

①Cooling (Heating)

- Market prices of air conditioners were calculated based on the research results on the websites below (October, 2008).
  (1) img.yamada-denkiweb.com/item/list.php/special/2ct28/tm002/?lorder=1&ltype=1&Current_Page=1
  (2) www.yodobashi.com/enjoy/more/productslist/cat_162_539_9560938/moid_542185/sr_nm/9560884.html
- The number of air conditioners installed for each room and their capacities are as follows (See 3.1 on p.064).
  Living and dining rooms: 5 kW × 1 unit, Master bedroom: 2.8 kW × 1 unit, Children's room: 2.2 kW × 2 units
- Prices are all special prices listed on websites (including tax).
- With regard to air conditioner installation fees, we checked local consumer electronics stores and used the following prices (basic installation fee only, including tax).
  Capacity 2.8 kW or lower: 15,000 yen per unit, 2.9 kW or higher: 20,000 yen per unit
- As for electric fans, we checked local consumer electronics stores and used the price at 4,000 yen (including tax) per unit.

②Ventilation

- Regular prices listed in manufacturers' catalogues are used as unit prices, and local labor costs for the region in question are used for other prices (October, 2008).
- As for cut lengths (flexible pipes), converted unit prices for each unit of length were used.
- As for cost per man-hour, labor costs (electrical work) in the region in question are used for each specialist.
- With regard to the man-hours for labor costs, we assumed numbers within the bounds of common sense of equipment installation for a new detached house.
- Expenses regarding expendable supplies and miscellaneous materials, transportation cost and other expenses are not included.
- Prices do not include tax.

③Domestic hot water

- Regular prices listed in manufacturers' catalogues are used as unit prices, and local labor costs for the region in question are used for other prices (October, 2008).
- The range of estimates includes the water heater itself (including necessary items separately sold such as a remote control and circulation adaptor), piping around the water heater (water pipes, hot water pipes and gas pipes), piping and devices inside the building (kitchen faucets and bathroom shower faucets).
- As for cut lengths (each pipe), converted unit prices for each unit of length were used.
- As for cost per man-hour, labor costs (plumbing work, electrical work) in the region in question are used for each specialist.
- With regard to the man-hours for labor costs, we assumed numbers within the bounds of common sense of equipment installation for a new detached house.
- Expenses regarding expendable supplies and miscellaneous materials, transportation cost and other expenses are not included.
- Prices do not include tax.

④Lighting

- Regular prices listed in manufacturers' catalogues are used as unit prices (January, 2009).
- As for switches, their prices were calculated based on the cost component percentages listed in the existing "Design Guidelines for Low Energy Housing with Validated Effectiveness" (published in June, 2005).
- As for costs per man-hour, labor costs in the region in question are used for each specialist (October, 2008).
- Expenses regarding expendable supplies and miscellaneous materials, transportation cost and other expenses are not included.
- Prices do not include tax.

⑤Photovoltaic power generation

- The range of estimates includes costs of photovoltaic power generation system components, costs of wiring, processing and system installation, costs of electricity application and inspection, and other expenses. The same temporary scaffolding as that used when constructing the building is assumed to be used for the installation of the system.
- Prices do not include tax.

■Conditions for annual energy cost (running cost) test calculation (Zone V)

①Processed natural gas cost

・Processed natural gas costs were calculated based on the list of rates provided by Nihon Gas (http://www.nihongas.co.jp/). See Table.

Note 1: Calorific value: 46.04655 MJ/Nm^3

Note 2: Rate category B was applied.

Note 3: Basic rates were proportionally divided according to the composition ratio of each energy use listed in the reference energy consumption in Zone V (Kagoshima). See Table 2 on p.339.

Table: List of rates provided by Nihon Gas (Applicable period: Gas rates between April 2008 and September 2008) Unit: Yen (including tax)

Fee classification	Usage per month	Basic rate per month	Reconciliation unit price* per m^3	Base unit price per m^3
A	Up to 25 m^3	719.95	268.9994	258.3787
B	Up to 25 m^3 to 150 m^3	2,237.55	208.2464	197.6257
C	Over 150 m^3	6,731.55	178.2899	167.6692

Note 1: Unit price adjusted based on raw material costs; increase by 10.6207 yen/m^2 (unit price adjusted every six months according to changes in raw material costs).
Note 2: Gas rate = basic rate + (quantity consumed × reconciliation unit price).
* Reconciliation unit price = basic unit price + unit price adjusted based on raw material costs (Note 1); unit price used for calculating actual prices

②Kerosene cost

・Kerosene costs were calculated based on the price information provided by the Oil Information Center (http://oil-info.ieej.or.jp/).

* Research results in January 2009 were applied.

Retail price of kerosene at a gas station (Kagoshima): 1,323 yen/18 L

③Electricity cost

・Electricity costs for devices other than night heat storage devices were calculated based on the reference unit price of electric charges (22 yen/kWh including tax). Therefore, if there is a need to calculate the precise electricity energy cost, it is necessary to covert reference unit price provided by each electric power company.

* Reference unit price of electric charges: This is used for indicating electric charges specified in the manufacturing business display rules by the Home Electric Appliances Fair Trade Conference (http://www.eftc.or.jp/).

・Electricity costs for night heat storage devices were calculated based on "Denka de Night", a seasonal and hourly rate lighting service offered by Kyushu Electric Power Co., Inc. (Table).

Note 1: Basic rates were proportionally divided according to the composition ratio of each energy use listed in the reference energy consumption in Zone V (Kagoshima). See Table 2 on p.339.

Note 2: A power distribution control discount for an electric water heater with a natural refrigerant heat pump (device capacity: 2 kW) can be applied.

Table: Denka de Night unit price table (Electric charges for meter reading in Jan. 2009; unit price adjusted based on fuel costs is 0.79 yen/kWh)

	Classification		Unit	Unit price(yen, including tax)
Basic charge	In the case of 6 kVA or lower		1 contract	1,155.00
	In the case of over 6 kVA	Up to 10 kVA	1 contract	1,575.00
		Over 10 kVA	Over 10 kVA	283.50
Electricity charge	Daytime	Summer	1 kWh	32.73
		Other seasons	1 kWh	27.23
	Active hours		1 kWh	20.55
	Nighttime		1 kWh	8.05
Discount for 8-hour rechargeable devices			1 kVA	210.00
Discount for 5-hour rechargeable devices			1 kVA	231.00
Minimum monthly charge			1 contract	420.00

Notes:
1. "Summer" is the season between July 1 and September 30; "Other seasons" means the rest of the year.
2. "Daytime" means the period of time between 10:00 and 17:00 every day.
3. "Active hours" mean the period of time between 8:00 and 10:00 and between 17:00 and 22:00 every day.
4. "Nighttime" means the period of time other than "Daytime" and "Active hours".

Comment ● Prime energy and secondary energy

In addition to indicating energy consumption by primary energy conversion, there is a method of indicating it through secondary energy conversion. In this case, the electricity conversion factor is 3,600 kJ/kWh.

The ratio of the secondary energy conversion factor to the primary energy conversion factor (= 3,600 / 9,760 = 0.369) indicates the ratio of energy that is delivered as electricity to customers excluding any loss during power generation and transmission from the energy provided by fuels (oil and natural gas) used for generating power at a thermal power plant.

Since energy consumption at houses is sometimes labeled secondary energy, it is necessary to confirm whether it is labeled as primary or secondary energy.

Comment ● Method of calculating annual primary energy consumption based on utility bills

Electricity, gas and kerosene bills show each purchase volume. The units are kilowatts-hour (kWh) for electricity, cubic meters (m^3) for gas, and liters (L) for kerosene. Primary energy consumption, which is measured in joules (J), can be calculated by multiplying the purchase volume by the following primary energy conversion factor.

Electricity: 9,760 kJ/kWh

Gas: Processed natural gas 13A 62 MJ/m^3 (Okinawa)

Processed natural gas 13A 46 MJ/ m^3 (Kagoshima)

Kerosene: 37 MJ/L

For example, when 5,000 kWh electricity and 400 m^3 processed natural gas (13A) are used in Kagoshima, the primary energy consumption is as follows: 5,000 × 9.76 + 400 × 46 = 67,200 MJ = 67.2 GJ (1 GJ = 1,000 MJ; GJ reads "gigajoule" and MJ reads "megajoule").

6.3 Energy Consumption Estimation Methods and Design Calculation Examples

6.3.1 Overview of Energy Consumption Estimation Methods

In this section, we list the methods of estimating energy consumption (energy saving effect) that occurs when elemental technologies discussed in this document are employed. While the development of a more precise energy consumption estimation method is a task that we will continue to focus on in the future, the methods listed in this section allow us to know the rough guidelines of energy consumption and reduction in the designing process. Please make use of them since they can be used for reviewing design details as well as for making suggestions or giving explanations to owners.

From next page onward, we list two tables, “Quick reference for energy consumption ratio of elemental technology” and “Energy consumption calculation table”, which can be used for energy consumption estimation.

- “Quick reference” is a table that allows you to check applicable methods for each elemental technology and the energy consumption ratio determined by such methods. This table, according to the contents of Chapter 3, 4 and 5, covers all conditions that are required for achieving each level including methods, except for the technology related to “treatment and efficient use of water and kitchen waste”. The table summarizes the methods of elemental technologies for designing a house that aims to be LEHVE and the effects of the methods. Please make use of it.
- “Calculation table” is a table for estimating energy consumption for each energy use as well as the total energy consumption by using the energy consumption ratio of elemental technology obtained from “Quick reference”. By comparing with the reference energy consumption, the energy consumption reduction rate can be estimated.

We list several types of “Quick reference” and “Calculation table” according to region as well as differences in the heating and cooling system operation, so please select the one that is appropriate. The types of tables listed are as follows.

Zone VI (6.3.2)

■Attached Table 1-1: Quick reference for energy consumption ratio of elemental technology (for Zone VI)

■Attached Table 1-2: Energy consumption calculation table (for Zone VI)

Zone V (6.3.3)

■Attached Table 2-1: Quick reference for energy consumption ratio of elemental technology (for Zone V in the case of partial intermittent heating and cooling)

■Attached Table 2-2: Energy consumption calculation table (for Zone V in the case of partial intermittent heating and cooling)

■Attached Table 3-1: Quick reference for energy consumption ratio of elemental technology (for Zone V in the case of whole-building continuous heating and cooling)

■Attached Table 3-2: Energy consumption calculation table (for Zone V in the case of whole-building continuous heating and cooling)

6.3.2 Energy Consumption Estimation Methods and Design Calculation Examples in Zone VI

■Attached Table 1-1: Quick reference for energy consumption ratio of elemental technology (for Zone VI)

Use	Reference energy consumption	Elemental technology*	Evaluation index/method		Energy consumption ratio (reference consumption is 1.0)				
					Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	10.3 GJ	Wind utilization/control (3.1)	Methods	(1) Opening area on cross ventilation route a: small, b: large (2) Opening area according to prevailing wind direction (3) High window a: small, b: large	1.0	0.96	0.91	0.88	
			Location 1	Wind speed 1m/s or more	□Method not introduced	□(1) a, (3) a	□(1) b, (3) b	—	
			Location 2	Wind speed 1m/s or less	□Method not introduced □(1) a, (3) a	□(1) a + (2), (3) a + (2) □(1) b, (3) b	□(1) b + (2) □(3) b + (2)	—	
				Wind speed 1 - 2m/s or less	□Method not introduced	—	□(1) a, (3) a □(1) a + (2), (3) a + (2)	□(1) b, (3) b □(1) b + (2), (3) b + (2)	
				Wind speed 2m/s or more	□Method not introduced	—	□(1) a, (3) a	□(1) a + (2), (3) a + (2) □(1) b, (3) b □(1) b + (2), (3) b + (2)	
		Solar shading method (4.2)	Methods	(1) Outside shading device (2) Envelope a: cavity ventilation, b: insulation, c: reflection	1.0	0.9	0.8	0.75	0.7
			Location 1	(1) Class 0	□No measures	□(2) a: Cavity ventilation	—	□(2) b: Insulation	□(2) c: Reflection
				(1) Class 1 Class 2	□No measures	□(2) a: Cavity ventilation	—	—	□(2) b: Insulation □(2) c: Reflection
				(1) Class 3	—	□No measures	□(2) a: Cavity ventilation		□(2) b: Insulation □(2) c: Reflection
			Location 2	(1) Class 0	□No measures	□(2) a: Cavity ventilation	—	□(2) b: Insulation □(2) c: Reflection	—
				(1) Class 1	□No measures	□(2) a: Cavity ventilation	—	□(2) b: Insulation	□(2) c: Reflection
				(1) Class 2 Class 3	—	□No measures	□(2) a: Cavity ventilation		□(2) b: Insulation □(2) c: Reflection
			Location 3	(1) Class 0	□No measures	□(2) a: Cavity ventilation	□(2) b: Insulation □(2) c: Reflection	—	—
				(1) Class 1	□No measures	□(2) a: Cavity ventilation	—	□(2) b: Insulation □(2) c: Reflection	—
				(1) Class 2	□No measures	□(2) a: Cavity ventilation	—	—	□(2) b: Insulation □(2) c: Reflection
				(1) Class 3	□No measures	□(2) a: Cavity ventilation	□(2) a: Cavity ventilation	—	□(2) b: Insulation □(2) c: Reflection
		Cooling system planning (5.1)	Methods	(1) High-efficiency air conditioner (COP) (2) Use of fan/ceiling fan	1.0	0.9	0.8	0.75	0.65
					□COP3	□COP4	□COP3 + (2) □COP5	□COP4 + (2)	□COP5 + (2)
Ventilation	3.1 GJ 2.8 GJ	Ventilation system planning (5.3)	Duct ventilation	(1) Duct pressure loss decrease (2) High-efficiency device	1.0	0.7	0.5		
					□Method not introduced	□(1)	□(1) + (2)		
			Through-the-wall ventilation	(1) Optimizing the combination of fan and outside air unit	1.0	0.8			
					□Method not introduced	□(1)			
Domestic hot water	13.8 GJ	Solar water heating (3.5)	Methods	(1) Heat collection area a: small, b: medium, c: large (2) Connection to auxiliary heat source a: none, b: three-way valve, c: solar connection unit (3) Energy-efficient circulating pump	1.0	0.9	0.7	0.5	0.3
					□Conventional gas water heater	□(1) a + (2) a	□(1) a + (2) c □(1) b + (2) b	□(1) b + (2) c □(1) b + (2) c + (3)	□(1) c + (2) c □(1) c + (2) c + (3)
		Domestic hot water system planning (5.4)	Methods	(2)-1 Latent heat recovery water heater (2)-2 CO_2HP water heater (3) Piping method/hot water saving tools	1.0	0.9	0.8	—	0.6
					□Conventional gas water heater	□(2)-1 □(3)	□(2)-1 + (3) □(2)-2 (medium boiling mode)	—	□(2)-2 (energy-efficient mode) □(2)-2 (energy-efficient mode) + (3)
Lighting	13.6 GJ	Daylight utilization (3.2)	Conditions for daylighting	(1) Bi-directional daylighting for living/dining rooms (2) Bi-directional daylighting for living/dining/senior's rooms (3) Bi-directional daylighting for living/dining/senior's rooms + mono-directional daylighting for non-habitable room	1.0	0.97 - 0.98	0.95	0.9	
					□Conditions for daylighting meeting with Building Standard Law	Location 1 □ (3)	—	—	
						Location 2 □ (2)	□ (3)	—	
						Location 3 □ (1)	□ (2)	□ (3)	
		Lighting system planning (5.5)	Methods	(1) Method using device (2) Method using operation and control (3) Method using design	1.0	0.85	0.8	0.7	
					□Conventional models	□(1)	□(1) + (2)	□(1) + (2) + (3)	
Consumer electronics	21.4 GJ	Introduction of high-efficiency consumer electronics (5.6)	Guidelines for the year device was made		1.0	0.8	0.6		
					□Year 2000 regular model (0 kWh)	□Energy-efficient products (▲500 k/Wh)	□Energy-efficient products (▲1,000 kWh) + standby power consumption decrease		
Other uses (cooking)	4.4 GJ				1.0				
					□Cooking device				
Total	66.6 GJ 66.3 GJ								
Electricity		Photovoltaic power generation (3.3)	(Naha) Solar cell capacity		No reduction	33.7 GJ reduction	45.0 GJ reduction		
					□Not to be introduced	□Approx. 3 kW	□Approx. 4 kW		

* Numbers in parentheses under each elemental technology indicate which section of Chapter 3, 4 or 5 describes it.

■Attached Table 1-2: Energy consumption calculation table (for Zone VI)

Use	Calculation formulas	Design value	Reference value	Reduction rate
Cooling	10.3 × (☐ × ☐ × ☐)	GJ	10.3J	
Ventilation	3.1 × ☐ (2.8)	GJ	3.1GJ (2.8GJ)	
Domestic hot water	13.8 × ☐ (Solar water heating or Domestic hot water system planning)	GJ	13.8GJ	
Lighting	13.6 × (☐ × ☐)	GJ	13.6GJ	
Consumer electronics	21.4 × ☐	GJ	21.4GJ	
Other uses (cooking)	4.4 × ☐	GJ	4.4GJ	
Subtotal		GJ	66.6GJ (66.3GJ)	
Electricity (reduction amount)	Power generation with solar cell (☐ 0.0 GJ ☐ 33.7 GJ ☐ 45.0 GJ)	▲ GJ		
Total		GJ	66.6GJ (66.3GJ)	

【Notes】

1. Common

(1) Reference energy consumption indicates rough estimate of annual energy consumption at reinforced concrete single-storey house for family of four located in Zone VI.

(2) Energy consumption ratio indicates energy consumption at each level when reference consumption is 0.

(3) Areas indicated by slash show that level is not set or no methods are applicable.

(4) Check off applicable method for each elemental technology and circle value of energy consumption ratio.

(5) Among elemental technologies, " 5.7 Treatment and Efficient Use of Water and Kitchen Waste " effective for water saving is exempt from estimation methods.

2. Cooling-related

(1) As for " Use and control of wind " , after selecting site conditions and outside wind speed, determine level from 1), 2) and 3) according to method used. Site conditions are classified into following two based on building coverage ratio of adjacent area (building coverage ratio of area with diameter of 50 m surrounding planned building).

Location 1: Urban location (building coverage ratio of adjacent area is over 20%)

Location 2: Suburban location (building coverage ratio of adjacent area is 20% or below)

(2) As for " Solar shading method " , after selecting site conditions and the class of outside shading device, determine level, either 1) or 2), according to method used. Site conditions are classified into following three based on horizontal distance to adjacent building in each direction.

Location 1: North and south – within 6 m; East and west – within 3 m

Location 2: North and south – over 6 m and within 10 m; East and west – over 3 m and within 6 m

Location 3: All directions – over 10 m

Outside shading device class is divided into following three according to setting of the overhang in each direction (distance between window and overhang: Y1, window height: Y2, projection of overhang: Z, block with decorative openings). (As for distance between window and overhang, only north direction of class 1 is Y1 = 0, and others are Y1≤400.)

Class 1: North - Y2~900, Z≥200; east - Y2≤1,300, Z≥600; south - Y2≤2,000, Z≥1,000; west - Y2≤1,300, Z≥1,000

Class 2: North - Y2~900, Z≥600; east - Y2~1,300, Z≥1,000; south - Y2≤2,000, Z≥1,500; west - Y2≤1,300, Z≥1,500

Class 3: North - Y2~900, Z≥600; east - Y2≤1,300, Z≥1,000; south - Y2≤2,000, Z≥1,500; west - Y2≤1,300, Z≥1,500, block with decorative openings)

(3) For "Cooling system planning", determine level according to which method is applied out of 1) and 2).

3. Ventilation-related

For "Ventilation system planning", determine level according to applied method after selecting ventilation system (duct system, through-the-wall system).

4. Domestic-hot-water-related

(1) For "Solar water heating", determine level according to which method is applied out of 1), 2) and 3).

(2) For "Domestic hot water system planning", determine level according to which method is applied out of 2) and 3).

5. Lighting-related

(1) For "Daylight utilization", determine level according to daylighting conditions of room after selecting site conditions. As for daylighting conditions, "LD" refers to living and dining rooms, "S/C" refers to seniors'/children's rooms, and "non-habitable room" refers to kitchen, hallway, entrance, washing room, bathroom and toilet. Site conditions are classified into following three.

Location 1: Location where sunlight utilization is difficult due to surrounding high-rise, dense buildings

Location 2: Location where creative measures are required for sunlight utilization due to dense surrounding buildings

Location 3: Suburban location where sunlight utilization is easy

(2) For "Lighting system planning", please determine level according to which method is applied out of 1), 2) and 3).

6. Consumer-electronics-related

For "Introduction of high-efficiency consumer electronics", determine level according to manufacturing year or annual electricity consumption reduction (assuming products that were owned around year 2000 as standard) of prime consumer electronics (refrigerator, television) and priority consumer electronics (hot water heated toilet seat, electric hot water pot, washing machine).

7. Other uses (cooking)

Since target cooking energy consumption does not vary significantly by device, use the reference value, 4.4 GJ.

8. Electricity-related

When "Photovoltaic power generation" is adopted, select reduction (power generation) of primary energy consumption estimated based on region and solar cell capacity. Quick reference shows reduction in Naha (For reduction in other regions, see 3.3 on p.085).

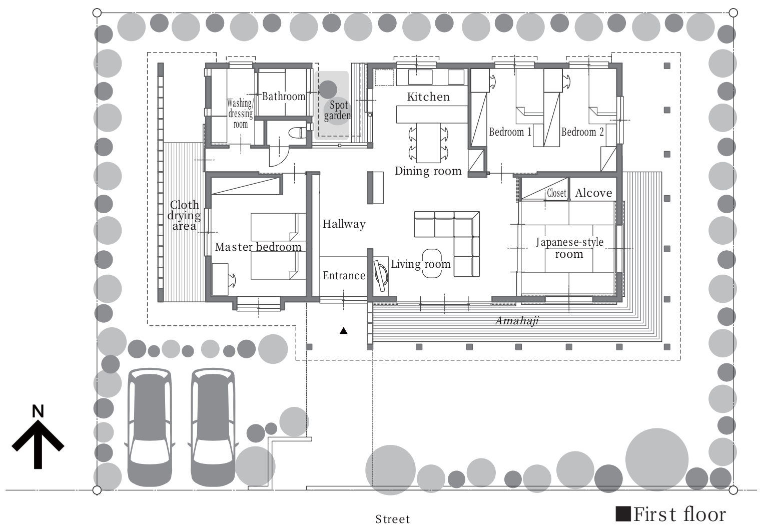
9. Description in calculation table

(1) In calculation formula column, write down energy consumption ratio of each elemental technology determined in quick reference. Energy consumption design value and reduction rate can be calculated for each use.

(2) In total section, write down total of energy consumption design values, from cooling to other uses (cooking). In grand total section, write down grand total of design values obtained by subtracting electricity reduction through photovoltaic power generation.

[Zone VI: Design calculation example 1]

◆Building outline



■First floor plan view

■Design specifications
Structure: Reinforced concrete
Number of stories: One-story house
Site area: 432.0 m² (4,650 ft2)
Building area: 185.5 m² (1,996.7 ft2)
Total floor area: 145.3 m² (1,564 ft2)
Family structure: Husband and wife with two children

◆Design process outline

Design procedure I Understanding given conditions and required conditions	Site is located in suburb of Naha. Density of surrounding buildings is low, which makes it highly possible to use natural energy. With regard to occupant's awareness, "level of dedication to natural living" is high while "level of dedication to a stable indoor environment" is low. Occupant seeks traditional nature-oriented lifestyle or nature-oriented lifestyle.
▼	
Design procedure II Setting design goals and policies	Maximize measures for architectural techniques (natural energy application technology, heat control technology of building envelope). Aim to introduce highly efficient devices with regard to mechanical techniques (energy-efficient equipment technology) in certain areas (domestic hot water, consumer electronics). Through above-mentioned efforts, strive to achieve energy reduction rate of approx. 30%.
▼	
Design procedure III Creating design model	Reinforced concrete single-storey building has structure where three rooms are located in direction of south-facing frontage. Make connection of rooms as open as possible. As for outside perimeter, place deep overhangs on south and east sides and block with decorative openings on west side.
(Application of main elemental technologies)	● Use and control of wind / Level 3 Condition Location 2: Suburban location (building coverage ratio of adjacent area is 20% or below), outside wind speed of 2 m/s or higher in summer Method applied Use combination of patio doors and waist-level windows for exterior opening, and apply method 1a (combination of small opening areas). In addition, place one surface of opening in prevailing wind direction and adopt method 2. ● Solar shading method / Level 4 Condition Location 3: Horizontal distance to adjacent buildings, etc., is over 10 m Method applied Outside shading device class 3: place over 1,500 mm deep overhangs on south and east sides and block with decorative openings on west side. Solar shading measures for envelope: coat roof surface with finishing material that offers 0.7 or higher solar reflectance (since maintenance of roof surface is relatively easy because it is single-storey building). (M value: 0.096) ● Daylight utilization / Level 3 Condition Location 3: Location where sunlight utilization is easy Method applied Ensure bi-directional daylighting for living and dining rooms, seniors'room (Japanese-style room assumed) and children's room and mono-directional daylighting for secondary rooms (daylighting condition 3 achieved).
▼	
Design procedure IV Analyze design model and verify effects	Energy efficiency: approx. 32% Cost: Number of years for recovery – approx. 9.4 years (cooling, ventilation, domestic hot water, lighting)

◆Verification of energy efficiency

■Attached Table 1-1: Quick reference for energy consumption ratio of elemental technology (for Zone VI) – Case 1

Use	Energy reference consumption	Elemental technology*	Evaluation index/method		Energy consumption ratio (reference consumption is 1.0)				
					Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	10.3 GJ	Wind utilization/control (3.1)	Methods	(1) Opening area on cross ventilation route a: small, b: large (2) Opening area according to prevailing wind direction (3) High window a: small, b: large	1.0	0.96	0.91	0.88	
			Location 1	Wind speed 1m/s or more	☐Method not introduced	☐(1) a, (3) a	☐(1) b, (3) b	—	
			Location 2	Wind speed 1m/s or less	☐Method not introduced ☐(1) a, (3) a	☐(1) a + (2), (3) a + (2) ☐(1) b, (3) b	☐(1) b + (2) ☐(3) b + (2)	—	
				Wind speed 1 - 2m/s or less	☐Method not introduced	—	☐(1) a, (3) a ☐(1) a + (2), (3) a + (2)	☐(1) b, (3) b ☐(1) b + (2), (3) b + (2)	
				Wind speed 2m/s or more	☐Method not introduced	—	☐(1) a, (3) a	☑(1) a + (2), (3) a + (2) ☐(1) b, (3) b ☐(1) b + (2), (3) b + (2)	
		Solar shading method (4.2)	Methods	(1) Outside shading device (2) Envelope a: cavity ventilation, b: insulation, c: reflection	1.0	0.9	0.8	0.75	0.7
			Location 1	(1) Class 0	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation	☐(2) c: Reflection
				(1) Class 1 Class 2	☐No measures	☐(2) a: Cavity ventilation	—	—	☐(2) b: Insulation ☐(2) c: Reflection
				(1) Class 3	—	☐No measures	☐(2) a: Cavity ventilation		☐(2) b: Insulation ☐(2) c: Reflection
			Location 2	(1) Class 0	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation ☐(2) c: Reflection	—
				(1) Class 1	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation	☐(2) c: Reflection
				(1) Class 2 Class 3	—	☐No measures	☐(2) a: Cavity ventilation		☐(2) b: Insulation ☐(2) c: Reflection
			Location 3	(1) Class 0	☐No measures	☐(2) a: Cavity ventilation	☐(2) b: Insulation ☐(2) c: Reflection	—	—
				(1) Class 1	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation ☐(2) c: Reflection	—
				(1) Class 2	☐No measures	☐(2) a: Cavity ventilation	—	—	☐(2) b: Insulation ☐(2) c: Reflection
				(1) Class 3	☐No measures	☐(2) a: Cavity ventilation	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation ☑(2) c: Reflection
		Cooling system planning (5.1)	Methods	(1) High-efficiency air conditioner (COP) (2) Use of fan/ceiling fan	1.0	0.9	0.8	0.75	0.65
					☐COP3	☐COP4	☐COP3 + (2) ☐COP5	☑COP4 + (2)	☐COP5 + (2)
Ventilation	3.1 GJ	Ventilation system planning (5.3)	Duct ventilation	(1) Duct pressure loss decrease (2) High-efficiency device	1.0	0.7	0.5		
					☐Method not introduced	☑(1)	☐(1) + (2)		
	2.8 GJ		Through-the-wall ventilation	(1) Optimizing the combination of fan and outside air unit	1.0	0.8			
					☐Method not introduced	☐(1)			
Domestic hot water	13.8 GJ	Solar water heating (3.5)	Methods	(1) Heat collection area a: small, b: medium, c: large (2) Connection to auxiliary heat source a: none, b: three-way valve, c: solar connection unit (3) Energy-efficient circulating pump	1.0	0.9	0.7	0.5	0.3
					☐Conventional gas water heater	☐(1) a + (2) a	☐(1) a + (2) c ☐(1) b + (2) b	☐(1) b + (2) c ☐(1) b + (2) c + (3)	☐(1) c + (2) c ☐(1) c + (2) c + (3)
		Domestic hot water system planning (5.4)	Methods	(2)-1 Latent heat recovery water heater (2)-2 CO_2HP water heater (3) Piping method/hot water saving tools	1.0	0.9	0.8	—	0.6
					☐Conventional gas water heater	☐(2)-1 ☐(3)	☑(2)-1 + (3) ☐(2)-2 (medium boiling mode)	—	☐(2)-2 (energy-efficient mode) ☐(2)-2 (energy-efficient mode) + (3)
Lighting	13.6 GJ	Daylight utilization (3.2)	Conditions for daylighting	(1) Bi-directional daylighting for living/dining rooms (2) Bi-directional daylighting for living/dining/senior's rooms (3) Bi-directional daylighting for living/dining/senior's rooms + mono-directional daylighting for non-habitable room	1.0	0.97 - 0.98	0.95	0.9	
					☐Conditions for daylighting meeting with Building Standard Law	Location 1 ☐ (3)	—	—	
						Location 2 ☐ (2)	☐ (3)	—	
						Location 3 ☐ (1)	☐ (2)	☑ (3)	
		Lighting system planning (5.5)	Methods	(1) Method using device (2) Method using operation and control (3) Method using design	1.0	0.85	0.8	0.7	
					☐Conventional models	☐(1)	☑(1) + (2)	☐(1) + (2) + (3)	
Consumer electronics	21.4 GJ	Introduction of high-efficiency consumer electronics (5.6)	Guidelines for the year device was made		1.0	0.8	0.6		
					☐Year 2000 regular model (0 kWh)	☐Energy-efficient products (▲500 k/Wh)	☑Energy-efficient products (▲1,000 kWh) + standby power consumption decrease		
Other uses (cooking)	4.4 GJ				1.0				
					☑Cooking device				
Total	66.6 GJ								
	66.3 GJ								

Electricity		Photovoltaic power generation (3.3)	(Naha)	No reduction	33.7 GJ reduction	45.0 GJ reduction		
			Solar cell capacity	☑Not to be introduced	☐Approx. 3 kW	☐Approx. 4 kW		

* Numbers in parentheses under each elemental technology indicate which section of Chapter 3, 4 or 5 describes it.

■Attached Table 1-2: Energy consumption calculation table (for Zone VI) – Case 1

Use	Calculation formulas	Design value	Reference value	Reduction rate
Cooling	10.3 × (0.88 × 0.70 × 0.75)	4.76GJ	10.3GJ	53.8%
Ventilation	3.1 × 0.70	2.17GJ	3.1GJ	30.0%
Domestic hot water	13.8 × 0.80 (Solar water heating or Domestic hot water system planning)	11.04GJ	13.8GJ	20.0%
Lighting	13.6 × (0.90 × 0.80)	9.79GJ	13.6GJ	28.0%
Consumer electronics	21.4 × 0.60	12.84GJ	21.4GJ	40.0%
Other uses (cooking)	4.4 × 1.0	4.4GJ	4.4GJ	0.0%
Subtotal		45.0GJ	66.6GJ	32.4%
Electricity (reduction amount)	Power generation with solar cell (☑ 0.0 GJ ☐ 33.7 GJ ☐ 45.0 GJ)	▲ 0.0GJ		
Total		45.0GJ	66.6GJ	32.4%

・Energy performance (annual primary energy consumption reduction rate) is approx. 32.4%.

◆Verification of cost

・With regard to each elemental technology and method applied, mainly estimate the initial cost and annual energy cost of equipment. As for use of wind, solar shading method, daylight utilization and consumer electronics, their verification is not included as evaluating increases in initial cost is difficult.

・Based on the results of cost evaluation listed in Table 11 and Table 12, the table below shows the increase in initial cost and the decrease in annual energy cost in each energy use while considering standard housing around 2000 as a basis. In this case, the number of years (simple payback time) required for recovering the increase in initial cost through the reduction of energy cost is approx. 9.4 years.

・Initial cost increase: approx. 348,000 yen

・Annual energy cost reduction: approx. 37,000 yen per year

・Number of years for recovery (simple payback time)

= Initial cost increase (yen) / annual energy cost reduction (yen per year)

= 348,000 yen / 37,000 yen per year

= 9.4 years

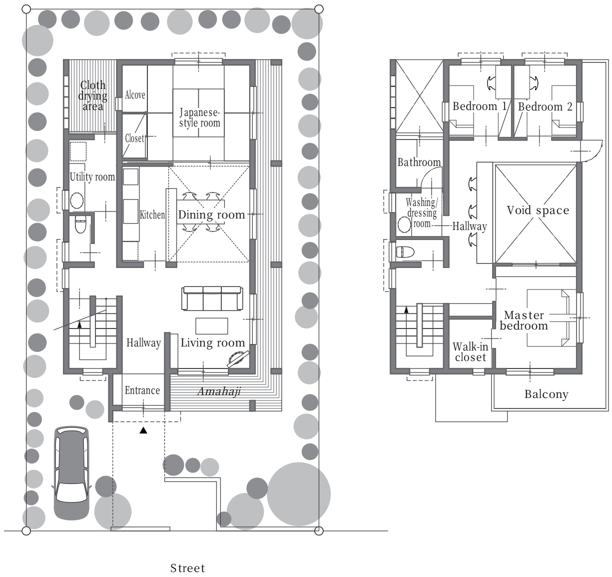
Initial cost and energy cost increase and decrease (Case 1)

Application	Initial cost increase	Annual energy cost reduction
Cooling Level 3	56,000 yen	7,000 yen/year
Ventilation Level 1	1,000 yen	3,000 yen/year
Domestic hot water Level 2	118,000 yen	20,000 yen/year
Lighting Level 2	173,000 yen	7,000 yen/year
Total	348,000 yen	37,000 yen/year

[Zone VI: Design calculation example 2]

◆Building outline

■Design specifications
Structure: Reinforced concrete
Number of stories: Two-story house
• Lot area: 215.6 m² (2,320.7 ft2)
• Building area: 102.3 m² (1,101.1 ft2)
• Total floor area: 147.8 m² (1,590.9 ft2)
Family structure: Husband and wife with two children



◆Design process outline

Design procedure I
Understanding given conditions and required conditions

Site is located in downtown of Naha. Density of surrounding buildings is relatively high, which makes it necessary to take creative measures when it comes to use of natural energy.
With regard to occupant's awareness, "level of dedication to natural living" is slightly high while "level of dedication to a stable indoor environment" is moderate. Occupant seeks nature-oriented lifestyle or machine-oriented lifestyle.

Design procedure II
Setting design goals and policies

Implement measures for architectural techniques (natural energy application technology, heat control technology of building envelope) as far as possible. As for solar shading, make as much effort as possible while taking shading effect by surrounding buildings into consideration.
Aim to introduce highly efficient devices as much as possible with regard to mechanical techniques (energy-efficient equipment technology).
Through above-mentioned efforts, strive to achieve energy reduction rate of approx. 40%.

Design procedure III
Creating design model

It is reinforced concrete two-storey building. Due to shape of site, the building has narrow south-facing frontage and greater depth.
Create void space at center so that continuity of first and second floors will be enhanced. Create high window at top of void space to promote cross ventilation and daylight utilization in dense residential area.

(Application of main elemental technologies)

● Use and control of wind / Level 1
Condition Location 1: Urban location (building coverage ratio of adjacent area is over 20%), outside wind speed of 1 m/s or higher in summer
Method applied Use combination of patio doors and waist-level windows for exterior opening, and apply method 1a (combination of small opening areas). (In addition, place top side window as high window, at top of void space and adopt method 3a.)
● Solar shading method / Level 2
Condition Location 1: Horizontal distance to adjacent buildings, etc., is 6 m or 3 m .
Method applied Outside shading device class 1: place over 1,000 mm deep overhangs on south and east sides. Solar shading measures for envelope: place spreading block on roof to secure ventilated cavity on roof (M value: 0.095).
● Daylight utilization / Level 2
Condition Location 2: Location where creative measures are required for sunlight utilization
Method applied Ensure bi-directional daylighting for living and dining rooms, seniors' room (Japanese-style room assumed) and children's room and mono-directional daylighting for non-habitable rooms (daylighting condition 3 achieved).

Design procedure IV
Analyze design model and verify effects

Energy efficiency: approx. 38%
Cost: Number of years for recovery – approx. 10.6 years (cooling, ventilation, domestic hot water, lighting)

◆Verification of energy efficiency

■Attached Table 1-1: Quick reference for energy consumption ratio of elemental technology (for Zone VI) – Case

Use	Reference energy consumption	Elemental technology*	Evaluation index/method		Energy consumption ratio (reference consumption is 1.0)				
					Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	10.3 GJ	Wind utilization/control (3.1)	Methods	(1) Opening area on cross ventilation route a: small, b: large (2) Opening area according to prevailing wind direction (3) High window a: small, b: large	1.0	0.96	0.91	0.88	
			Location 1	Wind speed 1m/s or more	☐Method not introduced	☑(1) a, (3) a	☐(1) b, (3) b	—	
			Location 2	Wind speed 1m/s or less	☐Method not introduced ☐(1) a, (3) a	☐(1) a + (2), (3) a + (2) ☐(1) b, (3) b	☐(1) b + (2) ☐(3) b + (2)	—	
				Wind speed 1 - 2m/s or less	☐Method not introduced	—	☐(1) a, (3) a ☐(1) a + (2), (3) a + (2)	☐(1) b, (3) b ☐(1) b + (2), (3) b + (2)	
				Wind speed 2m/s or more	☐Method not introduced	—	☐(1) a, (3) a	☐(1) a + (2), (3) a + (2) ☐(1) b, (3) b ☐(1) b + (2), (3) b + (2)	
		Solar shading method (4.2)	Methods	(1) Outside shading device (2) Envelope a: cavity ventilation, b: insulation, c: reflection	1.0	0.9	0.8	0.75	0.7
			Location 1	(1) Class 0	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation	☐(2) c: Reflection
				(1) Class 1 Class 2	☐No measures	☐(2) a: Cavity ventilation	—	—	☐(2) b: Insulation ☐(2) c: Reflection
				(1) Class 3	—	☐No measures	☑(2) a: Cavity ventilation		☐(2) b: Insulation ☐(2) c: Reflection
			Location 2	(1) Class 0	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation ☐(2) c: Reflection	—
				(1) Class 1	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation	☐(2) c: Reflection
				(1) Class 2 Class 3	—	☐No measures	☐(2) a: Cavity ventilation		☐(2) b: Insulation ☐(2) c: Reflection
			Location 3	(1) Class 0	☐No measures	☐(2) a: Cavity ventilation	☐(2) b: Insulation ☐(2) c: Reflection	—	—
				(1) Class 1	☐No measures	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation ☐(2) c: Reflection	—
				(1) Class 2	☐No measures	☐(2) a: Cavity ventilation	—	—	☐(2) b: Insulation ☐(2) c: Reflection
				(1) Class 3	☐No measures	☐(2) a: Cavity ventilation	☐(2) a: Cavity ventilation	—	☐(2) b: Insulation ☐(2) c: Reflection
		Cooling system planning (5.1)	Methods	(1) High-efficiency air conditioner (COP) (2) Use of fan/ceiling fan	1.0	0.9	0.8	0.75	0.65
					☐COP3	☐COP4	☐COP3 + (2) ☐COP5	☐COP4 + (2)	☑COP5 + (2)
Ventilation	3.1 GJ	Ventilation system planning (5.3)	Duct ventilation	(1) Duct pressure loss decrease (2) High-efficiency device	1.0	0.7	0.5		
					☐Method not introduced	☐(1)	☑(1) + (2)		
	2.8 GJ		Through-the-wall ventilation	(1) Optimizing the combination of fan and outside air unit	1.0	0.8			
					☐Method not introduced	☐(1)			
Domestic hot water	13.8 GJ	Solar water heating (3.5)	Methods	(1) Heat collection area a: small, b: medium, c: large (2) Connection to auxiliary heat source a: none, b: three-way valve, c: solar connection unit (3) Energy-efficient circulating pump	1.0	0.9	0.7	0.5	0.3
					☐Conventional gas water heater	☐(1) a + (2) a	☐(1) a + (2) c ☐(1) b + (2) b	☐(1) b + (2) c ☐(1) b + (2) c + (3)	☐(1) c + (2) c ☐(1) c + (2) c + (3)
		Domestic hot water system planning (5.4)	Methods	(2)-1 Latent heat recovery water heater (2)-2 CO_2HP water heater (3) Piping method/hot water saving tools	1.0	0.9	0.8	—	0.6
					☐Conventional gas water heater	☐(2)-1 ☐(3)	☐(2)-1 + (3) ☐(2)-2 (medium boiling mode)	—	☐(2)-2 (energy-efficient mode) ☑(2)-2 (energy-efficient mode) + (3)
Lighting	13.6 GJ	Daylight utilization (3.2)	Conditions for daylighting	(1) Bi-directional daylighting for living/dining rooms (2) Bi-directional daylighting for living/dining/senior's rooms (3) Bi-directional daylighting for living/dining/senior's rooms + mono-directional daylighting for non-habitable room	1.0	0.97 - 0.98	0.95	0.9	
					☐Conditions for daylighting meeting with Building Standard Law	Location 1 ☐ (3)	—	—	
						Location 2 ☐ (2)	☑ (3)	—	
						Location 3 ☐ (1)	☐ (2)	☐ (3)	
		Lighting system planning (5.5)	Methods	(1) Method using device (2) Method using operation and control (3) Method using design	1.0	0.85	0.8	0.7	
					☐Conventional models	☐(1)	☐(1) + (2)	☑(1) + (2) + (3)	
Consumer electronics	21.4 GJ	Introduction of high-efficiency consumer electronics (5.6)	Guidelines for the year device was made		1.0	0.8	0.6		
					☐Year 2000 regular model (0 kWh)	☐Energy-efficient products (▲500 k/Wh)	☑Energy-efficient products (▲1,000 kWh) + standby power consumption decrease		
Other uses (cooking)	4.4 GJ				1.0				
					☑Cooking device				
Total	66.6 GJ 66.3 GJ								
Electricity		Photovoltaic power generation (3.3)	(Naha) Solar cell capacity		No reduction	33.7 GJ reduction	45.0 GJ reduction		
					☑Not to be introduced	☐Approx. 3 kW	☐Approx. 4 kW		

* Numbers in parentheses under each elemental technology indicate which section of Chapter 3, 4 or 5 describes it.

■Attached Table 1-2: Energy consumption calculation table (for Zone VI) – Case 2

Use	Calculation formulas	Design value	Reference value	Reduction rate
Cooling	10.3 × (0.96 × 0.8 × 0.65)	5.14GJ	10.3GJ	50.1%
Ventilation	3.1 × 0.5	1.55GJ	3.1GJ	50.0%
Domestic hot water	13.8 × 0.5 (Solar water heating or Domestic hot water system planning)	6.9GJ	13.8GJ	50.0%
Lighting	13.6 × (0.95 × 0.7)	9.04GJ	13.6GJ	33.5%
Consumer electronics	21.4 × 0.6	12.84GJ	21.4GJ	40.0%
Other uses (cooking)	4.4 × 1.0	4.4GJ	4.4GJ	0.0%
Subtotal		39.9GJ	66.6GJ	40.1%
Electricity (reduction amount)	Power generation with solar cell (☑ 0.0 GJ ☐ 33.7 GJ ☐ 45.0 GJ)	▲ 0.0GJ		
Total		39.9GJ	66.6GJ	40.1%

・Energy performance (annual primary energy consumption reduction rate) is approx. 38.0%.

◆Verification of cost

- With regard to each elemental technology and method applied, mainly estimate the initial cost and annual energy cost of equipment. As for use of wind, solar shading method, daylight utilization and consumer electronics, their verification is not included as evaluating increases in initial cost is difficult.
- Based on the results of cost evaluation listed in Table 11 and Table 12, the table below shows the increase in initial cost and the decrease in annual energy cost in each energy use while considering standard housing around 2000 as a basis. In this case, the number of years (simple payback time) required for recovering the increase in initial cost through the reduction of energy cost is approx. 10.6 years.
- Initial cost increase: approx. 1,050,000 yen
- Annual energy cost reduction: approx. 99,000 yen per year
- Number of years for recovery (simple payback time)

  = Initial cost increase (yen) / annual energy cost reduction (yen per year)

  = 1,050,000 yen / 99,000 yen per year

  = 10.6 years

Increase and decrease in initial cost and energy cost (Case 2)

Application	Initial cost increase	Annual energy cost reduction
Cooling Level 4	203,000 yen	9,000 yen/year
Ventilation Level 2	89,000 yen	4,000 yen/year
Domestic hot water Level 4	490,000 yen	76,000 yen/year
Lighting Level 3	268,000 yen	10,000 yen/year
Total	1,050,000 yen	99,000 yen/year

6.3.3 Energy Consumption Estimation Methods and Design Calculation Examples in Zone V

■Attached Table 2-1: Quick reference for energy consumption ratio of elemental technology (for Zone V / in the case of partial intermittent heating and cooling)

Use	Reference energy consumption	Elemental technology*	Evaluation index/method		Energy consumption ratio (reference consumption is 1.0)				
					Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	5.7 GJ	Wind utilization/control (3.1)	Methods	(1) Opening area on cross ventilation route a: small, b: large (2) Opening area according to prevailing wind direction (3) High window a: small, b: large	1.0	0.95	0.88	0.82	
			Location 1	Wind speed 1m/s or more	☐Method not introduced	☐ (1) a, (3) a	☐ (1) b, (3) b	—	
			Location 2	Wind speed 1m/s or less	☐ Method not introduced ☐ (1) a, (3) a	☐ (1) a + (2), (3) a + (2) ☐ (1) b, (3) b	☐ (1) b + (2) ☐ (3) b + (2)	—	
				Wind speed 1 - 2m/s or less	☐ Method not introduced	—	☐ (1) a, (3) a ☐ (1) a + (2), (3) a + (2)	☐ (1) b, (3) b ☐ (1) b + (2), (3) b + (2)	
				Wind speed 2m/s or more	☐ Method not introduced	—	☐ (1) a, (3) a	☐ (1) a + (2), (3) a + (2) ☐ (1) b, (3) b ☐ (1) b + (2), (3) b + (2)	
		Solar shading method (4.3)	Direction of main opening surface	South	1.0	0.85	0.7	0.55	
				Southeast or southwest	1.3	0.8	0.75	0.65	
				East or west	1.1	0.8	0.75	0.65	
			Solar penetration rate of opening	True north ±30° Other than the above °	☐ Approx. 0.79	☐ 0.79 or less	☐ 0.55 or less	☐ 0.55 or less	
					☐ Approx. 0.79	☐ 0.60 or less	☐ 0.45 or less	☐ 0.30 or less	
		Heating and cooling system planning (cooling) (5.2)	Air conditioner	(1) High-efficiency air conditioner (ratedefficiency) (2) Adjustment of device capacity (3) Use of fan/ceiling fan	1.0	0.95	0.85	0.75	0.65
			Other habitable rooms: Class 0	☐ (1) (<3.8) ☐ (1) (<3.7) + (2) ☐ (1) (<3.3) + (3) ☐ (1) (<3.2) + (2) + (3)	LDK: Class 0 ☐ (1) (<3.5) ☐ (1) (<3.0) + (3)	LDK: Class 1 ☐ (1) (≧3.5) ☐ (1) (≧3.0) + (3)	LDK: Class 3 ☐ (1) (≧5.6) ☐ (1) (≧3.7) + (2) ☐ (1) (≧4.9) + (3) ☐ (1) (≧3.2) + (2) + (3)	LDK: Class 5 ☐ (1) (≧5.3) + (2) ☐ (1) (≧4.9) + (2) + (3)	
			Other habitable rooms: Class 1	☐ (1) (≧3.8) ☐ (1) (≧3.7) + (2) ☐ (1) (≧3.3) + (3) ☐ (1) (≧3.2) + (2) + (3)	—	LDK: Class 0 ☐ (1) (<3.5) ☐ (1) (<3.0) + (3)	LDK: Class 2 ☐ (1) (≧4.3) ☐ (1) (<3.7) + (2) ☐ (1) (≧3.7) + (3) ☐ (1) (<3.2) + (2) + (3)	LDK: Class 4 ☐ (1) (≧4.4) + (2) ☐ (1) (≧3.9) + (2) + (3)	
			Other habitable rooms: Class 2	☐ (1) (≧5.1) ☐ (1) (≧4.9) + (2) ☐ (1) (≧5.0) + (3) ☐ (1) (≧4.8) + (2) + (3)	—	—	LDK: Class 1 ☐ (1) (≧3.5) ☐ (1) (≧3.0) + (3)	LDK: Class 3 ☐ (1) (≧5.6) ☐ (1) (≧3.7) + (2) ☐ (1) (≧4.9) + (3) ☐ (1) (≧3.2) + (2) + (3)	LDK: Class 5 ☐ (1) (≧5.3) + (2) ☐ (1) (≧4.9) + (2) + (3)
Heating	5.0 GJ	Insulated building envelope planning (4.1)	Energy conservation standard		1.0	0.7	0.5	0.45	0.35
					☐ 1980 Standard	☐ 1992 Standard	☐ Intermediate of 1992 and 1999 Standards	☐ 1999 Standard	☐ Exceeding 1999 Standard
		Solar radiation heat utilization (3.4)	Methods	(1) Improvement of opening insulation (2) Increase in heat collection area (3) Heat storage	1.0	0.95	0.9	0.8	0.6
			Zone E	Location 2 Direction 0 - 15°	☐ Method not introduced	—	☐ (1) + (2)	☐ (1) + (2) + (3)	
				Direction 15 - 30°		☐ (1) + (2)	☐ (1) + (2) + (3)		
				Location 3 Direction 0 - 15°	☐ Method not introduced	—	☐ (1), (2)	☐ (1) + (3)	☐ (1) + (2) ☐ (1) + (2) + (3)
				Direction 15 - 30°		—	☐ (1), (1) + (3)	☐ (1) + (2)	☐ (1) + (2) + (3)
			Zone D* Zone C*	Location 2 Direction 0 - 15°	☐ Method not introduced	—	☐ (1) + (2)		
				Direction 15 - 30°		☐ (1) + (2) ☐ (1) + (2) + (3)			
				Location 3 Direction 0 - 15°	☐ Method not introduced	☐ (2)	☐ (1), (1) + (3)	☐ (1) + (2)	☐ (1) + (2) + (3)
				Direction 15 - 30°		—	☐ (1), (1) + (3)	☐ (1) + (2) ☐ (1) + (2) + (3)	
		Heating and cooling system planning (heating) (5.2)	Air conditioner (LDK)	(1) High-efficiency air conditioner (rated efficiency) (2) Adjustment of device capacity	1.0	0.95	0.85	0.75	0.7
					☐ (1) (<4.9)	☐ (1) + (≧4.9) ☐ (1) (<4.0) + (2)	☐ (1) (≧4.0) + (2)	☐ (1) (≧5.3) + (2)	☐ (1) (≧6.2) + (2)
Ventilation	3.1 GJ	Ventilation system planning (5.3)	Duct ventilation	(1) Duct pressure loss decrease (2) High-efficiency device	1.0	0.6	0.5		
					☐ Method not introduced	☐ (1)	☐ (1) + (2)		
	1.0 GJ		Through-the-wall ventilation	(1) Optimizing the combination of fan and outside air unit	1.0	0.8			
					☐ Method not introduced	☐ (1)			
Domestic hot water	19.2 GJ	Solar water heating (3.5)	Methods	(1) Heat collection area a: small, b: medium, c: large (2) Connection to auxiliary heat source a: none, b: three-way valve, c: solar connection unit (3) Energy-efficient circulating pump	1.0	0.9	0.7	0.5	0.3
					☐ Conventional gas water heater	☐ (1) a + (2) a	☐ (1) a + (2) c ☐ (1) b + (2) b	☐ (1) b + (2) c ☐ (1) b + (2) c + (3)	☐ (1) c + (2) c ☐ (1) c + (2) c + (3)
		Domestic hot water system planning (5.4)	Methods	(2)-1 Latent heat recovery water heater (2)-2 CO_2HP water heater (3) Piping method/hot water saving tools	1.0	0.9	0.8	0.7	0.6
					☐ Conventional gas water heater	☐ (2)-1 ☐ (2)-2 (medium boiling mode) ☐ (3)	☐ (2)-1 + (3)	☐ (2)-2 (energy-efficient mode)	☐ (2)-2 (energy-efficient mode) + (3)
Lighting	11.3 GJ	Daylight utilization (3.2)	Conditions for daylighting	(1) Bi-directional daylighting for living/dining rooms (2) Bi-directional daylighting for living/dining/senior's rooms (3) Bi-directional daylighting for living/dining/senior's rooms + mono-directional daylighting for non-habitable room	1.0	0.97-0.98	0.95	0.9	
					☐ Conditions for daylighting meeting with the Building Standard Law	Location 1 ☐ (3)	—	—	
						Location 2 ☐ (2)	☐ (3)	—	
						Location 3 ☐ (1)	☐ (2)	☐ (3)	
		Lighting system planning (5.5)	Methods	(1) Method using device (2) Method using operation and control (3) Method using design	1.0	0.7	0.6	0.5	
					☐ Conventional models	☐ (1)	☐ (1) + (2)	☐ (1) + (2) + (3)	
Consumer electronics	19.9 GJ	Introduction of high-efficiency consumer electronics (5.6)	Guidelines for the year device was made		1.0	0.8	0.6		
					☐ Year 2000 regular model (0 kWh)	☐ Energy-efficient products (−500 k/Wh)	☐ Energy-efficient products (−1,000 kWh) + standby power consumption decrease		
Other uses (cooking)	4.4 GJ	—	—		1.0 ☐ Cooking device				
Total	68.6 GJ / 66.5 GJ	—	—						

Electricity		Photovoltaic power generation (3.3)	(Kagoshima)	No reduction	32.7 GJ reduction	43.6 GJ reduction		
			Solar cell capacity	☐ Not to be introduced	☐ Approx. 3 kW	☐ Approx. 4 kW		

* Numbers in parentheses under each elemental technology indicate which section of Chapter 3, 4 or 5 describes it.

■ Attached Table 2-2: Energy consumption calculation table (for Zone V / in the case of partial intermittent heating and cooling)

Use	Calculation formulas	Design value	Reference value	Reduction rate
Cooling	5.7 × (☐ × ☐ × ☐)	GJ	5.7GJ	
Heating	5.0 × (☐ × ☐ × ☐)	GJ	5.0GJ	
Ventilation	3.1 (1.0) × ☐	GJ	3.1GJ (1.0GJ)	
Domestic hot water	19.2 × ☐ (Solar water heating or domestic hot water system)	GJ	19.2GJ	
Lighting	11.3 × (☐ × ☐)	GJ	11.3GJ	
Consumer electronics	19.9 × ☐	GJ	19.9GJ	
Other uses (cooking)	4.4 × ☐	GJ	4.4GJ	
Subtotal		GJ	68.6GJ (66.5GJ)	

Electricity (reduction amount)	Power generation with solar cell (☐ 0.0 GJ ☐ 32.7 GJ ☐ 43.6 GJ)	▲ GJ		
Total		GJ	68.6GJ (66.5GJ)	

【Notes】

1. Common

(1) Reference energy consumption indicates rough estimate of annual energy consumption at wooden single-storey house for family of four located in Zone V (in the case of partial intermittent heating and cooling system).
(2) Energy consumption ratio indicates energy consumption at each level when reference consumption is 1.0.
(3) Areas indicated by slash show that level is not set or no methods are applicable.
(4) Check"✓" off applicable method for each elemental technology and circle value of energy consumption ratio.
(5) Among elemental technologies, "5.7 Treatment and Efficient Use of Water and Kitchen Waste" effective for water saving is exempt from estimation methods.

2. Cooling-related

(1) As for "Use and control of wind", after selecting site conditions and outside wind speed, determine level from 1), 2) and 3) according to method used. Site conditions are classified into following two based on building coverage ratio of adjacent area (building coverage ratio of area with diameter of 50 m surrounding planned building).
Location 1: Urban location (building coverage ratio of adjacent area is over 20%)
Location 2: Suburban location (building coverage ratio of adjacent area is 20% or below)
(2) As for "Solar shading method", after selecting direction of main opening surface, determine level according to solar penetration rate of opening facing true north ±30° and other directions. Where there are multiple openings, determine level based on lowest solar penetration rate.
(3) For "Heating and cooling system planning" (cooling), determine level according to which method (class) is applied out of 1), 2) and 3). In this case, first select class of other habitable rooms (other than LDK), and then select LDK class. In addition, descriptions of following levels are omitted from attached table.
Level 2- (0.9): Other - class 0 + LDK - class 2, Other - class 1 + LDK - class 1, Other - class 2 + LDK - class 0
Level 3- (0.8): Other - class 0 + LDK - class 4, Other - class 1 + LDK - class 3, Other - class 2 + LDK - class 2
Level 4- (0.7): Other - class 1 + LDK - class 5, Other - class 2 + LDK - class 4

3. Heating-related

(1) As for "Insulated building envelope planning", select applicable insulation level by using existing energy conservation standard as guideline.
(2) As for "Use of solar radiation heat", insulated building envelope level must be 3 or higher. Determine level according to which method is applied out of 1), 2) and 3) after selecting PSP zone classification, site conditions and direction of heat collection opening (true south considered as basic 0°). Site conditions are classified into following two categories according to degree of obstruction of sunlight. *It is assumed that heating load is large in Zone D and Zone C (See Section 3.4 on p.094).
Location 2: Obstruction of sunlight is 25%
Location 3: Obstruction of sunlight is 0%
(3) "Heating and cooling system planning" (heating) targets LDK only. Determine level according to method applied, either 1) or 2).

4. Ventilation-related

For "Ventilation system planning", determine level according to applied method after selecting ventilation system (duct system, through-the-wall system).

5. Domestic-hot-water-related

(1) For "Solar water heating", determine level according to which method is applied out of 1), 2) and 3).
(2) For "Domestic hot water system planning", determine level according to which method is applied out of 2) and 3).

6. Lighting-related

(1) For "Daylight utilization", determine level according to daylighting conditions of room after selecting site conditions. As for daylighting conditions, "LD" refers to living and dining rooms, "S/C" refers to seniors'/children's rooms, and "non-habitable room" refers to kitchen, hallway, entrance, washing room, bathroom and toilet. Site conditions are classified into following three.
Location 1: Location where sunlight utilization is difficult due to surrounding high-rise, dense buildings
Location 2: Location where creative measures are required for sunlight utilization due to dense surrounding buildings
Location 3: Suburban location where sunlight utilization is easy
(2) For "Lighting system planning", please determine level according to which method is applied out of 1), 2) and 3).

7. Consumer-electronics-related

For "Introduction of high-efficiency consumer electronics", determine level according to manufacturing year or annual electricity consumption reduction (assuming products that were owned around year 2000 as standard) of prime consumer electronics (refrigerator, television) and priority consumer electronics (hot water heated toilet seat, electric hot water pot, washing machine).

8. Other uses (cooking)

Since target cooking energy consumption does not vary significantly by device, use the reference value, 4.4 GJ.

9. Electricity-related

When "Photovoltaic power generation" is adopted, select reduction (power generation) of primary energy consumption estimated based on region and solar cell capacity. Quick reference shows reduction in Kagoshima (For reduction in other regions, see Section 3.3 on p.085).

10. Description in calculation table

(1) In calculation formula column, write down energy consumption ratio of each elemental technology determined in quick reference. Energy consumption design value and reduction rate can be calculated for each use.
(2) In total section, write down total of energy consumption design values, from cooling to other uses (cooking). In grand total section, write down grand total of design values obtained by subtracting electricity reduction through photovoltaic power generation.

■Attached Table 3-1: Quick reference for energy consumption ratio of elemental technologies (for Zone V / in the case of whole-building continuous heating and cooling)

Use	Reference energy consumption	Elemental technology*	Evaluation index/method		Energy consumption ratio (reference consumption is 1.0) Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	27.1 GJ	Solar shading method (4.3)	Direction of main opening surface	South	1.0	0.85	0.7	0.55	
				Southeast or southwest	1.3	0.8	0.75	0.65	
				East or west	1.1	0.8	0.75	0.65	
			Solar penetration rate of opening	True north ±30°	☐ Approx. 0.79	☐ 0.79 or less	☐ 0.55 or less	☐ 0.55 or less	
				Other than the above	☐ Approx. 0.79	☐ 0.60 or less	☐ 0.45 or less	☐ 0.30 or less	
		Heating and cooling system planning (cooling) (5.2)	Methods	Central heating (1) High-efficiency device (2) Temperature control function added	1.0	0.75	0.6		
					☐ Method not introduced	☐ (1)	☐ (1) + (2)		
Heating	13.4 GJ	Insulated building envelope planning (4.1)	Energy conservation standard		1.0	0.6	0.5	0.4	0.3
					☐ 1980 Standard	☐ 1992 Standard	☐ Intermediate of 1992 and 1999 Standards	☐ 1999 Standard	☐ Exceeding 1999 Standard
		Solar radiation heat utilization (3.4)	Methods	(1) Improvement of opening insulation (2) Increase in heat collection area (3) Heat storage	1.0	0.95	0.85	0.75	0.65
			Zone E	Location 2 Direction 0 - 15°	☐ Method not introduced	—	☐ (1) + (2)	☐ (1) + (2) + (3)	
				Direction 15 - 30°		☐ (1) + (2)	☐ (1) + (2) + (3)		
				Location 3 Direction 0 - 15°	☐ Method not introduced	—	☐ (1), (2)	☐ (1) + (3)	☐ (1) + (2) ☐ (1) + (2) + (3)
				Direction 15 - 30°		—	☐ (1), (1) + (3)	☐ (1) + (2)	☐ (1) + (2) + (3)
			Zone D* Zone C*	Location 2 Direction 0 - 15°	☐ Method not introduced	—	☐ (1) + (2) ☐ (1) + (2) + (3)		
				Direction 15 - 30°		☐ (1) + (2) ☐ (1) + (2) + (3)			
				Location 3 Direction 0 - 15°	☐ Method not introduced	☐ (2)	☐ (1), (1) + (3)	☐ (1) + (2)	☐ (1) + (2) + (3)
				Direction 15 - 30°		—	☐ (1), (1) + (3)	☐ (1) + (2) ☐ (1) + (2) + (3)	
		Heating and cooling system planning (heating) (5.2)	Methods	Central cooling (1) High-efficiency device (2) Temperature control function added	1.0	0.8	0.55		
					☐ Method not introduced	☐ (1)	☐ (1) + (2)		
Ventilation	4.7 GJ	Ventilation system planning (5.3)	Duct ventilation	(1) Duct pressure loss decrease (2) High-efficiency device	1.0	0.6	0.5		
					☐ Method not introduced	☐ (1)	☐ (1) + (2)		
Domestic hot water	19.2 GJ	Solar water heating (3.5)	Methods	(1) Heat collection area a: small, b: medium, c: large (2) Connection to auxiliary heat source a: none, b: three-way valve, c: solar connection unit (3) Energy-efficient circulating pump	1.0	0.9	0.7	0.5	0.3
					☐ Conventional gas water heater	☐ (1) a + (2) a	☐ (1) a + (2) c ☐ (1) b + (2) b	☐ (1) b + (2) c ☐ (1) b + (2) c + (3)	☐ (1) c + (2) c ☐ (1) c + (2) c + (3)
		Domestic hot water system planning (5.4)	Methods	(2)-1 Latent heat recovery water heater (2)-2 CO_2HP water heater (3) Piping method/hot water saving tools	1.0	0.9	0.8	0.7	0.6
					☐ Conventional gas water heater	☐ (2)-1 ☐ (2)-2 (medium boiling mode) ☐ (3)	☐ (2)-1 + (3)	☐ (2)-2 (energy-efficient mode)	☐ (2)-2 (energy-efficient mode) + (3)
Lighting	11.3 GJ	Daylight utilization (3.2)	Conditions for daylighting	(1) Bi-directional daylighting for living/dining rooms (2) Bi-directional daylighting for living/dining/senior's rooms (3) Bi-directional daylighting for living/dining/senior's rooms + mono-directional daylighting for non-habitable room	1.0	0.97 - 0.98	0.95	0.9	
					☐ Conditions for daylighting meeting with the Building Standard Law	Location 1 ☐ (3)	—	—	
						Location 2 ☐ (2)	☐ (3)	—	
						Location 3 ☐ (1)	☐ (2)	☐ (3)	
		Lighting system planning (5.5)	Methods	(1) Method using device (2) Method using operation and control (3) Method using design	1.0	0.7	0.6	0.5	
					☐ Conventional models	☐ (1)	☐ (1) + (2)	☐ (1) + (2) + (3)	
Consumer electronics	20.4 GJ	Introduction of high-efficiency consumer electronics (5.6)	Guidelines for the year device was made		1.0	0.8	0.6		
					☐ Year 2000 regular model (0 kWh)	☐ Energy-efficient products (−500 k/Wh)	☐ Energy-efficient products (−1,000 kWh) + standby power consumption decrease		
Other uses (cooking)	4.4 GJ	—	—		1.0				
					☐ Cooking device				
Total	100.5 GJ	—	—						
Electricity		Photovoltaic power generation (3.3)	(Kagoshima)		No reduction	32.7 GJ reduction	43.6 GJ reduction		
			Solar cell capacity		☐ Not to be introduced	☐ Approx. 3 kW	☐ Approx. 4 kW		

* Numbers in parentheses under each elemental technology indicate which section of Chapter 3, 4 or 5 describes it.

■Attached Table 3-2: Energy consumption calculation table (for Zone V / in the case of whole-building continuous heating and cooling)

Use	Calculation formulas	Design value	Reference value	Reduction rate
Cooling	27.1 × (□ × □ × □)	GJ	27.1GJ	
Heating	13.4 × (□ × □ × □)	GJ	13.4GJ	
Ventilation	4.7 × □	GJ	4.7GJ	
Domestic hot water	19.2 × □ (Solar water heating or domestic hot water system)	GJ	19.2GJ	
Lighting	11.3 × (□ × □)	GJ	11.3GJ	
Consumer electronics	20.4 × □	GJ	20.4GJ	
Other uses (cooking)	4.4 × □	GJ	4.4GJ	
Subtotal		GJ	100.5GJ	

Electricity (reduction amount)	Power generation with solar cell (□ 0.0 GJ □ 32.7 GJ □ 43.6 GJ)	▲ GJ		
Total		GJ	100.5GJ	

【Notes】

1. Common

(1) Reference energy consumption indicates rough estimate of annual energy consumption at wooden single-storey house for family of four located in Zone V (in the case of whole-building continuous heating and cooling system).

(2) Energy consumption ratio indicates energy consumption at each level when reference consumption is 1.0.

(3) Areas indicated by slash show that level is not set or no methods are applicable.

(4) Check"✓" off applicable method for each elemental technology and circle value of energy consumption ratio.

(5) Among elemental technologies, "5.7 Treatment and Efficient Use of Water and Kitchen Waste" effective for water saving is exempt from estimation methods.

2. Cooling-related

(1) As for "Solar shading method", after selecting direction of main opening surface, determine level according to solar penetration rate of opening facing true north ±30° and other directions. Where there are multiple openings, determine level based on lowest solar penetration rate.

(2) For "Heating and cooling system planning" (cooling), determine level according to which method is applied out of 1) and 2).

3. Heating-related

(1) As for "Insulated building envelope planning", select applicable insulation level by using existing energy conservation standard as guideline.

(2) As for "Use of solar radiation heat", insulated building envelope level must be 3 or higher. Determine level according to which method is applied out of 1), 2) and 3) after selecting PSP zone classification, site conditions and direction of heat collection opening (true south considered as basic 0°). Site conditions are classified into following two categories according to degree of obstruction of sunlight. *It is assumed that heating load is large in Zone D and Zone C (See Section 3.4 on p.094).
 Location 2: Obstruction of sunlight is 25%
 Location 3: Obstruction of sunlight is 0%

(3) For "Heating and cooling system planning" (heating), determine level according to method applied, either 1) or 2).

4. Ventilation-related
 For "Ventilation system planning", determine level according to which method is applied out of 1) and 2).

5. Domestic-hot-water-related

(1) For "Solar water heating", determine level according to which method is applied out of 1), 2) and 3).

(2) For "Domestic hot water system planning", determine level according to which method is applied out of 2) and 3).

6. Lighting-related

(1) For "Daylight utilization", determine level according to daylighting conditions of room after selecting site conditions. As for daylighting conditions, "LD" refers to living and dining rooms, "S/C" refers to seniors'/children's rooms, and "non-habitable room" refers to kitchen, hallway, entrance, washing room, bathroom and toilet. Site conditions are classified into following three.
 Location 1: Location where sunlight utilization is difficult due to surrounding high-rise, dense buildings
 Location 2: Location where creative measures are required for sunlight utilization due to dense surrounding buildings
 Location 3: Suburban location where sunlight utilization is easy

(2) For "Lighting system planning", please determine level according to which method is applied out of 1), 2) and 3).

7. Consumer-electronics-related
 For "Introduction of high-efficiency consumer electronics", determine level according to manufacturing year or annual electricity consumption reduction (assuming products that were owned around year 2000 as standard) of prime consumer electronics (refrigerator, television) and priority consumer electronics (hot water heated toilet seat, electric hot water pot, washing machine).

8. Other uses (cooking)
 Since target cooking energy consumption does not vary significantly by device, use the reference value, 4.4 GJ.

9. Electricity-related
 When "Photovoltaic power generation" is adopted, select reduction (power generation) of primary energy consumption estimated based on region and solar cell capacity. Quick reference shows reduction in Kagoshima (For reduction in other regions, see Section 3.3 on p.085).

10. Description in calculation table

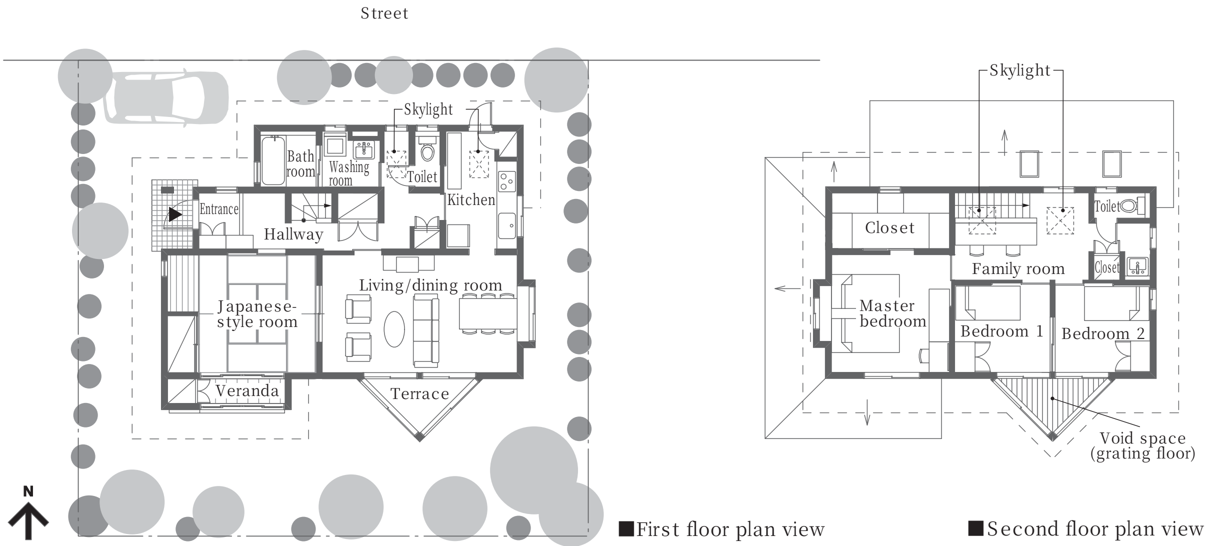
(1) In calculation formula column, write down energy consumption ratio of each elemental technology determined in quick reference. Energy consumption design value and reduction rate can be calculated for each use.

(2) In total section, write down total of energy consumption design values, from cooling to other uses (cooking). In grand total section, write down grand total of design values obtained by subtracting electricity reduction through photovoltaic power generation.

■Design specifications
Structure : Wooden
Number of stories : Two-storey house
Site area : 210.0 m² (2,260 ft²)
Building area : 77.8 m² (837.43 ft²)
Total floor area : 128.3 m² (1,381 ft²)
Family structure : Husband and wife with two children

Zone V: Design calculation example 1

◆Building outline



■First floor plan view ■Second floor plan view

◆Design process outline

Design procedure I Understanding given conditions and required conditions

Site is located in suburb of Kagoshima. Density of surrounding buildings is low, which makes the possibility of using natural energy relatively high.
With regard to occupant's awareness, "level of dedication to natural living" is slightly high while "level of dedication to a stable indoor environment" is moderate.
Occupant seeks nature-oriented lifestyle or machine-oriented lifestyle.

▼

Design procedure II Setting design goals and policies

Make as much effort as possible to implement measures for architectural techniques (natural energy application technology, heat control technology of building envelope) and be creative in designing spatial structure and opening layout for wind utilization.
Aim to introduce highly efficient devices as much as possible with regard to mechanical techniques (energy-efficient equipment technology) (partial intermittent system to be used for heating and cooling).
Through above-mentioned efforts, strive to achieve energy reduction rate of approx. 40%.

▼

Design procedure III Creating design model

Wooden two-storey building has plane structure where three habitable rooms are located in the south and moisture-prone rooms and stairs are placed in the north.
Create sunroom which connects to second floor in south of living room on first floor in order to promote cross ventilation and use of solar radiation heat. In addition, use structure where securing cross ventilation route inside room is taken into consideration.

(Application of main elemental technologies)

● Use and control of wind / Level 2
Condition Location 2 : Suburban location (building coverage ratio of adjacent area is 20% or below), outside wind speed of 1 - 2 m/s or lower in summer
Method applied Use combination of patio doors and waist-level windows for exterior opening, and apply method 1a (combination of small opening areas). In addition, place one surface of opening in prevailing wind direction and adopt method 2.
● Solar shading method / Level 3
Condition Direction of main opening surface: South
Method applied Select glass specifications in way that solar penetration rate of opening is 0.55 or below when facing true north ±30° and is 0.3 or below when facing other directions. Then, set up solar shading components, overhangs, etc.
● Daylight utilization / Level 2
Condition Zone E, Location 3: No influence caused by obstruction of sunlight, direction of opening for heat collection: True south ±15°, insulated building envelope planning at level 3 or higher
Method applied Enhance insulation performance of opening and apply method 1.

▼

Design procedure IV Analyze design model and verify effects

Energy efficiency: approx. 39%
Cost: Number of years for recovery – approx. 28.2 years (cooling/heating, ventilation, domestic hot water, lighting)

◆Verification of energy efficiency

■Attached Table 2-1: Quick reference for energy consumption ratio of elemental technology (for Zone V / In the case of partial intermittent heating and cooling) – Example

Use	Reference energy consumption	Elemental technology*	Evaluation index/method		Energy consumption ratio (reference consumption is 1.0) Level 0	Level 1	Level 2	Level 3	Level 4
Cooling	5.7 GJ	Wind utilization/ control (3.1)	Methods	(1) Opening area on cross ventilation route a: small, b: large (2) Opening area according to prevailing wind direction (3) High window a: small, b: large	1.0	0.95	0.88	0.82	
			Location 1	Wind speed 1m/s or more	☐Method not introduced	☐ (1) a, (3) a	☐ (1) b, (3) b	—	
			Location 2	Wind speed 1m/s or less	☐ Method not introduced ☐ (1) a, (3) a	☐ (1) a + (2), (3) a + (2) ☐ (1) b, (3) b	☐ (1) b + (2) ☐ (3) b + (2)	—	
				Wind speed 1 - 2m/s or less	☐ Method not introduced	—	☐ (1) a, (3) a ☑ (1) a + (2), (3) a + (2)	☐ (1) b, (3) b ☐ (1) b + (2), (3) b + (2)	
				Wind speed 2m/s or more	☐ Method not introduced	—	☐ (1) a, (3) a	☐ (1) a + (2), (3) a + (2) ☐ (1) b, (3) b ☐ (1) b + (2), (3) b + (2)	
		Solar shading method (4.3)	Direction of main opening surface	South	1.0	0.85	0.7	0.55	
				Southeast or southwest	1.3	0.8	0.75	0.65	
				East or west	1.1	0.8	0.75	0.65	
			Solar penetration rate of opening	True north ±30°	☐ Approx. 0.79	☐ 0.79 or less	☐ 0.55 or less	☑0.55 or less	
				Other than the above °	☐ Approx. 0.79	☐ 0.60 or less	☐ 0.45 or less	☑0.30 or less	
		Heating and cooling system planning (cooling) (5.2)	Air conditioner	(1) High-efficiency air conditioner (ratedefficiency) (2) Adjustment of device capacity (3) Use of fan/ceiling fan	1.0	0.95	0.85	0.75	0.65
			Other habitable rooms: Class 0	☐ (1) (<3.8) ☐ (1) (<3.7) + (2) ☐ (1) (<3.3) + (3) ☐ (1) (<3.2) + (2) + (3)	LDK: Class 0 ☐ (1) (<3.5) ☐ (1) (<3.0) + (3)	LDK: Class 1 ☐ (1) (≧3.5) ☐ (1) (≧3.0) + (3)	LDK: Class 3 ☐ (1) (≧5.6) ☐ (1) (≧3.7) + (2) ☐ (1) (≧4.9) + (3) ☐ (1) (≧3.2) + (2) + (3)	LDK: Class 5 ☐ (1) (≧5.3) + (2) ☐ (1) (≧4.9) + (2) + (3)	
			Other habitable rooms: Class 1	☐ (1) (≧3.8) ☑(1) (≧3.7) + (2) ☐ (1) (≧3.3) + (3) ☐ (1) (≧3.2) + (2) + (3)	—	LDK: Class 0 ☐ (1) (<3.5) ☐ (1) (<3.0) + (3)	LDK: Class 2 ☐ (1) (≧4.3) ☐ (1) (<3.7) + (2) ☐ (1) (≧3.7) + (3) ☐ (1) (<3.2) + (2) + (3)	LDK: Class 4 ☐ (1) (≧4.4) + (2) ☑(1) (≧3.9) + (2) + (3)	
			Other habitable rooms: Class 2	☐ (1) (≧5.1) ☐ (1) (≧4.9) + (2) ☐ (1) (≧5.0) + (3) ☐ (1) (≧4.8) + (2) + (3)	—	—	LDK: Class 1 ☐ (1) (≧3.5) ☐ (1) (≧3.0) + (3)	LDK: Class 3 ☐ (1) (≧5.6) ☐ (1) (≧3.7) + (2) ☐ (1) (≧4.9) + (3) ☐ (1) (≧3.2) + (2) + (3)	LDK: Class 5 ☐ (1) (≧5.3) + (2) ☐ (1) (≧4.9) + (2) + (3)
Heating	5.0 GJ	Insulated building envelope planning (4.1)	Energy conservation standard		1.0	0.7	0.5	0.45	0.35
					☐ 1980 Standard	☐ 1992 Standard	☐ Intermediate of 1992 and 1999 Standards	☑1999 Standard	☐ Exceeding 1999 Standard
		Solar radiation heat utilization (3.4)	Methods	(1) Improvement of opening insulation (2) Increase in heat collection area (3) Heat storage	1.0	0.95	0.9	0.8	0.6
			Zone E	Location 2 Direction 0 - 15°	☐ Method not introduced	—	☐ (1) + (2)	☐ (1) + (2) + (3)	
				Direction 15 - 30°		☐ (1) + (2)	☐ (1) + (2) + (3)		
				Location 3 Direction 0 - 15°	☐ Method not introduced	—	☑(1), (2)	☐ (1) + (3)	☐ (1) + (2) ☐ (1) + (2) + (3)
				Direction 15 - 30°		—	☐ (1), (1) + (3)	☐ (1) + (2)	☐ (1) + (2) + (3)
			Zone D* Zone C*	Location 2 Direction 0 - 15°	☐ Method not introduced	—	☐ (1) + (2)		
				Direction 15 - 30°		☐ (1) + (2) ☐ (1) + (2) + (3)			
				Location 3 Direction 0 - 15°	☐ Method not introduced	☐ (2)	☐ (1), (1) + (3)	☐ (1) + (2)	☐ (1) + (2) + (3)
				Direction 15 - 30°		—	☐ (1), (1) + (3)	☐ (1) + (2) ☐ (1) + (2) + (3)	
		Heating and cooling system planning (heating) (5.2)	Air conditioner (LDK)	(1) High-efficiency air conditioner (rated efficiency) (2) Adjustment of device capacity	1.0	0.95	0.85	0.75	0.7
					☐ (1) (<4.9)	☐ (1) + (≧4.9) ☐ (1) (<4.0) + (2)	☐ (1) (≧4.0) + (2)	☐ (1) (≧5.3) + (2)	☑(1) (≧6.2) + (2)
Ventilation	3.1 GJ	Ventilation system planning (5.3)	Duct ventilation	(1) Duct pressure loss decrease (2) High-efficiency device	1.0	0.6	0.5		
					☐ Method not introduced	☐ (1)	☑(1) + (2)		
	1.0 GJ		Through-the-wall ventilation	(1) Optimizing the combination of fan and outside air unit	1.0	0.8			
					☐ Method not introduced	☐ (1)			
Domestic hot water	19.2 GJ	Solar water heating (3.5)	Methods	(1) Heat collection area a: small, b: medium, c: large (2) Connection to auxiliary heat source a: none, b: three-way valve, c: solar connection unit (3) Energy-efficient circulating pump	1.0	0.9	0.7	0.5	0.3
					☐ Conventional gas water heater	☐ (1) a + (2) a	☐ (1) a + (2) c ☐ (1) b + (2) b	☐ (1) b + (2) c ☐ (1) b + (2) c + (3)	☐ (1) c + (2) c ☐ (1) c + (2) c + (3)
		Domestic hot water system planning (5.4)	Methods	(2)-1 Latent heat recovery water heater (2)-2 CO_2HP water heater (3) Piping method/hot water saving tools	1.0	0.9	0.8	0.7	0.6
					☐ Conventional gas water heater	☐ (2)-1 ☐ (2)-2 (medium boiling mode) ☐ (3)	☑(2)-1 + (3)	☐ (2)-2 (energy-efficient mode)	☐ (2)-2 (energy-efficient mode) + (3)
Lighting	11.3 GJ	Daylight utilization (3.2)	Conditions for daylighting	(1) Bi-directional daylighting for living/dining rooms (2) Bi-directional daylighting for living/senior's rooms (3) Bi-directional daylighting for living/dining/senior's rooms + mono-directional daylighting for non-habitable room	1.0	0.97-0.98	0.95	0.9	
					☐ Conditions for daylighting meeting with the Building Standard Law	Location 1 ☐ (3)	—	—	
						Location 2 ☐ (2)	☐ (3)	—	
						Location 3 ☐ (1)	☐ (2)	☑(3)	
		Lighting system planning (5.5)	Methods	(1) Method using device (2) Method using operation and control (3) Method using design	1.0	0.7	0.6	0.5	
					☐ Conventional models	☐ (1)	☐ (1) + (2)	☑(1) + (2) + (3)	
Consumer electronics	19.9 GJ	Introduction of high-efficiency consumer electronics (5.6)	Guidelines for the year device was made		1.0	0.8	0.6		
					☐ Year 2000 regular model (0 kWh)	☐ Energy-efficient products (−500 k/Wh)	☑Energy-efficient products (−1,000 kWh) + standby power consumption decrease		
Other uses (cooking)	4.4 GJ	———	———		1.0				
					☑Cooking device				
Total	68.6 GJ 66.5 GJ	———	———						

				Level 0	Level 1	Level 2	Level 3	Level 4
Electricity		Photovoltaic power generation (3.3)	(Kagoshima)	No reduction	32.7 GJ reduction	43.6 GJ reduction		
			Solar cell capacity	☑Not to be introduced	☐ Approx. 3 kW	☐ Approx. 4 kW		

* Numbers in parentheses under each elemental technology indicate which section of Chapter 3, 4 or 5 describes it.

■Attached Table 2-2: Energy consumption calculation table (for Zone V / In the case of partial intermittent heating and cooling) – Example

Use	Calculation formulas	Design value	Reference value	Reduction rate
Cooling	5.7 × (0.88 × 0.55 × 0.75)	2.07GJ	5.7GJ	63.7%
Heating	5.0 × (0.45 × 0.85 × 0.7)	1.34GJ	5.0GJ	73.2%
Ventilation	3.1 × 0.5	1.55GJ	3.1GJ	50.0%
Domestic hot water	19.2 × 0.8 (Solar water heating or domestic hot water system)	15.36GJ	19.2GJ	20.0%
Lighting	11.3 × (0.9 × 0.5)	5.09GJ	11.3GJ	55.0%
Consumer electronics	19.9 × 0.6	11.94GJ	19.9GJ	40.0%
Other uses (cooking)	4.4 × 1.0	4.4GJ	4.4GJ	0.0%
Subtotal		41.8GJ	68.6GJ	39.1%
Electricity (reduction amount)	Power generation with solar cell (☑ 0.0 GJ ☐ 32.7 GJ ☐ 43.6 GJ)	▲ 0.0GJ		
Total		41.8GJ	68.6GJ	39.1%

- Energy efficiency (annual primary energy consumption reduction rate) is approx. 39.1%.

◆Verification of cost

- With regard to each elemental technology and method applied, mainly estimate the initial cost and annual energy cost of equipment and insulation. As for use of wind, solar shading method, daylight utilization and consumer electronics, their verification is not included as evaluating increases in initial cost is difficult.
- Based on the results of cost evaluation listed in Table 15 and Table 16, the table below shows the increase in initial cost and the decrease in annual energy cost in each energy use while considering standard housing around 2000 as a basis. In this case, the number of years (simple payback time) required for recovering the increase in initial cost through the reduction of energy cost is approx. 28.2 years.
  - Initial cost increase: approx. 1,330,000 yen
  - Annual energy cost reduction: approx. 47,200 yen per year
  - Number of years for recovery (simple payback time)

    = Initial cost increase (yen) / annual energy cost reduction (yen per year)

    = 1,330,000 yen / 47,200 yen per year

    = 28.2 years

Initial cost and energy cost increase and decrease (Example)

Application		Initial cost increase	Annual energy cost reduction
Cooling	Level 3	60,000 yen	3,200 yen/year
Heating	Level 4	800,000 yen (insulated building envelope level 3)	3,400 yen/year
Ventilation	Level 2	102,000 yen	3,600 yen/year
Domestic hot water	Level 2	118,000 yen	25,000 yen/year
Lighting	Level 2	250,000 yen (distributed multiple simple type)	12,000 yen/year
Total		1,330,000 yen	47,200 yen/year

Note: Initial cost of insulated building envelope is taken from value listed in Figure 9 (Section 4.1) on p.131.

Appendices

1. Zone Classification Data
2. Color Images of Illustrations that Appear in Black and White
3. Weather Data
4. List of References

Appendix 1: Zone Classification Data

1. Zone Classification based on Energy Conservation Standard

The zone classification based on the energy conservation standard divides Japan into six zones: Zone I to Zone VI. The zone classification by prefecture is shown in Table 1 and municipalities that belong to a different zone classification are listed in tables (1) to (5) below. This document is targeted at Zones VI and V of the six zones.

*** See Fig. 1 on p.388 for the zone classification map.**

Table 1 Classification by prefecture

Zone classification	Prefecture names
Zone I	Hokkaido
Zone II	Aomori, Iwate, Akita
Zone III	Miyagi, Yamagata, Fukushima, Tochigi, Niigata, Nagano
Zone IV	Ibaraki, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Toyama, Ishikawa, Fukui, Yamanashi, Gifu, Shizuoka, Aichi, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama, Tottori, Shimane, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime, Kochi, Fukuoka, Saga, Nagasaki, Kumamoto, Oita
Zone V	Miyazaki, Kagoshima
Zone VI	Okinawa

(1) Municipalities classified as Zone I despite the classification of Table 1

Aomori	Shichinohe Town, Towadako Town, Takko Town,
Iwate	Kuzumaki Town, Iwate Town, Nishine Town, Matsuo Village, Yuda Town, Sawauchi Village, Yamagata Village, Ashiro Town

(2) Municipalities classified as Zone II despite the classification of Table 1

Hokkaido	Hakodate City, Matsumae Town, Fukushima Town, Shiriuchi Town, Kikonai Town, Esashi Town, Kaminokuni Town, Assabu Town, Otobe Town, Kumaishi Town, Taisei Town, Kitahiyama Town, Shimamaki Village, Suttsu Town
Miyagi	Kurikoma Town, Ichihasama Town, Uguisuzawa Town, Hanayama Village
Yamagata	Yonezawa City, Shinjo City, Sagae City, Nagai City, Obanazawa City, Nanyo City, Kohoku Town, Nishikawa Town, Asahi Town, Oe Town, Oishida Town, Kaneyama Town, Mogami Town, Funagata Town, Mamurogawa Town, Okura Town, Sakegawa Village, Tozawa Village, Takahata Town, Kawanishi Town, Oguni Town, Shirataka Town, Iide Town, Asahi Town
Fukushima	Kitakata City, Otama Village, Naganuma Town, Tenei Village, Tajima Town, Shimogo Town, Tateiwa Village, Hinoemata Village, Inan Village, Nango Village, Tadami Town, Atsushiokano Village, Kitashiobara Village, Yamato Town, Nishiaizu Town, Takasato Village, Bandai Town, Inawashiro Town, Kawahigashi Town, Mishima Town, Kaneyama Town, Showa Village, Yabuki Town, Taishin Village, Hirata Village, Ono Town, Takine Town, Ogoe Town, Tokiwa Town, Funehiki Town, Kawauchi Village, Iitate Village
Tochigi	Nikko City, Ashio Town, Kuriyama Village, Fujihara Town, Shiobara Town
Niigata	Irihirose Village, Tsunan Town, Nakasato Village
Nagano	Suzaka City, Komoro City, Ina City, Komagane City, Nakano City, Omachi City, Iiyama City, Chino City, Shiojiri City, Koshoku City, Saku City, Usuda Town, Saku Town, Koumi Town, Kawakami Village, Minamimaki Village, Minamiaiki Village, Kitaiki Village, Yachiho Village, Karuizawa Town, Mochizuki Town, Miyota Town, Tateshina Town, Asashina Town, Kitamimaki Village, Nagato Town, Tobu Town, Sanada Town, Takeishi Village, Wada Village, Fujimi Town, Hara Village, Takato Town, Tatsuno Town, Minowa Town, Minamiminowa Town, Miyada Village, Namiai Village, Hiraya Village, Shimojo Village, Kisofukushima Town, Agematsu Town, Narakawa Village, Kiso Town, Hiyoshi Village, Kaida Village, Mitake Village, Hata Town, Yamagata Village, Asahi Village, Nagawa Village, Azumi Village, Azusagawa Village, Ikeda Town, Matsukawa Village, Yasaka Village, Miasa Village, Hakuba Village, Otani Village, Obuse Town, Takayama Village, Yamanouchi Town, Kijimadaira Village, Nozawaonsen Village, Toyono Town, Shinano Town, Mure Village, Samizu Village, Togakushi Village, Kinasa Village
Gunma	Naganohara Town, Tsumagoi Village, Kusatsu Town, Kuni Village, Shirasawa Village, Tone Village, Katashina Village, Kawaba Village, Minakami Town
Yamanashi	Fujiyoshida City, Kobuchisawa Town, Nishikatsura Town, Oshino Village, Yamanakako Village, Kawaguchiko Town
Gifu	Takayama City, Nyukawa Village, Kiyomi Village, Shokawa Village, Shirakawa Village, Miya Village, Kuguno Town, Asahi Village, Takane Village, Furukawa Town, Kokufu Town, Kawai Village, Kamitakara Village

(3) Municipalities classified as Zone III despite the classification of Table 1

Aomori	Aomori City, Fukaura Town, Iwasaki Village
Iwate	Miyako City, Ofunato City, Ichinoseki City, Rikuzentakata City, Kamaishi City, Hanaizumi Town, Hiraizumi Town, Daito Town, Sanriku Town, Taro Town
Akita	Akita City, Noshiro City, Honjo City, Oga City, Hachimori Town, Yamamoto Town, Hachiryu Town, Minehama Town, Showa Town, Iitagawa Town, Tenno Town, Wakami Town, Ogata Village, Yuwa Town, Nikaho Town, Konoura Town, Kisakata Town, Yashima Town, Iwaki Town, Yuri Town, Nishime Town, Chokai Town, Ouchi Town
Ibaraki	Ishioka City, Shimodate City, Ogawa Town, Minori Town, Iwama Town, Iwase Town, Miwa Village, Daigo Town, Yasato Town, Chiyoda Town, Niihari Village, Akeno Town, Makabe Town, Yamato Village, Kyowa Town
Gunma	Numata City, Akagi Village, Kurohone Village, Azuma Village (Seta District), Kurabuchi Village, Onogami Village, Manba Town, Nakasato Village, Ueno Village, Shimonita Town, Nanmoku Village, Matsuida Town, Nakanojo Town, Azuma Village (Agatsuma District), Agatsuma Town, Takayama Village, Tsukiyono Town, Niiharu Village, Showa Village
Saitama	Ryokami Village, Otaki Village
Tokyo	Okutama Town
Toyama	Osawano Town, Oyama Town, Kamiichi Town, Tateyama Town, Unazuki Town, Hosoiri Village, Taira Village, Kamitaira Village, Toga Village
Ishikawa	Yoshinodani Village, Oguchi Village, Shiramine Village
Fukui	Izumi Village
Yamanashi	Tsuru City, Mitomi Village, Ashigawa Village, Kamikuisshiki Village, Sutama Town, Takane Town, Nagasaka Town, Oizumi Village, Hakushu Town, Mukawa Village, Katsuyama Village, Ashiwada Village, Narusawa Village, Kosuge Village, Tabayama Village
Gifu	Hachiman Town, Yamato Town, Shirotori Town, Takasu Village, Meiho Village, Wara Village, Higashishirakawa Village, Sakashita Town, Kawaue Village, Kashimo Village, Tsukechi Town, Fukuoka Town, Hirukawa Village, Kushihara Village, Kamiyahagi Town, Hagiwara Town, Osaka Town, Gero Town, Maze Village, Miyagawa Village, Kamioka Town

Aichi	Inabu Town
Hyogo	Muraoka Town, Mikata Town, Sekinomiya Town
Nara	Ikoma City, Tsuge Village, Heguri Town, Muro Village, Nosegawa Village, Oto Village
Wakayama	Koya Town, Hanazono Village
Tottori	Wakasa Town, Sekigane Town, Nichinan Town, Hino Town, Kofu Town
Shimane	Nita Town, Yokota Town, Tonbara Town, Akagi Town, Daiwa Village, Hasumi Village, Mizuho Town
Okayama	Niimi City, Hokubo Town, Bicchu Town, Osa Town, Shingo Town, Tetsuta Town, Tessei Town, Katsuyama Town, Yubara Town, Mikamo Village, Shinjo Village, Kawakami Village, Yatsuka Village, Chuka Village, Tomi Village, Okutsu Town, Kamisaibara Village, Aba Village
Hiroshima	Shobara City, Saiki Town, Yoshiwa Village, Tsutsuga Village, Togouchi Town, Geihoku Town, Oasa Town, Chiyoda Town, Yachiyo Town, Midori Town, Takamiya Town, Kozan Town, Sera Town, Yuki Town, Jinseki Town, Toyomatsu Village, Sanwa Town (Jinseki District), Joge Town, Soryo Town, Konu Town, Kimita Village, Funo Village, Sakugi Village, Kisa Town, Mirasaka Town, Saijo Town, Tojo Town, Kuchiwa Town, Takano Town, Hiwa Town
Tokushima	Higashiiyayama Village
Kochi	Hongawa Village

(4) Municipalities classified as Zone Ⅳ despite the classification of Table 1

Fukushima	Iwaki City, Hirono Town, Naraha Town, Tomioka Town, Okuma Town, Futaba Town
Tochigi	Utsunomiya City, Ashikaga City, Tochigi City, Sano City, Kanuma City, Oyama City, Moka City, Kaminokawa Town, Minamikawachi Town, Kamikawachi Town, Kawachi Town, Nishikata Town, Awano Town, Ninomiya Town, Mashiko Town, Motegi Town, Ichikai Town, Haga Town, Mibu Town, Ishibashi Town, Kokubunji Town, Nogi Town, Ohira Town, Fujioka Town, Iwafune Town, Tsuga Town, Ujiie Town, Takanezawa Town, Minaminasu Town, Karasuyama Town, Tanuma Town, Kuzuu Town
Niigata	Niigata City, Sanjo City, Kashiwazaki City, Shibata City, Niitsu City, Mitsuke City, Murakami City, Tsubame City, Itoigawa City, Ryotsu City, Shirone City, Toyosaka City, Joetsu City, Kyogase Village, Sasakami Village, Toyoura Town, Seiro Town, Kajikawa Village, Shiunji Town, Nakajo Town, Kurokawa Village, Kosudo Town, Yokogochi Town, Kameda Town, Iwamuro Village, Yahiko Village, Bunsui Town, Yoshida Town, Maki Town, Nishikawa Town, Ajikata Village, Katahigashi Village, Tsukigata Village, Nakanokuchi Village, Sakae Town, Nakanoshima Town, Mishima Town, Yoita Town, Washima Village, Izumozaki Town, Teradomari Town, Kariwa Town, Nishiyama Town, Kakizaki Town, Ogata Town, Kubiki Village, Yoshikawa Town, Sanwa Village, Nadachi Town, Nou Town, Omi Town, Arakawa Town, Kamihayashi Village, Sanboku Town, Awashimaura Village, Aikawa Town, Sawata Town, Kanai Town, Niibo Village, Hatano Town, Mano Town, Ogi Town, Hamochi Town, Akadomari Village
Nagano	Seinaiji Village, Oshika Village
Miyazaki	Miyakonojo City, Kobayashi City, Ebino City, Yamada Town, Takazaki Town, Takaharu Town, Suki Village, Nishimera Village, Nango Village, Saigo Village, Kitago Village, Kitakata Town, Morotsuka Village, Shiiba Village, Takachiho Town, Hinokage Town, Gokase Town
Kagoshima	Okuchi City, Miyanojo Town, Tsuruda Town, Satsuma Town, Hishikari Town, Yokogawa Town, Kurino Town, Yoshimatsu Town, Makizono Town, Kirishima Town, Osumi Town, Takarabe Town, Sueyoshi Town

(5) Municipalities classified as Zone V despite the classification of Table 1

Ibaraki	Hasaki Town
Chiba	Choshi City
Tokyo	Oshima Town, Toshima Village, Niijima Village, Kozushima Village, Miyake Village, Mikurajima Village, Hachijo Town, Aogashima Village, Ogasawara Village
Shizuoka	Atami City, Shimoda City, Kawazu Town, Minamiizu Town, Matsuzaki Town, Nishiizu Town, Omaezaki City, Hamaoka Town
Mie	Owase City, Kumano City, Mihama Town, Kiho Town, Udono Village
Wakayama	Gobo City, Shingu City, Hirogawa Town, Mihama Town, Hidaka Town, Yura Town, Shirahama Town, Hikigawa Town, Susami Town, Kushimoto Town, Nachikatsuura Town, Taiji Town, Koza Town, Kozagawa Town
Yamaguchi	Shimonoseki City
Tokushima	Yuki Town, Hiwasa Town, Mugi Town, Kainan Town, Kaifu Town, Shishikui Town
Ehime	Seto Town, Misaki Town, Tsushima Town, Uchiumi Village, Misho Town, Johen Town, Ipponmatsu Town, Nishiumi Town
Kochi	Kochi City, Muroto City, Aki City, Nangoku City, Tosa City, Susaki City, Sukumo City, Tosashimizu City, Toyo Town, Nahari Town, Tano Town, Yasuda Town, Kitagawa Village, Umaji Village, Geisei Village, Akaoka Town, Kagami Town, Noichi Town, Yasu Town, Yoshikawa Village, Ino Town, Haruno Town, Ogata Town, Otsuki Town, Mihara Village
Fukuoka	Fukuoka City: Hakata Ward, Chuo Ward, Minami Ward, Jonan Ward
Nagasaki	Nagasaki City, Sasebo City, Shimabara City, Fukue City, Hirado City, Koyagi Town, Iojima Town, Takashima Town, Nomozaki Town, Sanwa Town, Nagayo Town, Togitsu Town, Kinkai Town, Seihi Town, Saikai Town, Oshima Town, Sakito Town, Oseto Town, Sotome Town, Kuchinotsu Town, Manimiarima Town, Kitaarima Town, Nishiarie Town, Arie Town, Futsu Town, Fukae Town, Oshima Village, Ikitsuki Town, Ojika Town, Uku Town, Tabira Town, Emukae Town, Shikamachi Town, Kozasa Town, Saza Town, Yoshii Town, Sechibaru Town, Tomie Town, Tamanoura Town, Miiraku Town, Kishiku Town, Naru Town, Wakamatsu Town, Kamigoto Town, Shinuonome Town, Arikawa Town, Narao Town
Kumamoto	Yashiro City, Minamata City, Hondo City, Ushibuka City, Misumi Town, Sencho Town, Kagami Town, Tanoura Town, Ashikita Town, Tsunagi Town, Oyano Town, Himedo Town, Ryugatake Town, Goshoura Town, Kuratake Town, Sumoto Town, Shinwa Town, Amakusa Town, Kawaura Town
Oita	Saiki City, Tsurumi Town, Yonouzu Village, Kamae Town

Note: Names of the municipalities listed above are in accordance with Ordinance No. 2 of the Ministry of International Trade and Industry and the Ministry of Construction on March 30, 1999.

2. Passive Solar Zone Classification (PSP Classification)

The passive solar zone classification based on the solar radiation and temperature in winter explained in Section 3.4 Solar Radiation Heat Utilization divides Japan into five zones: Zone A to Zone E. The zone classification by prefecture is shown in Table 2 and municipalities that belong to a different zone classification are listed in tables (1) to (5) below. This document is targeted at Zones VI and V of the six zones.

*** See Fig. 2 on p.389 for the zone classification map.**

Table 2 Classification by prefecture

Zone classification	Prefecture names
Zone A	Hokkaido, Aomori, Akita, Yamagata, Niigata, Ishikawa
Zone B	Iwate, Toyama, Fukui, Gifu, Shiga, Kyoto, Nara, Tottori, Shimane, Hiroshima
Zone C	Miyagi, Fukushima, Nagano, Osaka, Hyogo, Okayama, Yamaguchi, Ehime, Fukuoka, Saga, Nagasaki
Zone D	Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Yamanashi, Aichi, Mie, Wakayama, Tokushima, Kagawa, Kumamoto, Oita
Zone E	Shizuoka, Kochi, Miyazaki, Kagoshima

(Note) Okinawa is not included in this classification.

(1) Municipalities classified as Zone A despite the classification of Table 2

Iwate	Kuzumaki Town, Yuda Town, Sawauchi Village, Ashiro Town
Fukushima	Tajima Town, Shimogo Town, Tateiwa Village, Hinoemata Village, Inan Village, Nango Village, Tadami Town, Atsushiokano Village, Kitashiobara Village, Yamato Village, Nishiaizu Town, Takasato Village, Yanaizu Town, Aizutakada Town, Mishima Town, Kaneyama Town, Showa Village
Toyama	Himi City
Shimane	Tonbara Town, Akagi Town, Daiwa Village

(2) Municipalities classified as Zone B despite the classification of Table 2

Hokkaido	Sapporo City, Hakodate City, Muroran City, Kushiro City, Obihiro City, Kitami City, Abashiri City, Tomakomai City, Nemuro City, Chitose City, Noboribetsu City, Eniwa City, Ono Town, Nanae Town, Toi Town, Esan Town, Todohokke Village, Minamikayabe Town, Shikabe Town, Sawara Town, Mori Town, Naganuma Town, Higashimokoto Village, Memanbetsu Town, Bihoro Town, Tsubetsu Town, Koshimizu Town, Tanno Town, Kunneppu Town, Oketo Town, Tokoro Town, Engaru Town, Kamiyubetsu Town, Yubetsu Town, Shiraoi Town, Hayakita Town, Oiwake Town, Atsuma Town, Mukawa Town, Hobetsu Town, Biratori Town, Monbetsu Town, Niikappu Town, Shizunai Town, Mitsuishi Town, Urakawa Town, Samani Town, Erimo Town, Otofuke Town, Shihoro Town, Kamishihoro Town, Shikaoi Town, Shintoku Town, Shimizu Town, Memuro Town, Nakasatsunai Village, Sarabetsu Village, Churui Village, Taiki Town, Hiroo Town, Makubetsu Town, Ikeda Town, Toyokoro Town, Honbetsu Town, Ashoro Town, Rikubetsu Town, Urahoro Town, Kushiro Town, Akkeshi Town, Hamanaka Town, Shibecha Town, Deshikaga Town, Akan Town, Tsurui Village, Shiranuka Town, Onbetsu Town, Betsukai Town, Nakashibetsu Town, Shibetsu Town
Aomori	Hachinohe City, Towada City, Shichinohe Town, Misawa City, Momoishi Town, Rokunohe Town, Kamikita Town, Shimoda Town, Rokkasho Village, Higashidori Village, Sannohe Town, Gonohe Town, Takko Town, Nagawa Town, Nanbu Town, Hashikami Town, Fukuchi Village, Nango Village, Kuraishi Village, Shingo Village
Miyagi	Zao Town, Shichikashuku Town, Murata Town, Kawasaki Town, Taiwa Town, Tomiya Town, Ohira Village, Nakaniida Town, Onoda Town, Miyazaki Town, Shikama Town, Iwadeyama Town, Naruko Town, Tsukidate Town, Wakayanagi Town, Kurikoma Town, Takashimizu Town, Ichihasama Town, Semine Town, Uguisuzawa Town, Kannari Town, Shiwahime Town, Hanayama Village, Hasama Town, Towa Town, Nakada Town, Ishikoshi Town, Minamikata Town
Yamagata	Yamagata City, Kaminoyama City, Tendo City, Higashine City, Yamanobe Town, Nakayama Town
Fukushima	Fukushima City, Aizuwakamatsu City, Kitakata City, Nihonmatsu City, Kori Town, Date Town, Kunimi Town, Tsukidate Town, Kawamata Town, Iino Town, Adachi Town, Otama Village, Motomiya Town, Towa Town, Naganuma Town, Kagamiishi Town, Iwase Village, Tenei Village, Kitaaizu Village, Shiokawa Town, Bandai Town, Inawashiro Town, Aizubange Town, Yugawa Village, Kawahigashi Town, Aizuhongo Town, Niitsuru Village, Nishigo Village, Yabuki Town, Taishin Village, Iitate Village
Tochigi	Kuriyama Village, Fujihara Town, Nasu Town
Gunma	Tsumagoi Village, Kusatsu Town, Katashina Village, Minakami Town, Niiharu Village
Niigata	Itoigawa City, Arai City, Yuzawa Town, Tsunan Town, Maki Village, Myokokogen Town, Nakago Village, Myoko Village, Itakura Town, Kiyosato Village, Omi Town
Ishikawa	Kanazawa City, Matto City, Yamanaka Town, Nonoichi Town, Shiramine Village, Tsubata Town, Takamatsu Town, Nanatsuka Town, Unoke Town, Uchinada Town
Nagano	Nagano City, Suzaka City, Nakano City, Omachi City, Iiyama City, Seinaiji Village, Achi Village, Namiai Village, Hiraya Village, Neba Village, Shimojo Village, Kisofukushima Town, Agematsu Town, Nagiso Town, Narakawa Village, Kiso Village, Hiyoshi Town, Kaida Village, Mitake Village, Otaki Village, Okuwa Village, Yamaguchi Village, Ikusaka Village, Hotaka Village, Nagawa Village, Azumi Village, Horigane Village, Ikeda Town, Matsukawa Village, Yasaka Village, Miasa Village, Hakuba Village, Otari Village, Ooka Village, Obuse Town, Takayama Village, Yamanouchi Town, Kijimadaira Village, Nozawaonsen Village, Shinshushin Town, Toyono Town, Shinano Town, Mure Village, Samizu Village, Togakushi Village, Kinasa Village, Ogawa Village, Nakajo Village, Toyota Village, Sakae Village
Aichi	Inabu Town
Hyogo	Toyooka City, Kami Town, Kanzaki Town, Okawachi Town, Yamasaki Town, Ichinomiya Town, Haga Town, Chikusa Town, Kinosaki Town, Takeno Town, Kasumi Town, Hidaka Town, Izushi Town, Tanto Town, Muraoka Town, Hamasaka Town, Mikata Town, Onsen Town, Yoka Town, Yabu Town, Oya Town, Sekinomiya Town, Ikuno Town, Wadayama Town, Santo Town, Asago Town, Hikami Town, Aogaki Town, Ichijima Town
Wakayama	Misato Town, Koya Town, Hanazono Village, Shimizu Town, Miyama Village, Ryujin Village
Okayama	Niimi City, Hokubo Town, Osa Town, Shingo Town, Tetsuta Town, Tessei Town, Katsuyama Town, Ochiai Town, Yubara Town, Kuse Town, Mikamo Village, Shinjo Village, Kawakami Village, Yatsuka Village, Chuka Village, Kamo Town, Tomi Village, Okutsu Town, Kamisaibara Village, Aba Village, Kagamino Town, Katsuta Town, Nagi Town, Shoboku Town, Ohara Town, Higashiawakura Village, Nishiawakura Village, Kume Town
Yamaguchi	Hagi City, Nagato City, Misumi Town, Heki Town, Yuya Town, Kawakami Village, Abu Town, Tamagawa Town, Ato Town, Mutsumi Village, Susa Town, Asahi Village, Fukue Village
Tokushima	Ikeda Town, Ikawa Town, Higashiiyayama Village, Nishiiyayama Village
Ehime	Kuma Town, Omogo Village, Mikawa Village, Yanadani Village, Oda Town, Hirota Village, Uchiko Town, Ikazaki Town, Kawabe Village

(3) Municipalities classified as Zone C despite the classification of Table 2

Iwate	Miyako City, Ofunato City, Kuji City, Rikuzentakata City, Taro Town, Yamada Town, Tanohata Village, Fudai Village, Noda Village
Ibaraki	Ishioka City, Yamagata Town, Miwa Village, Suifu Village, Satomi Village, Daigo Town, Yasato Town, Chiyoda Town, Makabe Town
Tochigi	Nikko City, Imaichi City, Otawara City, Yaita City, Kuroiso City, Kamikawachi Town, Ashio Town, Shioya Town, Ujiie Town, Kitsuregawa Town, Bato Town, Ogawa Town, Yuzukami Village, Kurobane Town, Nishinasuno Town, Shiobara Town
Gunma	Numata City, Akagi Village, Azuma Village (Seta District), Kurabuchi Village, Komochi Village, Onogami Village, Nakasato Village, Ueno Village, Nakanojo Town, Azuma Village (Agatsuma District), Agatsuma Town, Naganohara Town, Kuni Village, Takayama Village, Shirosawa Village, Tone Village, Kawaba Village, Tsukiyono Town, Showa Village

Saitama	Ogano Town, Ryokami Village, Otaki Village, Kamiizumi Village
Yamanashi	Fujiyoshida City, Mitomi Village, Ashigawa Village, Kamikuisshiki Village, Mitama Town, Takane Town, Nagasaka Town, Oizumi Village, Oshino Village, Yamanakako Village, Ashiwada Village, Narusawa Village
Gifu	Tajimi City, Seki City, Nakatsugawa City, Mino City, Mizunami City, Ena City, Minokamo City, Toki City, Kani City, Nanno City, Yoro Town, Kamiishizu Town, Tarui Town, Sekigahara Town, Godo Town, Ibigawa Town, Tanigumi Village, Ono Town, Ikeda Town, Kasuga Village, Motosu Town, Takatomi Town, Ijira Village, Mugegawa Town, Mugi Town, Kaminoho Village, Minami Village, Sakahogi Town, Tomika Town, Kawabe Town, Hichiso Town, Yaotsu Town, Shirakawa Town, Mitake Town, Kaneyama Town, Kasahara Town, Hirukawa Village, Iwamura Town, Yamaoka Town, Akechi Town, Kanayama Town
Shizuoka	Oyama Town
Aichi	Kasugai City, Inuyama City, Komaki City, Oguchi Town, Fuso Town, Fujioka Town, Obara Village, Shimoyama Village, Asuke Town, Asahi Town, Shitara Town, Toei Town, Toyone Village, Tomiyama Village, Tsugu Village
Kyoto	Kyoto City, Uji City, Kameoka City, Joyo City, Muko City, Nagaokakyo City, Yawata City, Kyotanabe City, Oyamazaki Town, Kumiyama Town, Ide Town, Ujitawara Town, Yamashiro Town, Kizu Town, Kamo Town, Kasagi Town, Wazuka Town, Seika Town, Miyamiyamashiro Village
Mie	Ueno City, Nabari City, Kameyama City, Hokusei Town, Inabe Town, Daian Town, Toin Town, Fujiwara Town, Komono Town, Seki Town, Geino Town, Hakusan Town, Misugi Village, Iinan Town, Iitaka Town, Iga Town, Shimagahara Village, Ayama Town, Oyamada Village, Aoyama Town
Shiga	Otsu City, Omihachiman City, Yokaichi City, Kusatsu City, Moriyama City, Shiga Town, Ritto City, Chuzu Town, Yasu Town, Ishibe Town, Kosei Town, Minakuchi Town, Azuchi Town, Gamo Town, Ryuo Town, Eigenji Town, Gokasho Town, Notogawa Town, Aichigawa Town, Taga Town
Nara	Nara City, Gojo City, Gose City, Ikoma City, Heguri Town, Santo Town, Soni Village, Mitsue Village, Shinjo Town, Taima Town, Kashiba City, Shimokitayama Village, Kamikitayama Village, Kawakami Village, Higashiyoshino Village
Wakayama	Kainan City, Hashimoto City, Nokami Town, Uchita Town, Kokawa Town, Naga Town, Momoyama Town, Kishigawa Town, Iwade Town, Katsuragi Town, Koyaguchi Town, Kudoyama Town, Kanaya Town, Nakatsu Village, Hongu Town
Hiroshima	Hiroshima City, Takehara City, Mihara City, Onomichi City, Fukuyama City, Fuchu City, Otake City, Higashihiroshima City, Hatsukaichi City, Fuchu Town, Ono Town, Yachiyo Town, Mukaihara Town, Fukutomi Town, Toyosaka Town, Kochi Town, Hongo Town, Akitsu Town, Mitsugi Town, Kui Town, Mukaishima Town, Utsumi Town, Numakuma Town, Kannabe Town, Shinichi Town
Tokushima	Ichiba Town, Awa Town, Kawashima Town, Yamakawa Town, Misato Village, Waki Town, Mima Town, Handa Town, Sadamitsu Town, Ichiu Village, Anabuki Town, Koyadaira Village, Mino Town, Miyoshi Town, Yamashiro Town, Mikamo Town
Kagawa	Kanonji City, Shionoe Town, Kagawa Town, Konan Town, Ayakami Town, Ryonan Town, Ayauta Town, Kotominami Town, Manno Town, Kotohira Town, Chunan Town, Takase Town, Yamamoto Town, Onohara Town, Toyoanaka Town, Toyohama Town, Saita Town
Kochi	Motoyama Town, Otoyo Town, Tosa Town, Okawa Village, Hongawa Village, Ikegawa Town, Agawa Village, Gohoku Village, Ochi Town, Yusuhara Town, Higashitsuno Village, Niyodo Village
Kumamoto	Tomochi Town, Kyokushi Village, Ozu Town, Ichinomiya Town, Aso Town, Minamioguni Town, Oguni Town, Ubuyama Village, Namino Village, Soyo Town, Takamori Town, Hakusui Village, Kugino Village, Choyo Village, Nishihara Village, Mifune Town, Mashiki Town, Yabe Town, Seiwa Village, Izumi Village, Mizukami Village
Oita	Hita City, Shonai Town, Yufuin Town, Kuju Town, Kokonoe Town, Kusu Town, Metsue Village, Nakatsue Village, Kamitsue Village, Oyama Town, Amagase Town, Sanko Village, Honyabakei Town, Yabakei Town, Yamakuni Town, Innai Town, Ajimu Town
Miyazaki	Gokase Town

(4) Municipalities classified as Zone D despite the classification of Table 2

Gifu	Gifu City, Ogaki City, Hashima City, Kagamihara City, Kawashima Town, Ginan Town, Kasamatsu Town, Yanaizu Town, Kaizu Town, Hirata Town, Wanouchi Town, Anpachi Town, Sunomata Town, Kitagata Town, Hozumi Town, Suminami Town, Shinsei Town, Itonuki Town
Shizuoka	Fujinomiya City, Gotenba City, Susono City, Shibakawa Town, Kawane Town, Nakakawane Town, Honkawane Town, Haruno Town, Tatsuyama Town, Sakuma Town, Misakiubo Town, Inasa Town
Osaka	Osaka City, Sakai City, Takaishi City, Tajiri Town
Hyogo	Kobe City, Amagasaki City, Akashi City, Nishinomiya City, Sumoto City, Ashiya City, Harima Town, Ieshima Town, Tsuna Town, Awaji Town, Hokudan Town, Ichinomiya Town, Goshiki Town, Higashiura Town, Midori Town, Seidan Town, Mihara Town, Nandan Town
Okayama	Okayama City, Kurashiki City, Tamano City, Kasaoka City, Nadasaki Town, Hayashima Town, Yamate Village, Kiyone Village, Funao Town, Konko Town, Kamogata Town, Yorishima Town, Satosho Town, Mabi Town
Hiroshima	Kure City, Innoshina City, Kaita Town, Kumano Town, Saka Town, Etajima Town, Ondo Town, Kurahashi Town, Shimokamagari Town, Kamagari Town, Miyajima Town, Nomi Town, Okimi Town, Ogaki Town, Kurose Town, Yasuura Town, Kawajiri Town, Toyohama Town, Yutaka Town, Osaki Town, Higashino Town, Kinoe Town, Setoda Town
Yamaguchi	Hofu City, Kudamatsu City, Iwakuni City, Hikari City, Yanai City, Kuka Town, Oshima Town, Towa Town, Yu Town, Obatake Town, Kaminoseki Town, Yamato Town, Tabuse Town, Hirao Town, Tachibana Town, Waki Town
Ehime	Matsuyama City, Imabari City, Hojo City, Asakura Village, Tamagawa Town, Namikata Town, Onishi Town, Kikuma Town, Yoshiumi Town, Miyakubo Town, Hakata Town, Uoshima Town, Yuge Town, Ikina Village, Iwagi Village, Kamiura Town, Omishima Town, Sekizen Village, Nakajima Town, Masaki Town, Misaki Town, Tsushima Town, Uchiumi Village, Misho Town, Johen Town, Ipponmatsu Town, Nishiumi Town
Kochi	Kitagawa Village, Umaji Village, Tosayamada Town, Kahoku Town, Monobe Village, Kagami Village, Tosayama Village, Ino Town, Sakawa Town, Kubokawa Town, Onomi Village, Hayama Village, Hidaka Village, Taisho Town, Towa Village, Nishitosa Village
Fukuoka	Omuta City, Yanagawa City, Chikugo City, Okawa City, Jojima Town, Oki Town, Mizuma Town, Setaka Town, Yamato Town, Mitsuhashi Town, Yamakawa Town, Takata Town
Saga	Saga City, Morodomi Town, Kawasoe Town, Higashiyoka Town, Kubota Town, Chiyoda Town, Ashikari Town, Tara Town
Nagasaki	Nagasaki City, Sasebo City, Shimabara City, Koyagi Town, Iojima Town, Takashima Town, Nomozaki Town, Sanwa Town, Tarami Town, Nagayo Town, Togitsu Town, Kinkai Town, Saikai Town, Oshima Town, Sakito Town, Oseto Town, Sotome Town, Konagai Town, Ariake Town, Kunimi Town, Mizuho Town, Minamikushiyama Town, Kazusa Town, Kuchinotsu Town, Nanamiarima Town, Kitaarima Town, Nishiarie Town, Izuhara Town, Mitsuhima Town, Toyotama Town, Mine Town, Kamiagata Town, Kamitsushima Town
Miyazaki	Ebino City, Nishimera Village, Nango Village, Morotsuka Village, Shiiba Village, Takachiho Town, Hinokage Town
Kagoshima	Sendai City, Kushikino City, Akune City, Izumi City, Okuchi City, Kaseda City, Kokubu City, Kasasa Town, Oura Town, Kawabe Town, Ichiki Town, Higashiichiki Town, Hiyoshi Town, Fukiage Town, Kinpo Town, Hiwaki Town, Iriki Town, Togo Town, Miyanojo Town, Tsuruda Town, Satsuma Town, Kedoin Town, Sato Village, Kamikoshiki Village, Shimokoshiki Village, Kashima Village, Noda Town, Takaono Town, Azuma Town, Nagashima Town, Hishikari Town, Kajiki Town, Aira Town, Kamo Town, Mizobe Town, Yokogawa Town, Kurino Town, Yoshimatsu Town, Makizono Town, Kirishima Town, Hayato Town, Fukuyama Town

(5) Municipalities classified as Zone E despite the classification of Table 2

Tokyo	Hachijo Town, Aogashima Village, Ogasawara Village
Kanagawa	Yokohama City, Yokosuka City, Miura City, Hayama City
Aichi	Toyohashi City, Tahara Town, Akabane Town, Atsumi Town
Mie	Ise City, Owase City, Toba City, Kumano City, Futami Town, Nansei Town, Nanto Town, Kisei Town, Ouchiyama Village, Hamashima Town, Daio Town, Shima Town, Ago Town, Isobe Town, Kiinagashima Town, Miyama Town, Mihama Town, Kiho Town, Udono Village
Wakayama	Shingu City, Shirahama Town, Kamitonda Town, Hikigawa Town, Susami Town, Kushimoto Town, Nachikatsuura Town, Taiji Town, Koza Town
Tokushima	Anan City, Wajiki Town, Aioi Town, Yuki Town, Hiwasa Town, Mugi Town, Kainan Town, Kaifu Town, Shishikui Town
Oita	Saiki City, Tsurumi Town, Yonouzu Village, Kamae Town

Note: Names of the municipalities listed above are in accordance with Ordinance No. 2 of the Ministry of International Trade and Industry and the Ministry of Construction on March 30, 1999.

Fig. 1 Zone classification by energy conservation standard

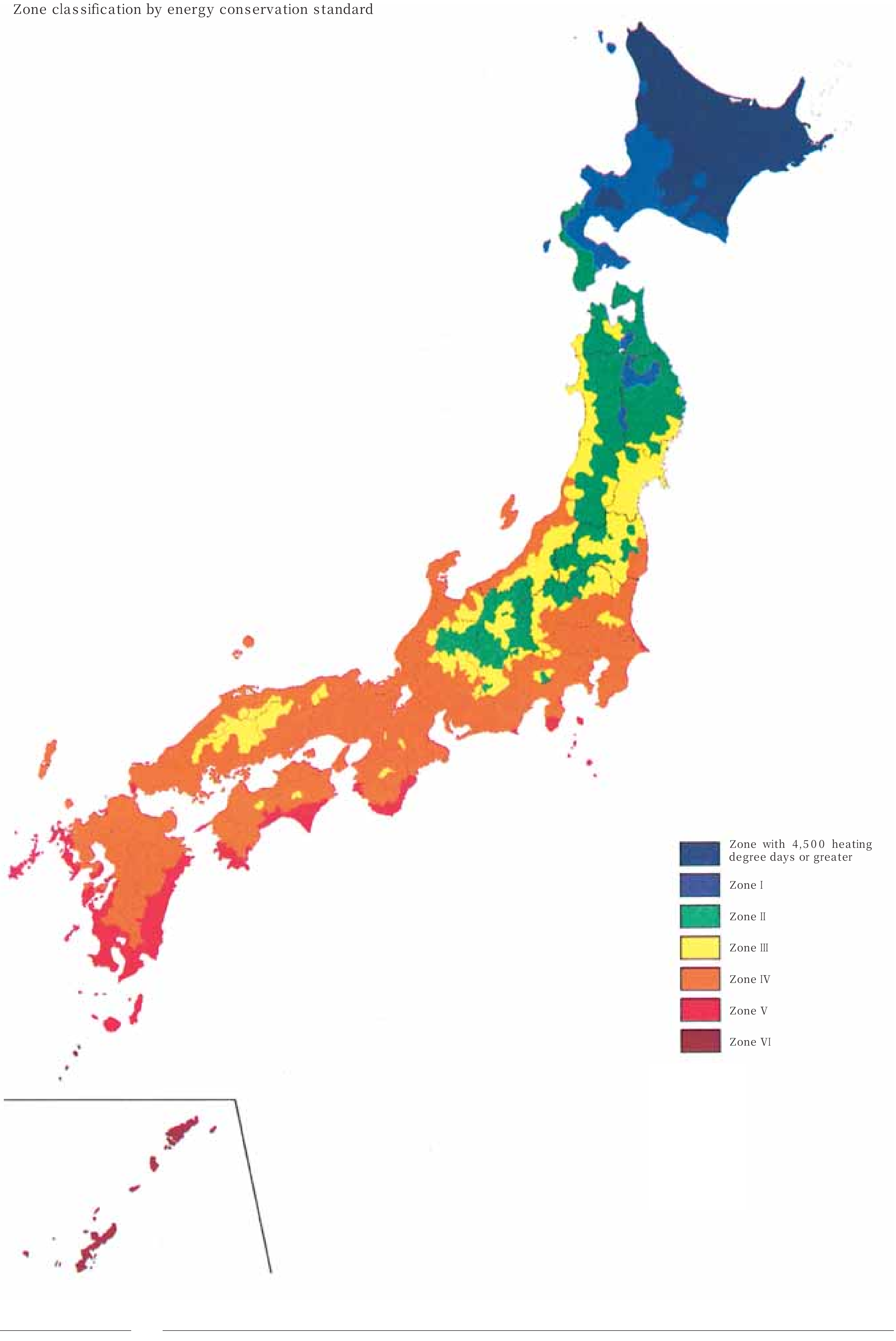
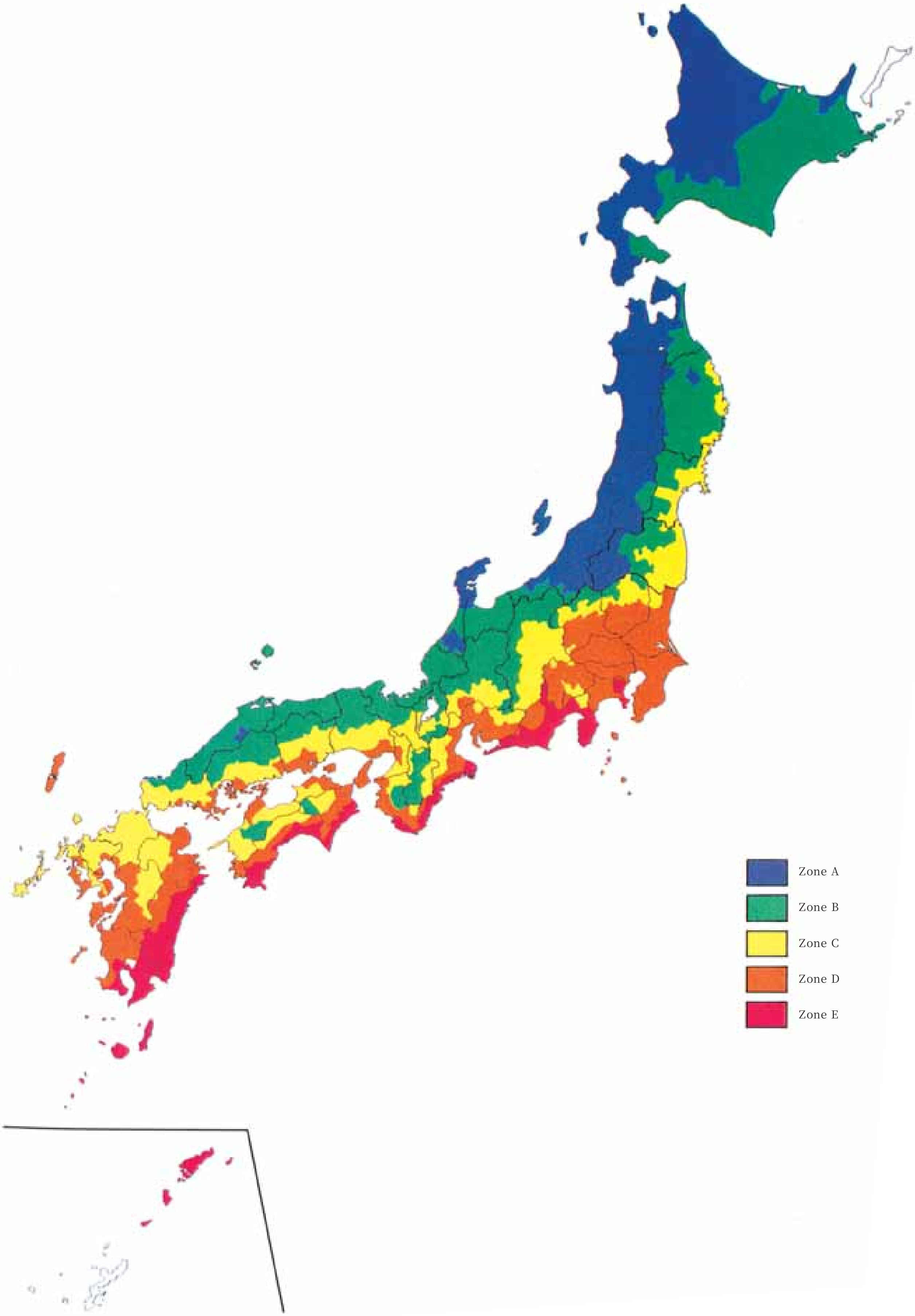


Fig. 2 Passive solar zone classification map (PSP classification map)



Appendix 2: Color Images of Illustrations that Appear in Black and White

■3.2 Daylight Utilization on p.074 – 075

Table 4 Characteristics of sun control devices 1 (installed outside)

Horizontal louver

Horizontal blind

Bamboo blind

Awning

Table 5 Characteristics of sun control devices 2 (installed inside)

Horizontal blind

Paper sliding door

Sheer curtain

No device

■3.2 Daylight Utilization on p.078

Photo 1　Stark contrast in lightning between window and inside of room

Photo 2　Example of using lighting to make room seem darker by creating contrast with windows

■4.3 Solar Shading Methods for Zone V on p.197

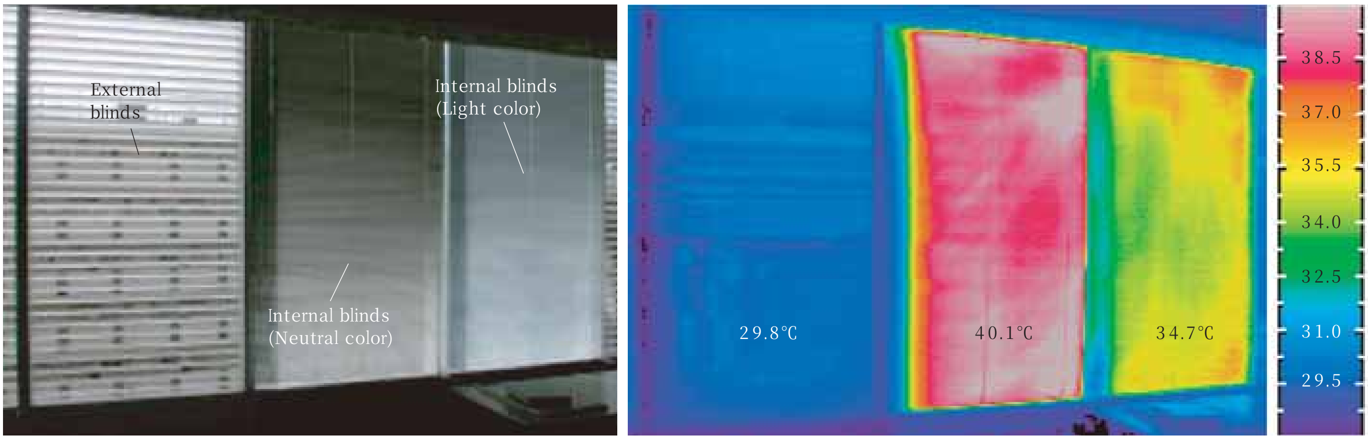


Fig. 4　Comparison of window surface temperatures with use of blinds

■4.3 Solar Shading Methods for Zone V on p.198

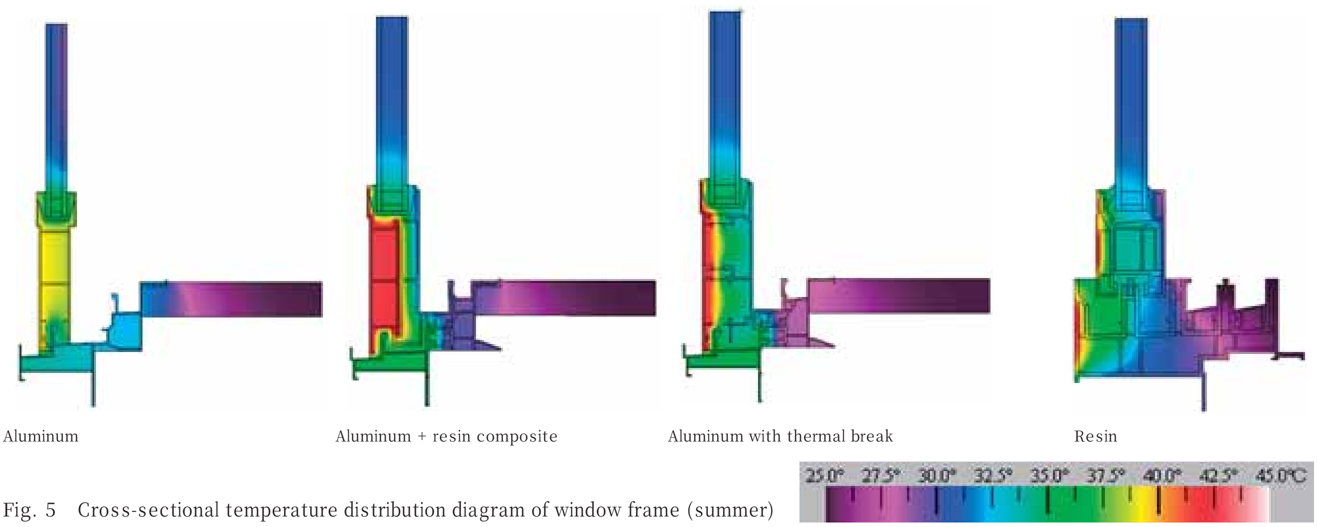


Fig. 5　Cross-sectional temperature distribution diagram of window frame (summer)

Appendix 3: Weather Data

You can refer to the LEHVE's website (http://www.jjj-design.org) for the weather data information (for 842 locations in Japan) that has been compiled for studying wind utilization methods (see Comment ● Publication of weather data on p.044). A summary of the weather data is introduced in this section.

1. Structure of website

- How to compile the weather data: Methods for processing and displaying data are explained.
- How to use the weather data: Types of data disclosed and method of using data are explained.
- Weather station map by prefecture: Weather stations are specified on a map by prefecture. By selecting a weather station that one wants to view, weather data for the station concerned is displayed (Fig. 1, Fig. 2).
- Weather data by weather station: Data on outside wind speed, outside wind direction, outside air temperature and relative humidity are organized by weather station (PDF format).

2. Weather station for gathering weather data in hot humid regions

Weather stations correspond to the weather station names and station numbers of the Expanded AMeDAS (Automated Meteorological Data Acquisition System) Weather Data. Among the 842 locations in Japan, weather stations which fall under Zone V (16 prefectures) and Zone VI (Okinawa prefecture), which are hot humid regions, are the ones listed in Table 1.

3. Types of weather data which can be viewed

(1) Outside wind speed

The mean values of outside wind speed for each month, from June until September and from April to November, are shown by time of day (waking hours, sleeping hours and entire day). Wind speed was measured at a height equivalent to that of eaves of a second-story detached house (value at a location 6.5 m above ground).

(2) Outside wind direction

Characteristics of outside wind direction are indicated by using the frequency of becoming windward and leeward shown by direction which openings face (16 directions) and by time of day (waking hours and sleeping hours). In addition, changes in outside wind direction caused by seasons and time of day are clearly shown in wind rose, etc.

(3) Outside air temperature

Average temperatures by time of day (waking hours and sleeping hours) are shown for each month between April and November.

(4) Relative humidity

Average relative humidity by time of day (waking hours and sleeping hours) is shown for each month between April and November.

4. Regarding use of data

The published weather data was created by the LEHVE Development Committee (Cross Ventilation Task Group, Phase II Validation Experiment Subcommittee), based on the expanded AMeDAS weather data (for 20 years) from *Expanded AMeDAS Weather Data 1981 – 2000* issued by the Architectural Institute of Japan (published in 2005).

Permission has been obtained from the Research Committee on Environment Engineering of the Architectural Institute of Japan and Meteorological Data System Co., Ltd. to publish the weather data on the LHEVE website only so that the data can be used as reference materials for Section 3.1 Use and Control of Wind of this document. Reproducing this information or employing it for other uses is not permitted.

Weather data on Naha and Kagoshima is listed on p.394 and 395.

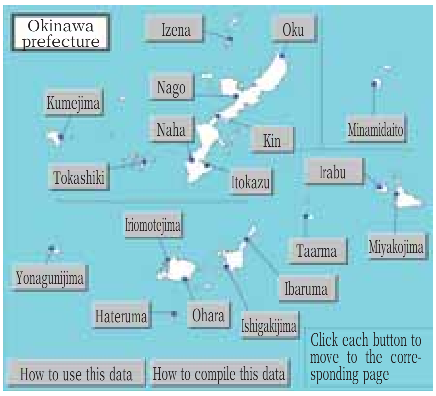


Fig. 1 Weather station map in Okinawa

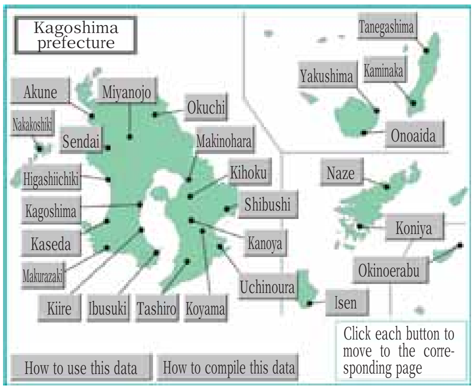


Fig. 2 Weather station map in Kagoshima

Table 1 Weather stations for obtaining weather data in hot humid regions

Indicates locations considered to fall under Zone V and Zone VI

Zone V

Prefecture name	Station name	Station number
Ibaraki prefecture	Kitaibaraki	309
	Daigo	310
	Ose	311
	Hitachi	312
	Kasama	313
	Mito	314
	Koga	315
	Tsukubasan	316
	Shimotsuma	317
	Hokota	318
	Nagamine	319
	Tsuchiura	320
	Kashima	321
	Ryugasaki	322
Tokyo	Ogouchi	358
	Oume	359
	Nerima	360
	Hachioji	361
	Fuchu	362
	Tokyo	363
	Shinkiba	364
	Ojima	365
	Nijima	366
	Miyakejima	367
	Hachijojima	368
	Chichijima	369
Chiba prefecture	Sawara	370
	Abiko	371
	Funabashi	372
	Sakura	373
	Choshi	374
	Yokoshiba	375
	Chiba	376
	Mobara	377
	Kisarazu	378
	Ushiku	379
	Sakahata	380
	Kamogawa	381
	Katsuura	382
	Tateyama	383
Shizuoka prefecture	Ikawa	428
	Gotenba	429
	Yoshiwara	430
	Mishima	431
	Sakuma	432
	Honkawane	433
	Shimizu	434
	Ajiro	435
	Shizuoka	436
	Tenryu	437
	Hamamatsu	438
	Makinohara	439
	Matsuzaki	440
	Inatori	441
	Fukude	442
	Omaezaki	443
	Irozaki	444
Mie prefecture	Kuwana	479
	Yokkaichi	480
	Kameyama	481
	Ueno	482
	Tsu	483
	Obata	484
	Kayumi	485

Prefecture name	Station name	Station number
Mie prefecture	Toba	486
	Nansei	487
	Kinagashima	488
	Owase	489
	Kumano	490
Wakayama prefecture	Katsuragi	594
	Wakayama	595
	Koyasan	596
	Shimizu	597
	Ryujin	598
	Kawanabe	599
	Kurisugawa	600
	Shingu	601
	Shirahama	602
	Nishikawa	603
	Shionomisaki	604
Tokushima prefecture	Ikeda	663
	Anabuki	664
	Tokushima	665
	Kyojo	666
	Kamoda	667
	Kito	668
	Hiwasa	669
	Shishikui	670
Ehime prefecture	Omishima	677
	Imabari	678
	Tanbara	679
	Niihama	680
	Mishima	681
	Matsuyama	682
	Nagahama	683
	Kuma	684
	Ozu	685
	Seto	686
	Uwa	687
	Uwajima	688
	Chikanaga	689
	Misho	690
Kochi prefecture	Hongawa	691
	Motoyama	692
	Odochi	693
	Kochi	694
	Gomen	695
	Aki	696
	Yusuhara	697
	Susaki	698
	Kubokawa	699
	Murotomisaki	700
	Ekawasaki	701
	Saga	702
	Sukumo	703
	Nakamura	704
	Shimizu	705
Yamaguchi prefecture	Susa	706
	Hagi	707
	Yuya	708
	Tokusa	709
	Akiyoshidai	710
	Hirose	711
	Nishiichi	712
	Yamaguchi	713
	Iwakuni	714
	Hohu	715
	Kudamatsu	716

Prefecture name	Station name	Station number
Yamaguchi prefecture	Kuga	717
	Shimonoseki	718
	Yanai	719
	Agenosho	720
Fukuoka prefecture	Munakata	721
	Yahata	722
	Yukuhashi	723
	Izuka	724
	Maebaru	725
	Fukuoka	726
	Dazaifu	727
	Soeda	728
	Amagi	729
	Kurume	730
	Kuroki	731
	Omuta	732
Oita prefecture	Kunimi	733
	Nakatsu	734
	Bungotakada	735
	Innai	736
	Kitsuki	737
	Hita	738
	Kusu	739
	Yufuin	740
	Oita	741
	Inukai	742
	Takeda	743
	Saiki	744
	Ume	745
	Kamae	746
Nagasaki prefecture	Waniura	747
	Izuhara	748
	Ashibe	749
	Hirado	750
	Matsuura	751
	Sasebo	752
	Arikawa	753
	Oseto	754
	Nagasaki	755
	Kinugasayama	756
	Shimabara	757
	Fukue	758
	Kuchinotsu	759
	Nomozaki	760
Kumamoto prefecture	Kahoku	766
	Minamioguni	767
	Taimei	768
	Kikuchi	769
	Aso/Kurokawa	770
	Kumamoto	771
	Asosan	772
	Takamori	773
	Misumi	774
	Kosa	775
	Matsushima	776
	Hondo	777
	Yatsushiro	778
	Minamata	779
	Hitoyoshi	780
	Ue	781
	Ushibuka	782
Miyazaki prefecture	Takachiho	783
	Furue	784
	Kuraoka	785

Prefecture name	Station name	Station number
Miyazaki prefecture	Nobeoka	786
	Hyuga	787
	Mikado	788
	Nishimera	789
	Takanabe	790
	Kakuto	791
	Saito	792
	Kobayashi	793
	Miyazaki	794
	Aoshima	795
	Miyakonojo	796
	Aburatsu	797
	Kushima	798
Kagoshima prefecture	Akune	799
	Okuchi	800
	Miyanojo	801
	Nakakoshiki	802
	Sendai	803
	Higashiichiki	804
	Makinohara	805
	Kagoshima	806
	Kihoku	807
	Kaseda	808
	Shibushi	809
	Kiire	810
	Kanoya	811
	Koyama	812
	Makurazaki	813
	Ibusuki	814
	Uchinoura	815
	Tashiro	816
	Tanegashima	817
	Kaminaka	818
	Yakushima	819
	Onoaida	820
	Naze	821
	Koniya	822
	Isen	823
	Okinoerabu	824

Zone VI

Prefecture name	Station name	Station number
Okinawa prefecture	Izena	825
	Oku	826
	Nago	827
	Kin	828
	Kumejima	829
	Tokashiki	830
	Naha	831
	Itokazu	832
	Minamidaito	833
	Irabu	834
	Miyakojima	835
	Tarama	836
	Ibaruma	837
	Yonagunijima	838
	Iriomotejima	839
	Ishigakijima	840
	Ohara	841
	Hateruma	842

Location name	**Naha**	Location number	831

Latitude (°) (North latitude)	26.2	Longitude (°) (East longitude)	127.7	Measurement point altitude (m)	28	Anemometer height (m)	47.7

● Average wind speed (m/s)

Waking hours	Sleeping hours	Entire day
3.5	2.8	3.3

* Mean value from June to September in Fig. 2

Back to Table of Contents

● Table for determining directions suitable for creating opening surfaces

	Direction	North	North-north east	Northeast	East-northeast	East	East-southeast	Southeast	South-southeast	South	South-southwest	Southwest	West-southwest	West	West-northwest	Northwest	North-northwest
Windward	Waking hours	×	△	△	○	○	◎	◎	◎	◎	○	○	○	△	×	×	×
	Sleeping hours	×	△	△	○	◎	◎	◎	◎	◎	○	○	△	×	×	×	×
Leeward	Waking hours	◎	○	○	○	△	×	×	×	×	△	△	○	○	◎	◎	◎
	Sleeping hours	◎	○	○	△	×	×	×	×	×	△	△	○	◎	◎	◎	◎

* Judgment criteria: In the "June-September" data in Fig. 1, 40% or higher is ◎, 30 - 40% is ○, 20 - 30% is △, and 20% or below is ×.

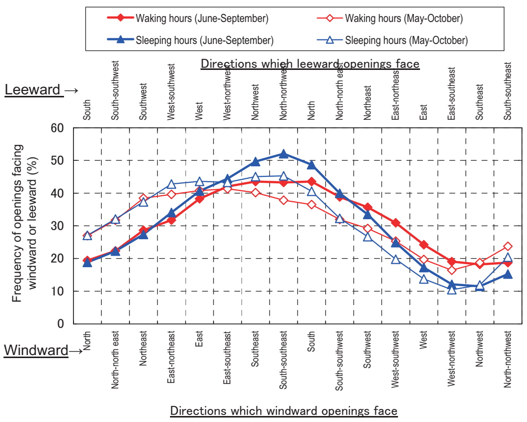


Fig. 1 Frequency of openings facing windward and

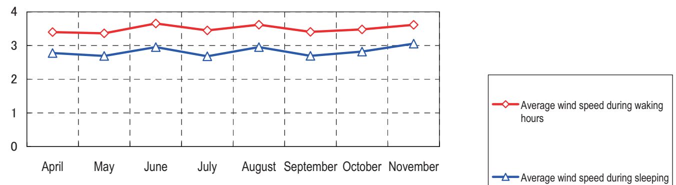


Fig. 2 Average wind speed

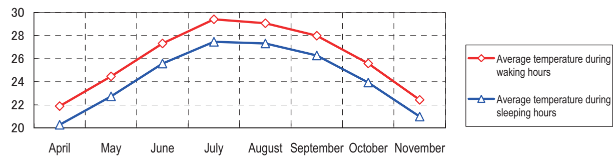


Fig. 3 Average temperature

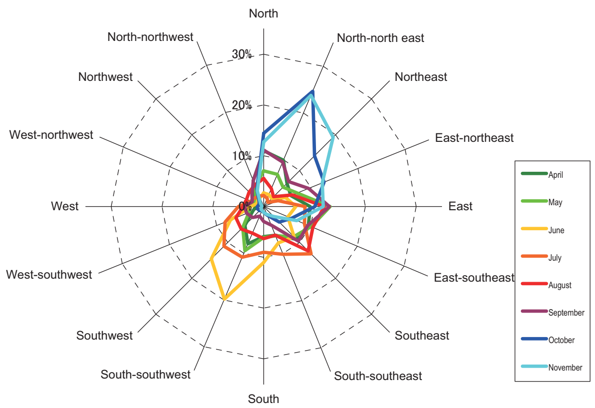


Fig. 4a Monthly wind rose (Waking hours)

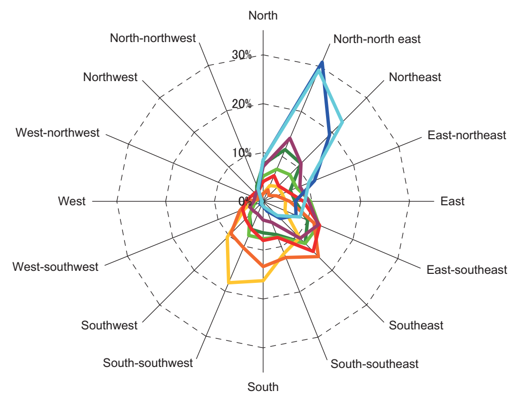


Fig. 4b Monthly wind rose (Sleeping hours)

Monthly weather data table

		April		May		June		July		August		September		October		November	
		Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours
Average temperature (°C)		21.9	20.3	24.5	22.7	27.3	25.6	29.4	27.5	29.1	27.3	28.0	26.3	25.6	23.9	22.4	21.0
Average relative humidity (%)		75	81	77	84	81	89	76	85	77	85	74	81	70	77	67	73
Average wind speed (m/s)		3.4	2.8	3.4	2.7	3.7	3.0	3.4	2.7	3.6	3.0	3.4	2.7	3.5	2.8	3.6	3.1
Wind direction	First direction	North 11%	Southeast 12%	East 13%	East-southeast 12%	South-southwest 20%	South-southwest 18%	Southeast 13%	Southeast 16%	Southeast 12%	Southeast 15%	East 13%	North-north east 14%	North-north east 25%	North-north east 31%	North-north east 24%	North-north east 29%
	First direction	North-north east 10%	North-north east 12%	East-southeast 10%	Southeast 12%	Southwest 15%	South 16%	Southwest 11%	South 13%	East 12%	East-southeast 13%	North 11%	East-southeast 12%	North 14%	Northeast 19%	Northeast 19%	Northeast 23%
	Third direction	East-southeast 10%	Northeast 11%	South-southwest 9%	East 10%	South 11%	South-southeast 11%	South-southwest 11%	South-southeast 12%	East-southeast 11%	East 8%	Southeast 10%	Northeast 11%	Northeast 14%	East-northeast 11%	North 13%	East-northeast 10%

* This data was created based on the expanded AMeDAS weather data (for 20 years) from *Expanded AMeDAS Weather Data 1981 - 2000* issued by the Architectural Institute of Japan (published in 2005, http://www.metds.co.jp/).
* This data can be used as reference materials for "3.1 Use and Control of Wind" of Design Guidelines for Low Energy Housing with Validated Effectiveness. Permission has been obtained from the Research Committee on Environment Engineering of the Architectural Institute of Japan and Meteorological Data System Co., Ltd. to publish the weather data on the Design Guidelines for LHEVE website only (www.jjj-design.org). Please refrain from reproducing this information or employing it for other uses.
* In this data, waking hours are from 7:00 to 22:00 and sleeping hours are 23:00 to 6:00.
* For details regarding how to use this data and how it was created, please see "3.1 Use and Control of Wind" of Design Guidelines for Low Energy Housing with Validated Effectiveness" and p.002 - 003 of this PDF file.

Location name	**Kagoshima**	Location number	806

Latitude (°) (North latitude)	31.6	Longtitude (°) (East longtitude)	130.6	Measurement point altitude (m)	4	Anemometer height (m)	44.8

Back to Table of Contents

● Average wind speed (m/s)

Waking hours	Sleeping hours	Entire day
2.2	1.6	2.0

* Mean value from June to September in Fig. 2

● Table for determining directions suitable for creating opening surfaces

	Direction	North	North-north east	Northeast	East-northeast	East	East-southeast	Southeast	South-southeast	South	South-southwest	Southwest	West-southwest	West	West-northwest	Northwest	North-northwest
Windward	Waking hours	△	△	△	△	○	○	○	○	○	△	△	○	○	○	○	△
	Sleeping hours	◎	◎	○	△	△	×	×	×	×	×	×	△	○	◎	◎	◎
Leeward	Waking hours	○	△	△	○	○	○	○	△	△	△	△	△	○	○	○	○
	Sleeping hours	×	×	×	△	○	◎	◎	◎	◎	◎	○	△	△	×	×	×

* Judgment criteria: In the "June-September" data in Fig. 1, 40% or higher is ◎, 30 - 40% is ○, 20 - 30% is △, and 20% or below is ×.

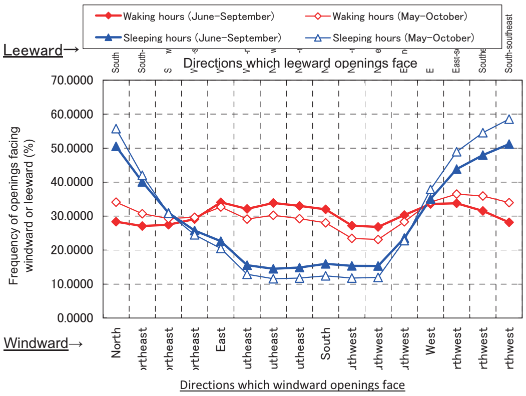


Fig. 1 Frequency of openings facing windward and leeward

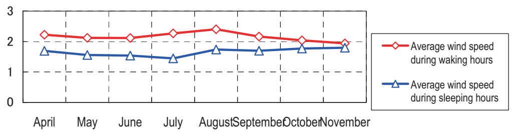


Fig. 2 Average wind speed

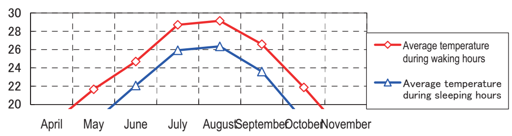


Fig. 3 Average temperature

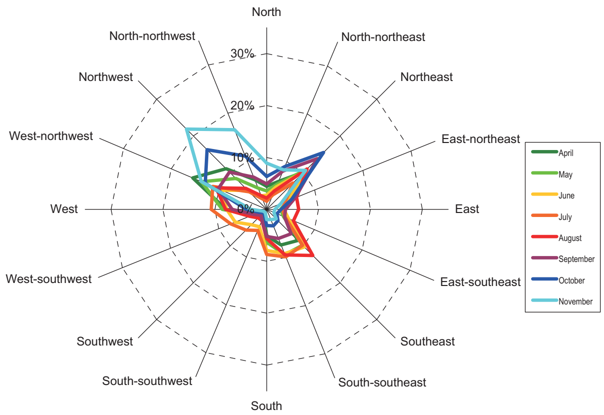


Fig. 4a Monthly wind rose (Waking hours)

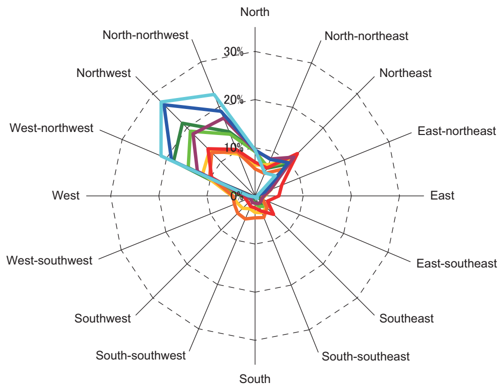


Fig. 4b Monthly wind rose (Sleeping hours)

Monthly weather data table

		April		May		June		July		August		September		October		November	
		Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours	Waking hours	Sleeping hours
Average temperature (°C)		17.9	14.3	21.7	18.1	24.7	22.1	28.7	25.9	29.1	26.4	26.6	23.6	21.9	18.2	16.7	13.1
Average relative humidity (%)		64	78	66	81	74	85	72	84	71	83	68	81	63	77	64	77
Average wind speed (m/s)		2.2	1.7	2.1	1.6	2.1	1.5	2.3	1.4	2.4	1.7	2.2	1.7	2.0	1.8	1.9	1.8
Wind direction	First direction	West-northwest 15%	Northwest 21%	West-northwest 14%	Northwest 19%	Northeast 10%	Northwest 13%	West-northwest 11%	Northwest 13%	Southeast 13%	Northwest 14%	Northeast 14%	Northwest 18%	Northwest 16%	Northwest 27%	Northwest 22%	Northwest 28%
	Second direction	Northwest 11%	West-northwest 18%	Northeast 11%	West-northwest 15%	Southeast 10%	West-northwest 12%	West 11%	West-northwest 10%	Northeast 11%	Northeast 12%	Northwest 10%	North-northwest 17%	Northeast 15%	North-northwest 19%	North-northwest 17%	North-northwest 23%
	Third direction	Northeast 10%	North-northwest 14%	Southeast 10%	North-northwest 14%	West-northwest 9%	Northeast 11%	South-southeast 10%	North-northwest 10%	West-northwest 11%	North-northwest 10%	West-northwest 10%	West-northwest 13%	West-northwest 13%	West-northwest 19%	West-northwest 14%	West-northwest 21%

* This data was created based on the expanded AMeDAS weather data (for 20 years) from *Expanded AMeDAS Weather Data 1981 - 2000* issued by the Architectural Institute of Japan (published in 2005, http://www.metds.co.jp/).
* This data can be used as reference materials for Section 3.1 Use and Control of Wind of *Design Guidelines for Low Energy Housing with Validated Effectiveness*. Permission has been obtained from the Research Committee on Environment Engineering of the Architectural Institute of Japan and Meteorological Data System Co., Ltd. to publish the weather data on the Design Guidelines for LHEVE website only (www.jjj-design.org). Please refrain from reproducing this information or employing it for other uses.
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* For details on how to use this data and how it was created, please see "3.1 Use and Control of Wind" of Design Guidelines for Low Energy Housing with Validated Effectiveness" and p.002 - 003 of this PDF file.

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