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Chapter 5

Case Study: Detached House Designed by Following the Control System

Kazutoshi Fujihira

Additional information is available at the end of the chapter

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Abstract

The previous chapter has demonstrated the control system for promoting sustainable housing design in which the sustainable design guidelines and sustainability checklist are incorporated. Following this control system, we have actually designed and constructed a detached house. To be concrete, the homeowner and the architects of the housing manufacture have designed the home's parts, or elements, so that as much as possible the elements' variables meet their desired values. The sustainable design guidelines and sustainability checklist have been readily accepted because the material and spatial elements are equivalent to real parts of the home. After the home started to be used, we have obtained external evaluations of the home's sustainability performance. For example, CASBEE for Detached Houses, a comprehensive assessment system, has readily ranked the house in the highest "S." An energy-saving performance assessment has shown that this home has reduced energy consumption by over 70%, as compared with the average home. On the other hand, the reactions of the occupants and visitors have indicated the comfort, healthiness and safety of this house. Furthermore, this home has received a sustainable housing award, especially due to its extremely high sustainability and energy-saving performance.

Keywords: sustainable design guidelines, sustainability checklist, energy-saving performance, sustainable housing award

1. Introduction

The preceding chapter has shown the methodology of applying control system to sustainable housing design. Utilizing this methodology, we have conducted a case study. That is to say, following the control system for promoting sustainable home design, we have designed a home and constructed it. After the home began to be used, we have obtained evaluations of the home's environmental and sustainability performance.

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The remaining three sections of this chapter illustrate the case study. The next section describes the design process of this house. Section 3 shows the results of the design and construction with many photos and diagrams. The last section demonstrates the environmental and sustainability performance of this house.

2. Design process

Building design process is divided into basic design and detailed design. In this case study, the homeowner, who is the author of this monograph, made the basic design by himself. Subsequently, the homeowner made a contract with a homebuilder whose skills appeared enough to satisfy the variables' desired values, which have been demonstrated in Table 2 of Chapter 4 [1]. After the contract, this homebuilder made the detailed design and constructed the house.

In the basic design stage, the homeowner used the "sustainable design guidelines" and "sustainability checklist," in addition to following related laws and regulations. To be concrete, he made the site plan, floor plans, and elevations, taking the information of relevant material and spatial elements into consideration. When arranging rooms of the house, first of all, he referred to two spatial elements: "specified bedroom" and "areas relating to water use and hot water supply." Subsequently, when determining the floor space of rooms and other areas, he considered spatial elements related to accessibility, such as "stairs," "specified bedroom," "toilet," and "bathroom." After that, the homeowner planned the elevation, considering several elements' variables. He determined "position and area of windows," taking daylighting and natural ventilation into consideration. He also considered variables of material elements related to basic plan, including sunlight adjustment capability of "windows," shape of "exterior," and energy harnessed by "equipment for harnessing natural energy." Furthermore, when making the exterior and garden plan, he mainly referred to three spatial elements: "garden area," "main access route to the entrance," and "slope."

When the detailed design stage began, the homeowner requested the designers of the homebuilder to refer to the "sustainable design guidelines" and "sustainability checklist." The designers readily accepted them since the material and spatial elements in the guidelines and checklist are equivalent to actual parts of the home [1]. Subsequently, examining the basic design results and various conditions, the designers and homeowner determined the site plan, floor plans, elevation, and fundamental specifications. Next, the designers of the homebuilder designed the home's elements, including framework, exterior, windows and doors, interior, and doorways, so that as much as possible, the elements' variables satisfy their desired values [1].

After the detailed design finished, we obtained building confirmation and Long-life Quality Housing (LQH) certification. After that, the home, a two-story wooden detached house, was built in a residential district on the outskirts of Tokyo.

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3. Results of the design and construction

This section shows the results of the design and construction, in accordance with the elements and their variables.

First, **Figure 1** demonstrates the site plan and floor plans in which the descriptions of five spatial elements are included.

- Total floor

We have identified "total floor area" as a variable, following the certification criteria of the LQH. The LQH certification requires "75 m^2 or more" as the criterion of the total floor area of detached houses. This criterion adds the proviso that at least one story's floor area (excluding stairs) is "40 m^2 or more" [2].

The total floor area of this detached house is 122.96 m^2; both the areas of the house's first and second floor (excluding stairs) exceed 40 m^2. These figures sufficiently satisfy the desired value, which has led to the LQH certification.

- Specified bedroom

A "specified bedroom" means a bedroom which is used or expected to be used by elderly or wheelchair users [3]. When the owner couple moved into this house, they were in their late 50s and not disabled. However, in order to prepare for their future, we have considered this bedroom as a specified bedroom [1].

In this house, their bedroom and other essential areas for daily life, namely toilet, bath, dining room, kitchen and entrance, all have been placed on the first floor [1]. This floor planning enables them to have easy access to such areas without any steps [1].

Meanwhile, the "internal floor space" of this specified bedroom is 12.6 m^2, which has fulfilled the desired value, 9 m^2 or more.

- Areas relating to water use and hot water supply

"Areas relating to water use and hot water supply," namely bath, kitchen, washing room, toilet, and a place to put the water heater, have been placed closer [1]. This arrangement leads to reduction of heat loss from hot water piping. Moreover, this consideration reduces the total length of water and hot water piping and drainage piping [1].

- Position and area of windows

Considering natural ventilation and daylighting, we have determined "position and area of windows" of this home.

We have located windows so as to allow breezes in and heat out. As shown in **Figure 1** and **Table 1**, all of the four living spaces, namely living/dining room & kitchen, bedroom, multipurpose room, and study, have windows which face two or three directions. This arrangement of the windows meets the desired value, "Level 5" of the CASBEE's relevant item. In

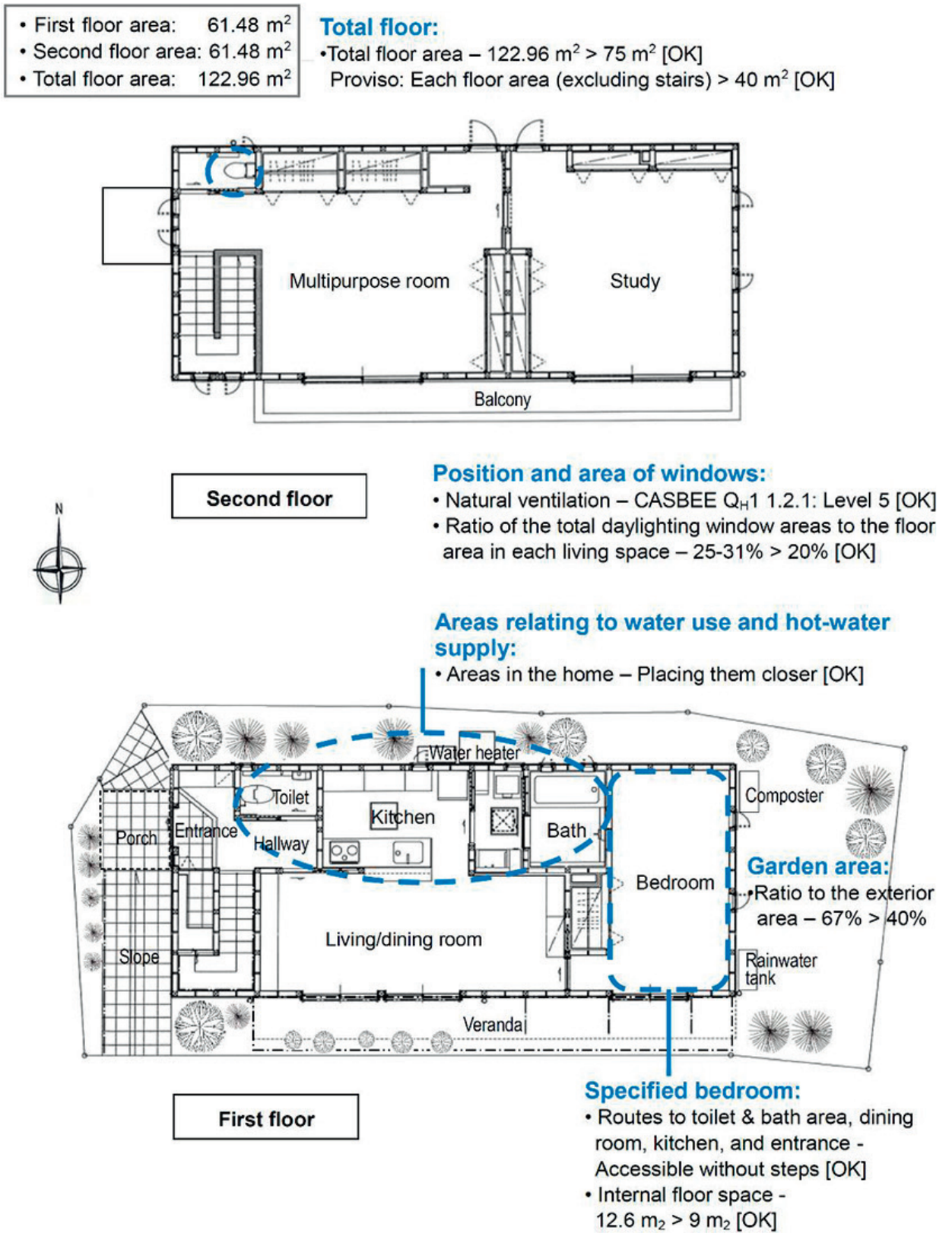


Figure 1. Site and floor plans.

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Floor	Living space	Directions windows face (natural ventilation)	Ratio of the total window area to the floor area (daylighting) (%)
First	Living/dining and kitchen	South, North	28.5
	Bedroom	South, East	30.7
Second	Multipurpose room	South, North, West	25.6
	Study	South, East, North	26.2

Table 1. Natural ventilation and daylighting of the living spaces of this home.

addition, all of the inside doors are the sliding type, which enables the whole house easily to secure paths for natural ventilation.

In order to take sufficient daylight in, we have secured larger window areas, especially on the southern side of each living space. As demonstrated in **Figure 1** and **Table 1**, the ratios of the window area to the floor area in the four living spaces range between 25 and 31%. These values have substantially satisfied the desired value, 20% or more.

- Garden area

In this building site, the "garden area" surrounds the areas of the house, veranda, approach to the entrance, and subsidiary equipment such as the rainwater tank, as demonstrated in **Figures 1** and **2**. The garden area and the total exterior area are 45.9 and 68.7 m^2, respectively. Therefore, the "ratio of the garden area to the total exterior area" is 67%, which satisfies its desired value, 40% or more. In the garden area of this home, various kinds of trees, shrubs, and herbs have been planted. Moreover, in a part of the garden area near the rainwater tank and composter, several kinds of vegetables are cultivated every year.

Figure 3 shows external appearance, including panoramic views in winter and summer, with the descriptions of two material elements: "exterior" and "windows and doors."

- Exterior (outer wall, roof, etc.)

In order to restrain the spread of fire, fire resistance of outer walls and eaves soffit is important. The outer walls of this home, made of ceramic siding, can block flames for 60 minutes or more. Similarly, the eaves soffit can block flames for 45 minutes or more. These fire resistance capacities fulfill the desired value, "Grade 3" in the "Fire resistance grades" of JHPIS.

The landscape of this area includes disorder; therefore, we have strived to make it more attractive through the construction of this house. The "shape" is simple but accented by the balcony; the "color" of the outer walls, light beige, is coordinated with the colors of other parts such as the windows, entrance porch, and rainwater pipes. The solar panels have been placed not on roof materials but on sheathing roof boards so that the roof surface is almost flat. We are expecting that these considerations bring harmony and stability to the landscape.



Figure 2. Plants in the garden area.

The roof is almost entirely covered with solar panels; therefore, when evaluating the "durability" of the exterior, we have focused on outer walls. Durability of ceramic siding, this home's outer wall material, is expected to 40 years [4]. A service life of 40 years is assessed at "Level 3" in the assessment levels of the "Exterior wall materials" of CASBEE. However, this house uses an installation method that does not damage the building structure and window sashes when exterior wall materials are replaced. As a result, the assessment grade has been raised to "Level 4," which has met the desired value.

Meanwhile, we could not utilize "materials" which promote resource saving or waste prevention, such as recycled, renewable, and recyclable material, due to financial restrictions. As a result, the assessment level of this variable has fallen below the desired value.

- Windows and doors

All of the "windows" of this house are combined sash of aluminum and resin, which is high in both thermal insulation and strength, with low radiation double glazing. The thermal insulation performance of all large windows has been graded as "H-1," the highest in the classification of the Japanese Industrial Standards. Meanwhile, the entrance "door" is a metal flush door filled up with heat-insulating materials. The installation of the above windows and door has led to "Q = 1.9 W/(m^2 * K)" as thermal loss coefficient of this house. This value has met the desired value of thermal loss coefficient in the area where Tokyo is included, namely "Q = 2.7 W/(m^2 * K) or less," which is equivalent to "Grade 4" in the "Energy-saving action grades (Thermal insulation performance grades)" of JHPIS [5].

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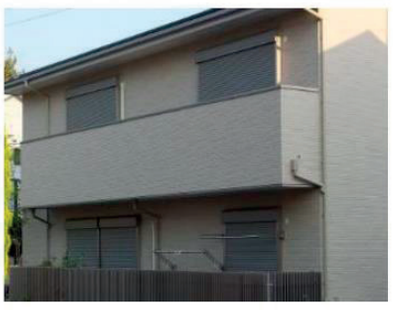




In order to adjust sunlight, related elements, such as eaves and even plants, work with windows' glass and lace curtains.

Windows and doors:

- Thermal insulation performance – JHPIS 5-1: Grade 4 [OK]
- Sunlight adjustment capability – CASBEE Q_H1 1.1.2: Level 5 > Level 4
- Sound insulation performance – CASBEE Q_H1 4: Level 5 > Level 4
- Measures to prevent intrusions – CASBEE Q_H1 2.3: Level 3 [No]
- Protection of glass against impacts – With shutters (large windows) [OK]



Exterior (outer wall, roof, etc.):

- Fire resistance (outer wall) – JHPIS 2-6: Grade 3 [OK]
- Shape & color – Consideration for the landscape [OK]
- Durability – CASBEE Q_H2 1.2 & 1.3: Level 4 [OK]
- Materials – CASBEE LR_H2 1.3: Level 1 [No]

Figure 3. External appearance.

Meanwhile, the "sunlight adjustment capability" of the windows facing south attains "Level 5" in the assessment levels of the CASBEE's relevant item [1]. "Level 5" requires that the sunlight penetration ratio of the subject windows can be adjusted to 0.6 or over in the winter and 0.3 or less in the summer [4]. The glass of the windows on the south side allows 63% of sunlight to penetrate to the rooms, which surpasses the desired value in winter, 60%. In the summer, in addition to the window glass and lace curtains, the balcony and the roof with pendent eaves can block the strong sunlight from entering the four living spaces, as shown in the left photo of **Figure 3**. The total reduction ratio amounts to 0.73; therefore, the sunlight penetration ratio in the summer can be reduced to 0.27. On the other hand, the deciduous tree that has been planted in front of the stairs' windows, blocks strong sunlight in the summer from entering the staircase. Accordingly, in this case, in addition to windows themselves, eaves, curtains, and even a tree work together, so as to control sunlight penetration.

The "sound insulation performance" of the windows has been classified as "Grade 3" in the "Transmission loss grades" of the JHPIS. "Grade 3" is equivalent to "Level 5," the highest level in the assessment levels of the CASBEE's relevant item, which has satisfied the desired value, "Level 4 or over." In addition, "Grade 3" in the "Transmission loss grades" meets 25db or more of sound transmission loss, measured by one third octave band analysis [5].

The entrance door of the home is equipped with two locks. The three double-sliding windows which face the veranda are equipped with shutters. These installations are equivalent to "effective measures to prevent intrusion" described in the section of the "Precautions against crimes" of CASBEE. On the other hand, only basic measures to prevent intrusion have been taken for the outward opening windows in the bedroom and kitchen. As a result, this home's anti-crime performance has been assessed at "Level 3" in the assessment levels of the relevant CASBEE's section.

As demonstrated in the bottom right-hand photo of **Figure 3**, "shutters" have been installed on the large windows which face south. The installment of these shutters have been aimed at protecting the glass against impacts, including fire, hurricane, and flying objects [1]. This installment can also reduce the risk of being damaged by the adverse impacts of climate change, such as typhoons [1], which are projected to increasingly become more severe.

- Equipment for harnessing natural energy

As demonstrated in **Figure 3**, the greater part of the single-pitch roof is covered with solar panels. The total power generation capacity of the 49 solar panels amounts to 11.4 kW. In the 1 year immediately after moving-in, this solar system generated the electricity of 15,911 kWh [1]. In the same period, the energy consumed in this house has been 3085 kWh [1]. Thus, as shown in **Figure 4**, the energy self-sufficiency reached a surprising 516%, which substantially exceeded the desired value, 100% [1].

The solar-generated electricity is preferentially used in this home and the surplus electricity is transmitted to the power grid. The electricity transmitted to the power grid is used by the neighboring electricity consumers including surrounding households.

In addition, equipment for harnessing natural energy secures alternative energy sources and increases resilience, or passive survivability in crises. Therefore, it is recognized as an "adaptation" measure as well as "mitigation" [6–8].

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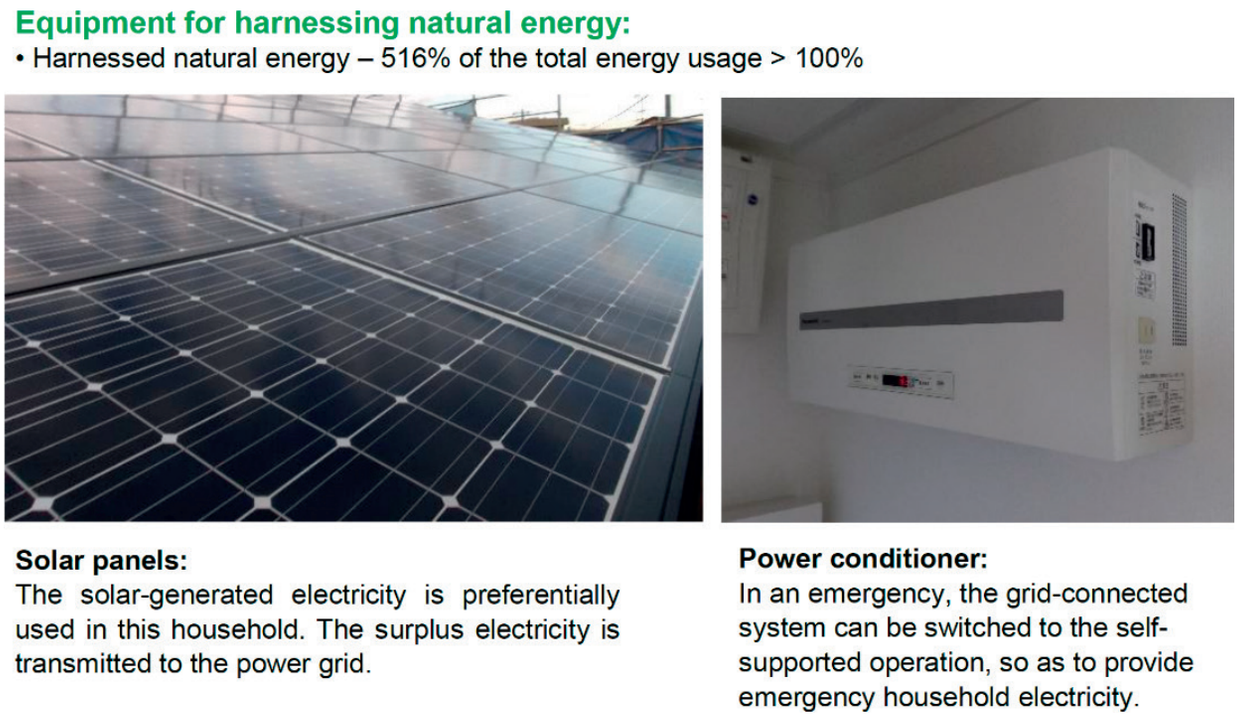


Figure 4. Equipment for harnessing natural energy.

- Framework

This home has been designed so that the "resistance to earthquakes" of the framework meets "Grade 3" in the Seismic resistance grades of JHPIS (**Figure 5**), which surpasses the required level, Grade 2. "Grade 3," the highest grade, means that the building can withstand 1.5 times the strength of an earthquake stipulated in the Building Standards Act of Japan, as an earthquake that occurs very rarely, that is, once every several 100 years [5].

The "durability" of the framework meets the desired value, that is, "Grade 3" in the Deterioration resistance grades of JHPIS [1]. "Grade 3," the highest grade, requires measures to extend the period of time between the construction and the first large-scale renovation up to three generations (about 75–90 years) or more, under ordinarily assumed conditions and maintenance [5].

More than half of the "material" used in this wooden house's framework has been produced from domestic sustainable forests. More specific, we have used wood from Fukushima Prefecture, Tohoku Region. In addition, the legality and sustainability of the wood are certified by a Japanese forestry organization, the *Mokuzai-Hyoji-Suishin-Kyogikai*, the English name of which is the Forest-products Identification Promotion Conference (FIPC). In the bottom left-hand photo of **Figure 5**, the mark of "FIPC" can be seen on the label put on the wood. These considerations meet the criterion of "Level 5," the highest level, of the CASBEE's "Materials useful for resource saving and waste prevention" [4].

- Thermal insulation

Rigid polyurethane foam and extruded polystyrene form are used as thermal insulation materials of this home. Boards of rigid polyurethane foam, one of the most efficient high performance insulation material with minimal occupation of space [9, 10], are placed in the walls facing outside as well as on the ceiling of the second floor (**Figure 5**, right). Boards of extruded



Figure 5. Framework and thermal insulation.

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polystyrene foam, features of which includes greater insulating power and higher resistance to compression and moisture [9, 10], are installed on the base and earth slab concrete.

The installation of the above thermal insulation boards enables the home's insulation performance to achieve the desired value, the highest grade in the "Energy-saving action grades" of JHPIS. To be concrete, the heat loss coefficient (Q) of this house is "Q = 1.90 W/(m^2 * K)." This value is substantially better than the target value of heat loss coefficient of the classified area where Tokyo is included, namely "Q = 2.70 W/(m^2 * K)."

Figure 6 illustrates three material elements, namely "interior," "appliances," and "lighting fixtures".



Figure 6. Interior, appliances, and lighting fixtures.

- Interior

Interior, including floors, walls, and ceilings, requires "measures against formaldehyde" as a significant variable. Formaldehyde, a colorless, strong-smelling gas, is used in making building materials and many household products; exposure to formaldehyde can cause adverse health effects, such as irritation of the skin, eyes, nose, and throat [11]. We have set the desired value of "measures against formaldehyde" at "Level 5" of the "Countermeasures against chemical contaminants" of CASBEE. "Level 5," which is equivalent to "Grade 3" in the relevant item of the JHPIS, requires that formaldehyde emissions from interior finish and base materials are "extremely low" [4, 5]. Meanwhile, all of the interior finish and base materials used in this home have been "F-four-star" certified products by the Japanese Industrial Standards or Japanese Agricultural Standards. Overall utilization of "F-four-star" certified products has satisfied the desired value [1].

Three kinds of "materials" which promote resource saving or waste prevention have been used for the interior finishing and sheathing materials of this home. The product used for wall sheathing and ceiling sheathing is plasterboard made of desulfurized plaster. The tiles laid on the entrance floor are made of waste silica sand and waste clay from ceramic industry. Interior fixtures such as the sliding doors and door frames are made of recycled medium density fiberboard. On the other hand, we could not use recycled, renewable and recyclable materials for the wall and ceiling finishing and floor sheathing. As a result, the variable "materials" of interior has been evaluated at "Level 3" in the assessment levels of the relevant item of CASBEE, which has not reached the desired value.

- Appliances

Home appliances are necessary to be energy-saving devices. We have identified the variable of such appliances as the "Energy-saving standard achievement rate" and set their desired value at "100% or more" in principle. Instead of "100% or more," "three or more stars" has been identified as its desired value for several kinds of appliances including air conditioners, refrigerators and televisions.

All of appliances used in this home are energy efficient. For example, the energy-saving standard achievement rates of the refrigerator, television, and air conditioner are "five stars," "five stars," and "four stars," respectively. These rating levels have satisfied the desired value, "three or more stars."

- Lighting fixtures

All of the "lighting fixtures" of this house use "LED" lights, which meets the desired value.

In addition, the lighting fixtures in the four living spaces, namely the living room, bedroom, study and multipurpose room, are equipped with dimmer device. By operating dimmer remote control, the occupants can adjust the brightness of the light, as need demand.

- Water heater

We have selected an "electric heat pump water heater" as hot water supply equipment. Heat pump water heaters take the heat from surrounding air and transfer it to water in an enclosed

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tank. Heat pump water heaters use electricity to move heat from one place to another, instead of generating heat directly [12, 13]. Therefore, they can be much more energy efficient than conventional electric resistance water heaters.

The utilization of an electric heat pump water heater meets the desired value, "Level 5" in the assessment levels of the CASBEE's relevant item. In addition, the heat pump water heater used in this home (**Figure 7**) can produce three times as much heat energy as consumed electric energy.

- Piping

"Piping," including drainage pipes, water pipes and gas pipes, needs "measures for maintenance" as an important variable toward a long service life. The "measures for maintenance" of this home has achieved the highest level in the Maintenance grades of the JHPIS, Grade 3 (**Figure 8**, left). The Grade 3 requires "creating openings for cleaning and inspection," in addition to the basic provisions such as "not burying piping under concrete" [5].

"Method of water and hot water piping," the other variable of piping, requires "header and pipe-in-pipe system" as its desired value. Recently, the header and pipe-in-pipe system has



Figure 7. Water heater.

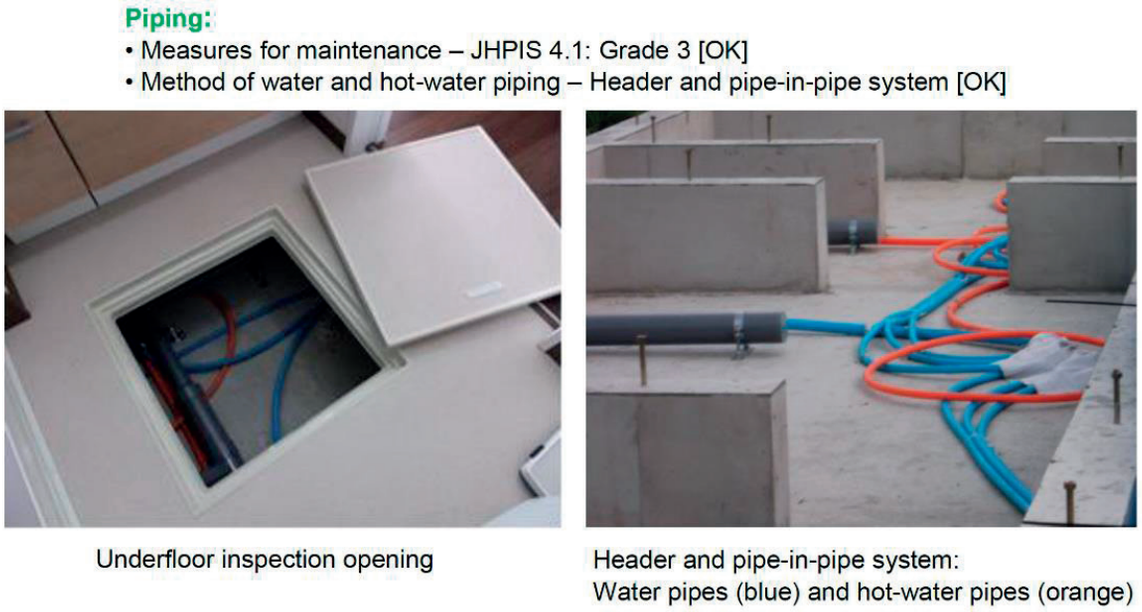


Figure 8. Piping.

been becoming widespread in Japan, due to its several advantages, including easy maintenance, easy piping work, and energy efficiency. Consequently, we have naturally adopted this piping method and achieved the desired value (**Figure 8**, right).

- Water-using equipment

"Water-using equipment," including toilet bowls, faucets, and shower heads, requires "water-saving functions" as its key variable. The water-using equipment of this home includes three types of water-saving functions: water-saving type toilets, kitchen thermostat type water faucet, and bathroom thermostat type water faucet plus water-saving shower head equipped with hand-operated water-shutoff mechanism (**Figure 9**, left). The inclusion of the three functions has led to "Level 5" in the five levels of the "Water-saving systems" of CASBEE [4].

- Bathtub

As illustrated in the right of **Figure 9**, the bathtub used in this home is "insulated," which meets the desired value. This type of bathtub sets conforms to the "High thermal insulation bathtub" of Japan Industrial Standards. This insulated bathtub and lid can control temperature drop of the warm water in the bathtub within 2.5° as long as 4 hours [14].

Figure 10 illustrates four spatial elements, namely "bathroom," "toilet," "hallway," and "stairs."

- Bathroom

When designing this home, we have selected a relatively large prefabricated bath unit with a handrail. In addition, recently modular bathrooms are widely used in Japan. The internal width of this bath unit is 160 cm, which has met the criterion, namely 130 cm or more. The internal floor

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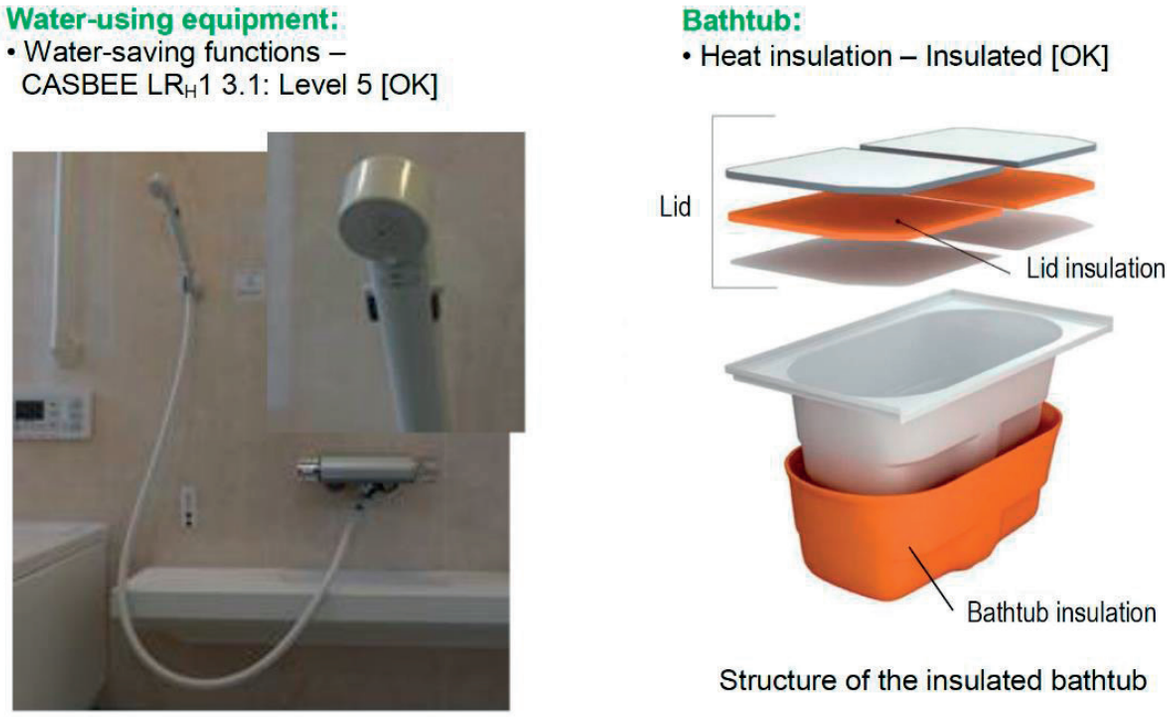


Figure 9. Water-using equipment and bathtub [14].

space of this bath unit is 3.2 m^2, which also has satisfied the criterion, 2 m^2 or more. Meanwhile, the installed handrail can help users to go in and out of the bathtub.

- Toilet

The toilet on the first floor has a larger area than usual Japanese toilet areas. The internal length of the space is 169 cm, which has met the criterion, namely 130 cm or more. The spacing from the front rim of the toilet bowl to the wall is 98 cm, which has sufficiently surpassed the target figure, 50 cm.

As shown in the bottom left-hand photo of **Figure 10**, "handrails" are installed beside the toilet bowl, so as to help users to sit and stand. The vertical handrail is a common cylindrical bar; the horizontal handrail doubles as a shelf.

- Hallway

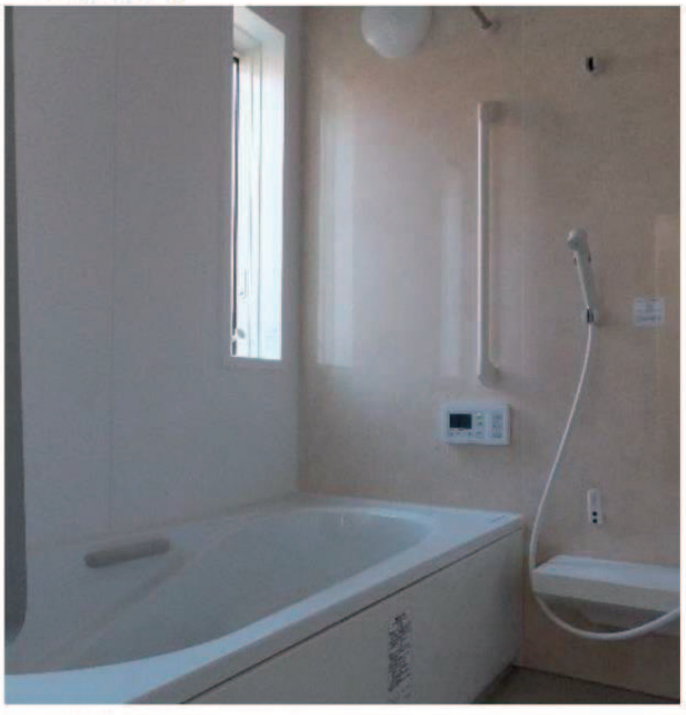
We have designed the hallway, which connects the entrance and the doors for the living and dining room and the toilet, considering future possibilities of wheelchair usage. The "width" of this hallway is 104 cm, which has satisfied the desired value, 78 cm or more.

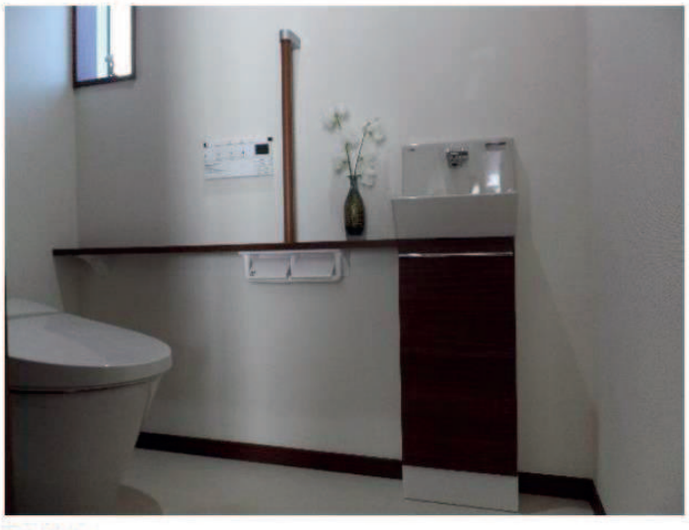
- Stairs

We have designed the stairs in this home, so as to meet higher safety requirements. The three numerical values relating to "grade of steepness" of the stairs, namely (1) rise/run, (2) rise * 2 + run, and (3) run, are "18/25," "610," and "250 mm," respectively. These figures have satisfied the following criteria: (1) rise/run ≤22/21, (2) 550 mm ≤ (rise * 2 + run) ≤ 650 mm, and

Bathroom:

- Width – 160 cm > 130 cm [OK]
- Floor space – 3.2 m^2 > 2 m^2 [OK]
- Handrail helps users go in out of the bathtub – Installed [OK]





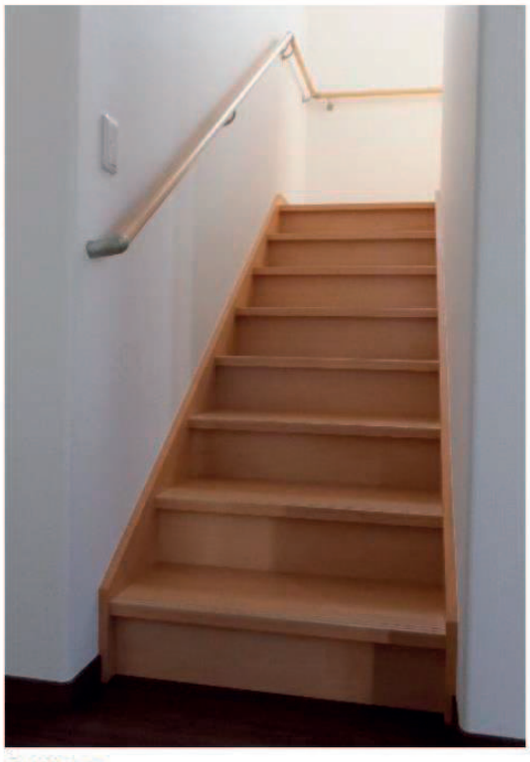
Toilet:

- Length – 169 cm > 130 cm [OK]
- Spacing from the front rim of the toilet bowl to the wall – 98 cm > 50 cm [OK]
- Handrails help users sit and stand – Installed [OK]

Hallway:

- Width – 104 cm > 78 cm [OK]





Stairs:

- Grade of steepness:
  Rise/Run – 18/25 < 22/21 [OK]
  (Rise * 2 + run) – 610 mm < 650 mm [OK]
  Run – 250 mm > 195 mm [OK]
- Handrail – Installed [OK]

Figure 10. Bathroom, toilet, hallway, and stairs.

(3) run ≥195 mm. Accordingly, the "grade of steepness" of the stairs fulfills the desired value, "Grade 3" of the JHPIS's relevant item. Meanwhile, a "handrail" has been "installed" on one side, which has also met the desire value.

- Doorways

Figure 11 demonstrates "doorways," focusing on "difference in level" and "width." All of the doorways in this home have no difference in level. The width of the doorways on the first floor except for the bathroom is 75 cm and that for the bathroom is 67 cm, both of which have met the desired values, 75 cm and 60 cm.

In addition, at the entrance door, traditionally stepped thresholds help with weather protection. Level access requires consideration of alternative solutions to maintain appropriate protection from the wet weather. In this case, a grated drain and a larger cover over the porch play a role of limiting the quantity of water around the entrance door area.

- Main access route to the entrance and slope

In the case of this home, "main access route to the entrance" is the path from the southern frontal road to the entrance porch, as shown in the upper left photo of **Figure 12**. In order to achieve stepless approach, the area that connects the frontal road and the porch has a sloping "surface." Meanwhile, the "width" of this access route is 140 cm, which has easily met the desired value, 90 cm or more.

The level difference between the frontal road and the porch is 45 cm; the horizontal distance of the slope is 410 cm. Consequently, the "grade of steepness" of the "slope" is approximately 1/9, which reaches the desired value, 1/8 or less. Moreover, a "handrail" has been "installed" on one side, which has also satisfied the desire value.

- Outdoor facilities (Fence, etc.)

When designing the exterior of this home, we have strived to make it open and ecological. The approach area on the west side of this lot is not enclosed by any fences and door gates. The garden area, which covers two-third of the exterior area, is not also fenced. However, we have surrounded the veranda with a fence, in order to secure privacy and prevent crimes. This section evaluates this home's "outdoor facilities," including the fence, veranda deck, porch roof, and approach floor, from the perspective of the three variables: "form," "appearance," and "materials."

"Form," the desired value of which is set at "not blocking sightlines," is significant for fences and barriers, in particular. The vertical-latticed and 180 cm-high fence screens the home and the washing hung in the veranda from the public view. On the other hand, any suspicious person hiding behind the fence can be seen through the openings of the vertical lattice. Meanwhile, the height of the fence from the veranda deck level is 130 cm; therefore, a person standing on the veranda deck can communicate with neighboring residents without being hindered, as shown in the right photos of **Figure 12**. In this way, this fence's form does not block sightlines and contribute to "safety" and "mutual help" in this area, through preventing crime and allowing face-to-face communication.

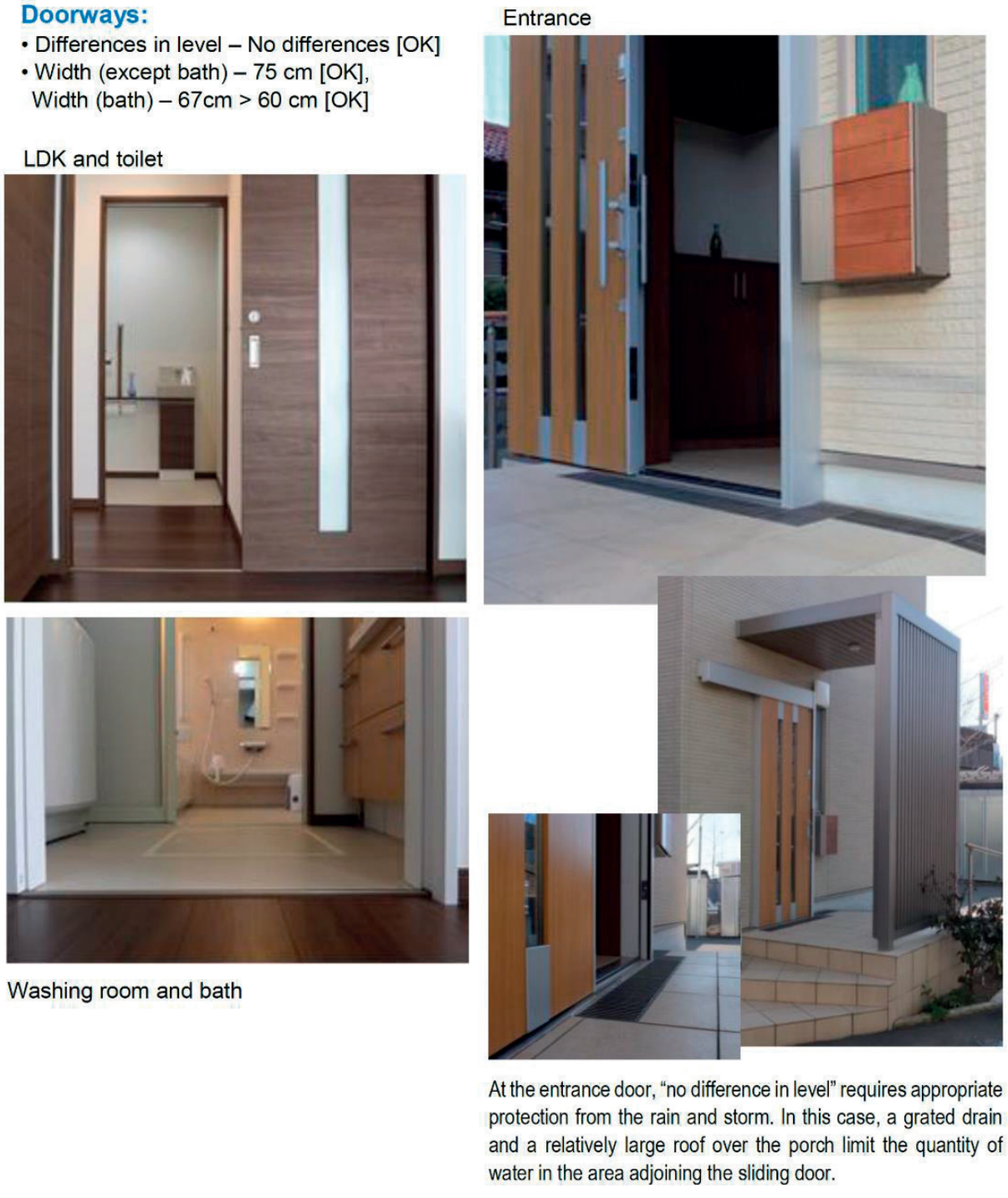


Figure 11. Doorways.

"Appearance" of outdoor facilities, including color and shape, requires "consideration for the landscape." The color of the fence and the porch's roof and screen, which is called "shining gray," is the same as that of the house's window frames and shutters. The tiles of the approach floor have a similar color to that on the outer walls, namely light beige. We expect that the above color coordination creates sense of unity between the house and outdoor facilities and moreover brings stability to the landscape.

http://dx.doi.org/10.5772/intechopen.71323



Figure 12. Main access route to the entrance/slope and outdoor facilities.

Furthermore, when selecting outdoor home products, we have also paid attention to their "materials" and "sustainable use of natural resources." The floor tile of the approach is a recycled product made of waste silica sand and waste clay from ceramic industry. The fence and the porch roof and screen are made of recyclable and long-life aluminum. The veranda deck is made of artificial materials produced from wood powder and the thermoplastic resin. These considerations have easily enabled the assessment of the "materials" to reach its desired value, "Level 5" of the relevant item of CASBEE.

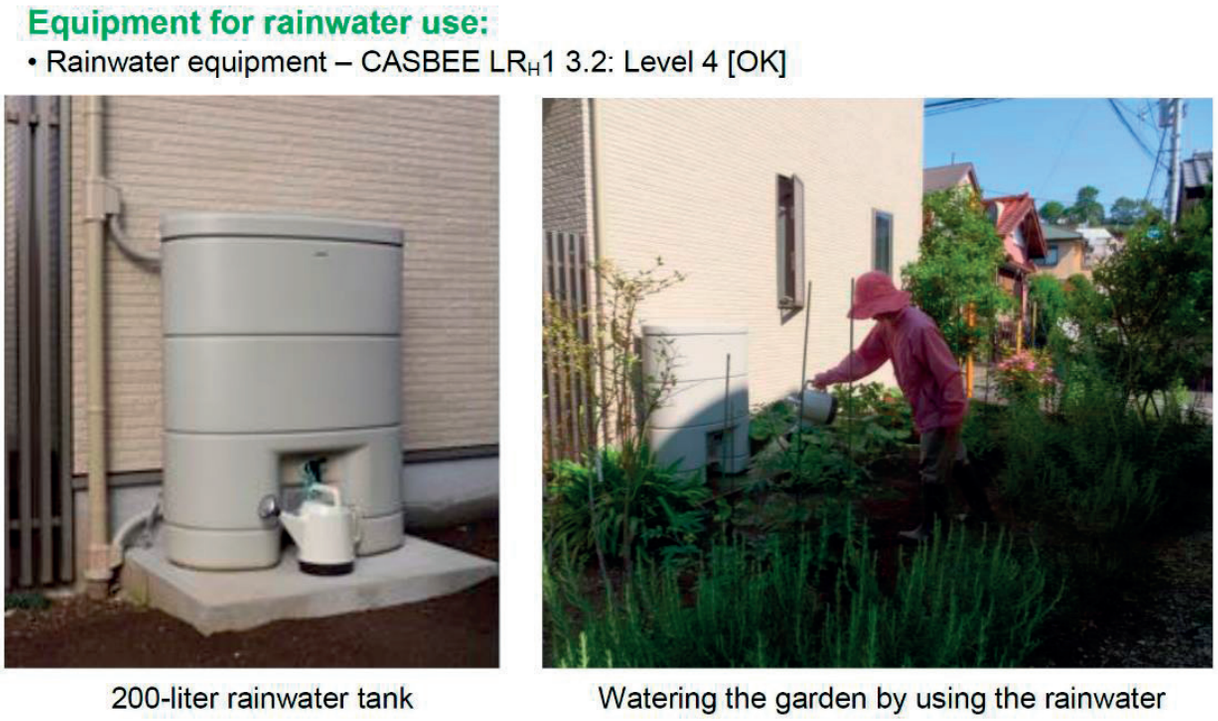


Figure 13. Equipment for rainwater use.

- Equipment for rainwater use

"Equipment for rainwater use," in this case, a 200-L rainwater tank, meets the desired value. As demonstrated in **Figure 13**, the rainwater in this tank is used for watering the garden. Using rainwater can reduce the quantity of water supply. At the same time, storing rainwater is also considered one of "adaptation" measures because it leads to securing emergency water supply [6–8].

4. Performance evaluation

4.1. Quantitative evaluation

4.1.1. Evaluation by CASBEE for detached houses

After the home started to be used, we had its sustainability evaluated by the "CASBEE for Detached Houses (New Construction, 2010 edition)."

"CASBEE for Detached Houses" evaluates the comprehensive environmental performance of detached houses based on the following six categories: Comfortable, healthy and safe indoor environment (Q1), Durability for long-term use (Q2), Consideration for the townscape and ecosystem (Q3), Energy and water conservation (L1), Conservation of resources and reduction of waste (L2), and Consideration for the global, local and surrounding environment (L3). Dividing "Q" by "L," CASBEE represents building environmental performance with a single

score of Built Environment Efficiency (BEE). According to the BEE value, detached houses are graded into five ranks: S (Excellent, five stars), A (Very good, four stars), B+ (Good, three stars), B- (Fairly poor, two stars), and C (Poor, one star) [15].

The evaluation results show that the "Q" and "L" have been "88" and "13," respectively. Consequently, as demonstrated in the left of **Figure 14**, the BEE score has reached 6.7, which has rated and certified the home as the highest "S," or "five stars" with ease. All scores of the six categories are high, namely Q1 = 4.4, Q2 = 4.6, Q3 = 4.6, L1 = 4.7, L2 = 4.0, and L3 = 4.6, as shown in the right of **Figure 14** [16]. These values prove that this house excels in both environmental quality and environmental load reduction.

4.1.2. Life-cycle-carbon-minus (LCCM) house certification

After the CASBEE evaluation, this home was certified as a life-cycle-carbon-minus (LCCM) house. The LCCM house is defined as a "house with a negative CO_2 emission in its total life cycle, including construction, utilization and demolition" [17]. There are several key factors in achieving an LCCM house, that is, a long service life, least amount of CO_2 emissions for constructing, using and demolishing the house, and the utilization of renewable energy, such as solar power generation [17]. LCCM House Certification requires that the house is rated "S" or "A" of CASBEE rating, as its precondition. The Certification is classified into "five stars" and "four stars;" only houses with "five stars" meet the above definition.

The Life Cycle CO_2 of this house has been considerably less than zero, due to its higher energy-saving performance and larger solar power generation capacity. As shown in the left of **Figure 15**, it has been "minus 35%," as compared with 100% of common houses' Life Cycle CO_2, or the reference value [18]. As a result, the LCCM House Certification has also been classified into "five stars" with ease. In addition, as of July 2016, the number of LCCM certified houses with "five stars" is 17 nationwide, including this house [19]. In Tokyo Metropolis, this house has been the first one.

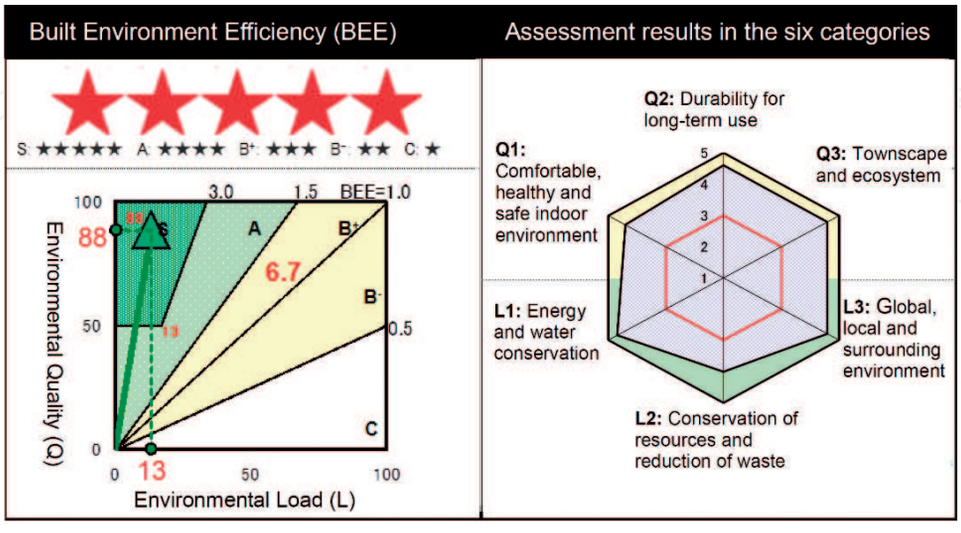


Figure 14. CASBEE assessment results of this home [16].

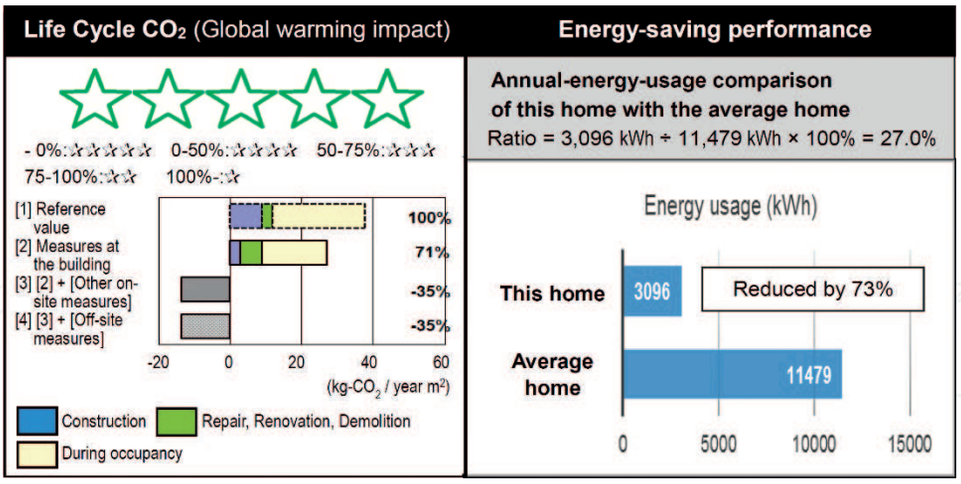


Figure 15. Life cycle CO_2 analysis [18] and energy-saving performance of this house [1].

4.1.3. Energy-saving performance

We have assessed the energy-saving performance of this house, by comparing its annual energy consumption with that of the average house. The total energy consumption of this house per year was 3085 kWh [1]. On the other hand, the average annual energy consumption of the same two-person-household detached houses amounts to 41,325 MJ [20], which is equal to 11,479 kWh. This home's annual usage, 3085 kWh, is equivalent to 27.0% of 11,479 kWh. Accordingly, as illustrated in the right of **Figure 15**, this home has reduced energy usage by over 70%, as compared to the average home of the same condition [1].

4.1.4. Water-saving performance

We have also checked the water usage. The monthly average water consumption of this home was 12.8 m^3, whereas that of the same two-person-household homes was 16.2 m^3 [21]. Accordingly, this home has saved water consumption by 21%, in comparison to the ordinary home of the same condition.

4.2. Reactions of the occupants and visitors

After the moving-in, the occupants, the owner couple, expressed various impressions on this home as well as differences between living in it and in their previous home. Meanwhile, the visitors gave their reactions to this home and its various parts. Choosing several points from such impressions and reactions, this section describes these points, in line with related elements and their variables.

4.2.1. Thermal insulation performance

"Higher thermal insulation performance" has contributed to more stable indoor temperature and less demand for heating and air-conditioning. These favorable effects have naturally led to comfort and energy conservation, as we expected.

Furthermore, another remarkable change which occurred to the occupants was a significant improvement in allergy symptoms of the owner wife. While living in the previous house, she suffered from cedar pollen allergy every spring. In the spring immediately after moving-in, her symptoms sharply changed for the better. Also in the following springs her improved condition has continued. The mechanism which has brought this symptomatic relief is uncertain; however, there is a strong possibility that higher thermal insulation performance of this home has influenced it. The previous home's windows, door, and walls facing outside had poor thermal insulation performance; as a result, water condensation and mold frequently appeared. On the other hand, water condensation and mold have rarely been observed in this home since the thermal performance of the building envelope is superior as a whole.

In addition, there have been many studies which indicate a causal relationship between upgrading of the thermal insulation performance and decrease in the occupants' prevalence rates of various diseases including allergies [22, 23]. Accordingly, this case is considered as one example of supporting such a causal relationship.

4.2.2. Areas relating to water use and hot water supply

Originally, "placing areas relating to water use and hot water supply closer" has been intended to reduce materials for piping and heat loss from hot water piping. After starting to use this home, the occupants have noticed that this consideration also leads to comfort and convenience in daily life. First, placing such areas closer can reduce time until hot water comes out. Moreover, in this case, the floor planning, where the kitchen, laundry space, and bath are arranged closer together, has naturally shortened working route and improved efficiency of household tasks.

4.2.3. Main access route to the entrance

When designing the main access route to the entrance as a slope, we mainly aimed to prepare for the occupants' future. However, this sloped access route has already gained approval beyond our expectation. As a woman visited this home, she pointed out that this slope is favorable for wheeling a stroller or baby carriage, in addition to using a wheelchair. Moreover, when the owner wife experienced difficulty in walking due to a leg injury, she had a real feeling that using the slope is much easier than going up or down the stairs. These remarks show that a step-free approach enables a variety of people to have easier access.

4.2.4. Doorways

In addition to the step-free approach, the level and slightly wider doorways have also been received favorably on various occasions. The occupants have never stumbled over doorways in this home, unlike in their previous home. Furthermore, they often feel comfortable and unimpeded movement between spaces, for instance, when moving furniture or baggage, and vacuuming or cleaning the floors. These experiences show that flat and wider doorways can bring safety and convenience as well as easy access for people with mobility difficulties.

4.2.5. Protection of glass against impacts

We have installed "shutters" on the large windows facing south, in order to protect glass, the most vulnerable part of housing exterior. This installment is expected to reduce the risk of being damaged by current and future impacts such as fire and serious extreme weather events. Moreover, this consideration has offered the occupants other benefits, that is to say, it has given them a sense of security and enhanced thermal insulation performance. In cases where a typhoon is approaching or a tornado warning is issued, closing shutters brings a feeling of safety. Installing shutters is also useful to prevent intrusions and increase the home's anti-crime performance. Furthermore, the closed shutters increase thermal insulation performance, which is effective especially on winter nights, by adding an air layer between the windows and shutters.

4.3. Other evaluation: sustainable housing award

This home has won the Japan Wooden Houses & Industry Association President Award, in the Sixth Sustainable Housing Awards [24]. The Sustainable Housing Awards is a housing design competition which is held every 2 years under the auspices of the Institute for Building Environment and Energy Conservation [25] of the Ministry of Land, Infrastructure, Transport and Tourism. What are publicly commended at the competition are excellent detached houses that combine a comfortable living environment while lowering the burden on the natural environment [25].

In the selection process of the Sixth Sustainable Housing Awards, the screening committee, which was composed of 11 experts including 7 university professors, examined 46 entries [26];



Figure 16. Certificate of the sustainable housing award, CASBEE assessment, and LCCM house.

as a result, this home has received that award. The award review states that the main attractive points of this home have been its strikingly high energy-saving efficiency and energy self-sufficiency [27]. Furthermore, this home has been highly assessed, due to the certification as a Life-cycle-carbon-minus (LCCM) house with five stars as well as the extremely high value of Built Environment Efficiency (BEE) in the "CASBEE for Detached Houses" evaluation (**Figure 16**) [27].

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