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Solar Town Fuchu - Plan and Performance -

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Abstract

Tokyo Metropolitan Government planned a residential area with sixteen high-performance solar houses, for the purpose of reducing carbon dioxide emitted from houses in Tokyo. We collected data on energy consumption and room temperature for two and a half years and conducted a questionnaire survey on the awareness and lifestyle of the residents to investigate the performance of the houses. As a result, it was found that the energy consumption of solar houses is about half of the ordinary houses and the carbon dioxide emissions is over 75% lesser than the ordinary houses considering the contribution of PV generation sold. Also the issues for zero energy houses (ZEH) are clarified based on the characteristics of each type of house.

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Keywords: *high-performance solar house; energy consumption; CO_2-emission; room environment; eco-frendly living way*

1. Introduction

The reduction of carbon dioxide emissions is an important issue that requires the urgent collaborative action of all countries. In Japan, the total amount of carbon dioxide emissions has decreased in recent years but the energy demand of the household sector has continued to increase. In 2013, the Japanese government introduced a new act on energy saving standards for houses [1]. The act designates targets not only on house performance such as thermal

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insulation and solar shielding but also on the primary energy consumption of houses, which includes air conditioning, hot-water supply, and electrical appliances. The standards will become obligatory in 2020.

Tokyo Metropolitan Government, which takes the lead in formulating Japanese policies, established a plan called "Tokyo, after 10 years" in 2006 [2] and set the target of reducing greenhouse gas emissions by 25% of the 2000 level by 2020. One of the measures for reducing carbon dioxide is the "Long-life, environment-friendly house model project" [3], which started in 2011, to develop Solar Town Fuchu (hereafter simply "ST Fuchu").

In addition to reducing carbon dioxide in the life cycle of houses by 50% and widely distributing information to citizens and house companies, the "Long-life, environment-friendly house model project" aims to:

(1) Promote the development of new houses aiming at a low-carbon city
(2) Raise the awareness of eco-friendly ways of living
(3) Improve technology and activate small and medium-sized builders in Tokyo

The houses proposed in the "Long-life, environment-friendly house model project" are designed to be highly durable and energy saving. It is easy to update and maintain the facilities of these houses so that the residents can live in their houses for a long time. Attention was paid to enhancing the living environment such as the landscape, green plants and ecology.

We studied the actual performance of high-performance houses in ST Fuchu and the energy saving activities of the residents. In this paper, we present the results of our study on the environmental performance of the houses based on three years of measurements and a questionnaire survey and identify problems to solve for future ZEH.

2. Outline of high-performance houses and town planning

2.1. Overview of town planning

The construction area in Fuchu City, Tokyo (Climate Division 6 in 2013 Energy Saving Standard [1]), is about 90 m long in the north-south direction and 30 m and 20 m wide in east-west direction on the south side and on the north side, respectively, as shown in Fig. 1a. For the promotion of high performance houses, the sale price of the houses needs to be at the same level as the sale price of ordinary houses in the area. This point was taken into account in the residential area planning and the number of houses was determined to be 16. A bird's-eye view photograph is shown in Fig. 1b.

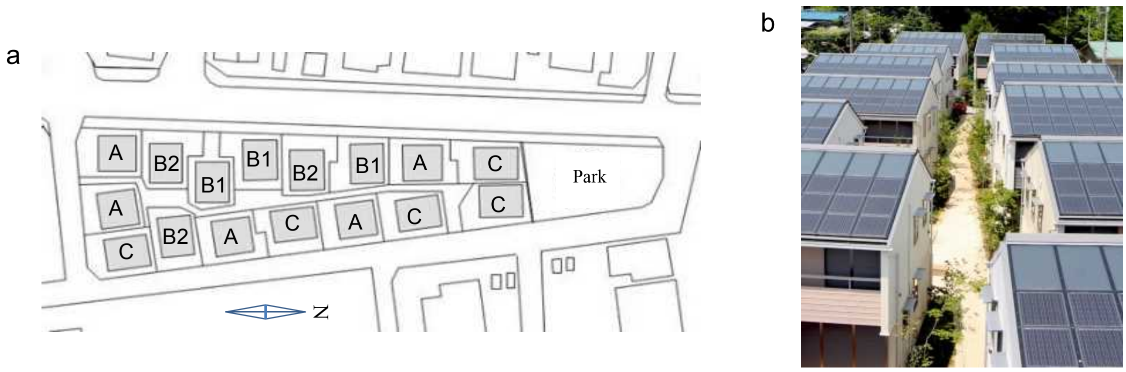

Fig. 1. Solar Town Fuchu (a) Site plan and house type; (b) Bird's-eye view

The layout of the houses was determined by taking account of sunlight in winter and wind in summer. A garden pathway was made in the middle of the area extending from north to south by considering the wind direction in summer. The garden pathway has a soil surface with trees on both sides to provide shade and reduce the temperature in summer [4]. The house positions and orientations were determined in order to allow winter sunlight into the living rooms on the ground floor. For the three houses located close to each other (B2-type; see Sec. 2.2), living rooms were made on the first floors.

2.2. Outline of high-performance houses

There are four types of houses which have different floor plans, as shown in their site plans: the A type (five houses), the B1 type (three houses), the B2 type (three houses) and the C type (five houses). Their total floor areas are almost the same, ranging from 109.3 to 112.6 m^2.

These houses have wooden structures, but show a skeleton/infill concept. This is because a theme of ST Fuchu is that of the ‘Long-life house’. Pillars and earthquake-resistant walls are arranged at the perimeter and there are only one or two pillars in the interior, to change the layout of house easily (Fig. 2b). Therefore, the foundation walls are only located at the perimeter and the space under the floor is not divided (Fig. 2c). Electric wires and pipes are arranged at the top of the perimeter walls (Fig. 2d, e).

‘Environmentally friendly’ is another theme of ST Fuchu. Considering the policy ‘locally produced and consumed’, domestic wood produced in the Tama area is used.

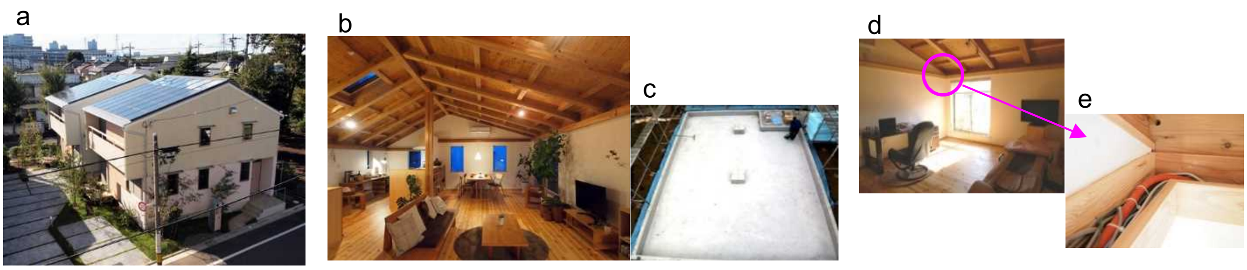

Fig. 2. Photos of the ST Fuchu house (a) out-side of C-type house; (b) living room of B2-type house; (c) ground slab and foundation wall; (d) wiring space in bedroom; (e) detail of wiring space

Table 1. General outline of the houses

Establish(completion)	2013
Number of residents	2-5, average 3.4
Structure	Wooden skeleton/infill structure, 2 stories
Air-conditioning system	Air-type solar floor heating system + Room air conditioner and heater
Hot-water system	Air-type solar water heating system + Gas water heater (Latent heat recovery-type)
Solar collector	W916 x H1572, Effective collector area 1.3m^2
PV power generation module	Single crystal silicon type, 112 W/module, W890 x H980 x D35 (A:3x8 modules, B1&B2:3x9, C:4x7)

Table 2 Performance of the houses

	Average	A-type	B1-type	B2-type	C-type
Plan form (E-W x S-N [m])	-	7.28 x 7.28	8.19 x 6.37		6.37 x 8.19
Floor of Living room	-	grand	grand	first	grand
Total floor area [m^2]	111.0	112.6	111.8	109.3	110.1
Heat loss coeeficient [W/m^2K]	1.87	1.87	1.88	1.87	1.85
Solar gain coefficient in summer	0.047	0.047	0.048	0.052	0.043
Solar collector area [m^2]	10.5	10.4	11.7	11.7	9.1
PV area + collector area [m2]	33.8	31.3	35.2	35.2	33.5
PV capacity [kW]	2.97	2.69	3.02	3.02	3.13
PV power generation efficiency	module; 12.8% (Cell; 18.6%)				
Window specification	Low-e pair glass + plastic combined aluminum sash				
Heat insulation material	Roof: phenol foam 90mm Wall: high-performance glass-wool 105mm Floor: phenol foam 60mm (Foundation: 90mm)				

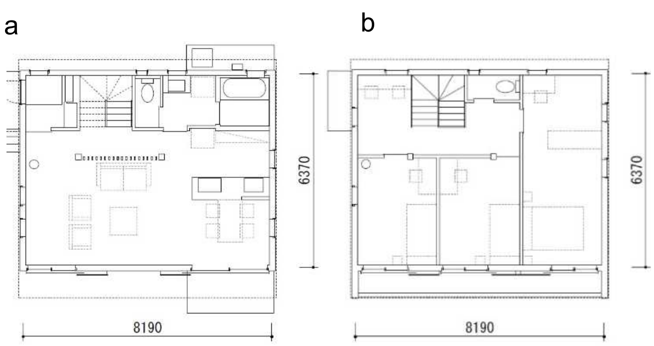

Fig. 3. Plan of B1-type house (a) grand floor; (b) 1st floor

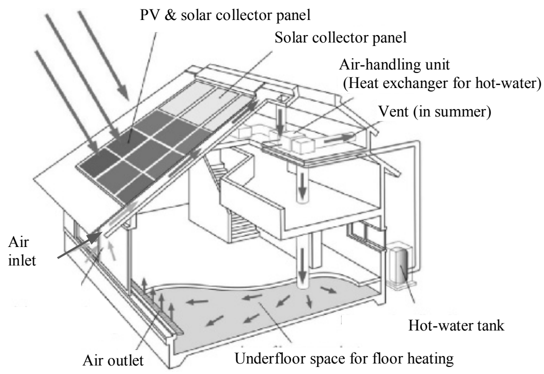

Fig. 4. System diagram

The general outline of the houses and their performance are shown in Tables 1 and 2. As an example of house types, the floor plan of the B1-type house is illustrated in Fig. 3. The thermal insulation specification of the houses is shown in Table 2. The heat-loss coefficient is under 1.9 W/m2K meeting the standard for the north of the Japanese mainland, which is colder than this area. The houses of ST Fuchu have been recognized as ‘Long Life Quality Housing’, ‘LCCM (Life Cycle Carbon Minus) Housing 4 Stars’ and ‘CASBEE (Comprehensive Assessment System for Built Environment Efficiency) S-Rank’.

2.3. Outline of solar and natural energy utilization system

The high-performance houses of ST Fuchu have solar and natural energy utilization systems, which consists of i) a PV (Photovoltaic) system, ii) an air-type solar floor heating system and iii) a solar hot-water system, as shown in Fig. 4. In addition, this system has iv) a solar heat exhaust function and v) a cooling function with a night purge in the hot season. Accordingly, this system has many modes of operation. Representative modes are the floor heating mode in the cold season and the hot-water/heat-exhaust mode in the hot season. In the floor heating mode, the outside air drawn in at the eaves is warmed under the PV panels at first and is heated at the solar collector panel. The heated air passes through the air-handling unit and the vertical duct. The air reaching the under-floor space warms up the floor and the concrete slab and then is supplied to the room. In the hot season, hot air is sent out by the exhaust of the air-handling unit after being heat-exchanged with water. This system can also operate the floor heating system and the hot-water system at same time. While the outside air passes under the PV panel, the air is warmed up and the PV panel is cooled down. This means that the rate of PV power generation is increasing.

The number of solar collector panels and the solar collection area including PV panels are as shown in Tables 1 and 2: 8 sheets/31.3 m^2 for A type, 9 sheets/35.2 m^2 for B1 and B2 types and 7 sheets/33.5 m^2 for C type. The number of PV panels and the power generation capacity are 24 sheets/2.69 kW for A-type, 27 sheets/3.02 kW for B1 and B2 types and 28 sheets/3.13 kW for C-type.

This system has a control and monitoring system, which uses a touch panel connected with HEMS (Home Energy Management System) recording the outside air temperature, room temperature, electricity generated and heat collected. There is another monitor for the PV system, which allows residents to check the electricity generated, the electricity consumed and other data.

3. Measurement and survey

Table 3 shows the contents of the investigation. The HEMS records data every 15 min, such as electricity, temperatures, solar heat collected and system movements. We installed three temperature and humidity recorders in the living room, in the bedroom and in the hall on the first floor. Electric and gas consumption data were collected from the each company website [7]. Kerosene consumption was reported by residents. A questionnaire survey was distributed to residents about the thermal comfort, energy-saving behaviour and awareness and other items. The monitoring period was from October 2013 to March 2016 (2.5 years). In this study, data from October 2013 to September 2015 is used.

Table 3. Investigation contents

Means	Investigation item
Home Energy Management System	Electric power generation, electricity consumption, collected heat, temperatures of solar system, system movement, etc.
Measuring instrument	Temperature and humidity (Living room, bed room and 1st floor hall)
Account record	Electricity, Gas and Kerosene consumption
Questionnaire	Thermal comfort, energy saving behavior and awareness, etc.

4. Average Energy consumption and carbon dioxide emissions

4.1. Monthly average temperature of living room

Room temperature is a presupposed condition for energy consumption. In Fig. 5, the monthly average temperatures of the living rooms of 12 houses are shown. Average temperatures are approximately 18–20°C in winter and 27–29°C in summer. With the exception of three houses, temperature differences among houses are approximately 2°C. The major reasons for the temperature differences between each of the three houses and others were clarified by the survey, as follows:

- House B1-3: The room temperature in the summer was lower than that of other houses (from March to November in 2014). The reason is that the residents have pets and use an air conditioner.
- House B2-1: Room temperature was lower in winter and was higher in the summer than in other houses. The living room is located on the first (upper) floor, where it is warm without using a heater. It is hot in summer, but residents remained time on the ground floor for a long.
- House C-2: Room temperature was higher than that of other houses from October 2014 to January 2015. The residents used an electric carpet for their pets.

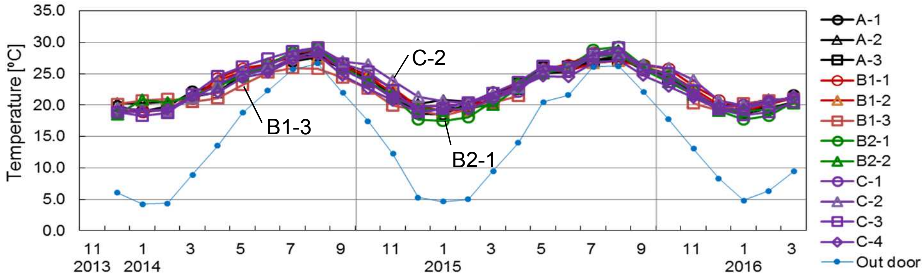

Fig. 5. Monthly average temperature of living room

4.2. Annual energy consumption of each house

Annual energy consumption of 12 houses shown in Fig. 5 is illustrated in Fig. 6 [Secondary energy, the same hereinafter. The conversion coefficients see Appendix A.]. Only House A-1 used a kerosene heater. Houses A-3 and C-3 show no PV power data, so the average value of the other 10 houses is illustrated. In addition, the A-type and B1-type houses use an IH stove and the B2-type and C-type houses use a gas stove in the kitchen.

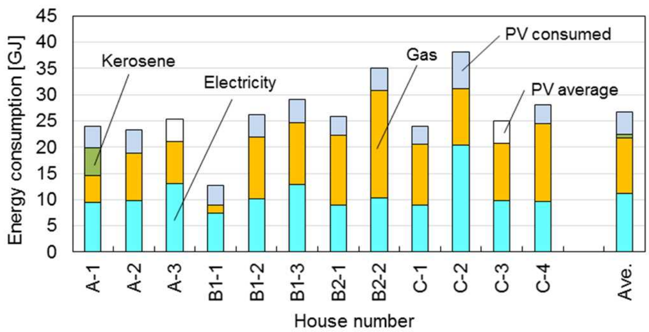

Fig. 6. Annual energy consumption of each houses (2014.10-2015.9)

Total energy consumption is nearly 25 GJ, but House B1-1 is small, about half the size of the others. Houses B2-2 and C-2 are bigger, and their consumption is 35–38 GJ. The reasons for this difference were also clarified by the survey.

- House B1-1: The number of residents was two, thus the household size is smaller than the average household size of 3.4. Their gas consumption, i.e. hot-water consumption, is very low, though this reason is not clear.
- House B2-2: The gas consumption was higher. One person in this family is very sensitive to cold, and thus, hot-water consumption was higher.
- House C-2: Electricity consumption is high. One reason for this, as mentioned above, is the use of an electric carpet. Other reasons are the presence of much electric equipment, the refrigerator being old and a resident leaving the equipment turned on.

4.3. Average monthly energy consumption

The average monthly energy consumption (purchase energy) of 12 houses is shown in Fig. 7. The figures start from October which is the beginning of the monitoring period.

Fig. 7a shows that monthly energy consumption in summer is under half of that in winter. This is due to low consumption of gas in summer. Electricity consumption increases after spring, but gas consumption decreases greatly through the use of the solar hot-water system. Fig. 7b shows a comparison with an ordinary detached house [5] and another high-performance detached house [6] in this region. The consumption of an ST Fuchu house is about half of an ordinary house. This establishes the high performance of ST Fuchu houses. Further, the consumption is lesser than that of the other high-performance houses, with a particularly large difference in summer. Other high-performance houses have no solar heating or hot-water systems, which is the cause of the difference.

It is evident that the solar heating and hot-water systems contribute considerably to saving energy. Therefore, we have to popular solar heating and hot-water systems rapidly. In particular, solar hot-water systems are recommended for existing houses because a popular solar hot-water system for family use requires a small collector area, as small as about 4 m^2, and is a comparably low in cost. Of course, a combination of a solar heating system and a PV system is ideal.

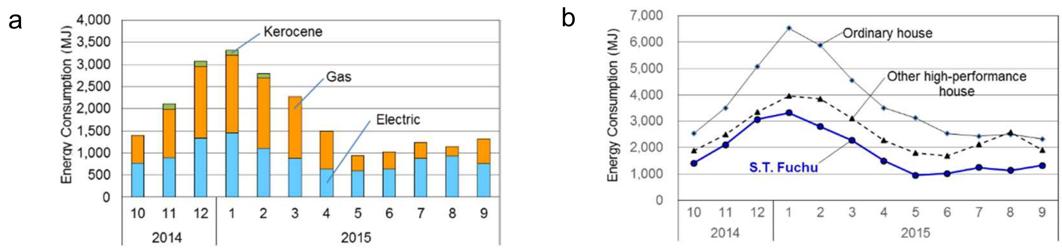

Fig. 7. Monthly energy consumption (Purchase energy; secondary energy converted value)
(a) S.T. Fuchu (average of 12 houses); (b) Comparison with other houses

4.4. Average annual energy consumption and carbon dioxide emissions

The comparison of the average annual energy consumption of ST Fuchu houses (S.T.F.) with that of the ordinary house is illustrated in Fig. 8a. The values for ST Fuchu are from an average of 8 houses, which show complete data for 2 years. The 8 houses are A-1, A-2, B1-1, B1-3, B2-2, C-2, C-3 and C-4. The total energy consumption of an ST Fuchu house, including PV power generation consumed in each one, is about 60% of an ordinary house, and the energy consumption purchased, which is the same as an ordinary house's energy consumption, is about 50% of an ordinary house. The total PV power generation is about 12 GJ, and the self-sufficiency rate is about 45%.

The comparison of the annual carbon dioxide emissions of an ST Fuchu house (S.T.F.) with an ordinary house is shown in Fig. 8b [The conversion coefficients see Appendix A.]. Through a simple calculation, an ST Fuchu house emits about 50% of the carbon dioxide of an ordinary house, but considering the contribution of PV generation sold over 7 GJ, an ST Fuchu house has over 75% lesser emissions than an ordinary house. The result means it amply clears the target of this model project that is over 50% reduction.

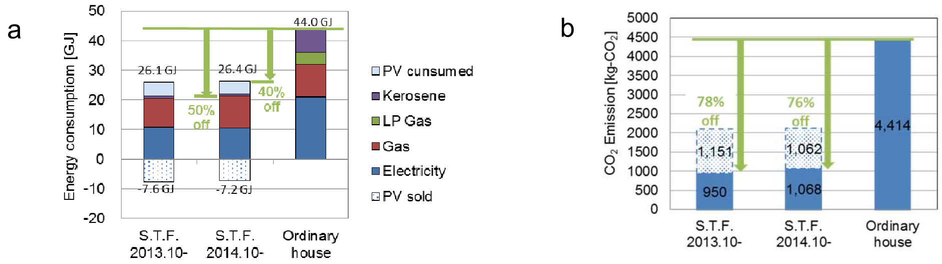

Fig. 8. Performance of ST Fuchu (a) Annual energy consumption; (b) Annual carbon dioxide emissions

5. Issues for Zero Energy House

As above mentioned, it is clear that the energy performance of an ST Fuchu house is quite high. If PV were operating at double capacity, it can easily fulfil the goal of a zero-energy house or a plus-energy house. However, such a policy is not wise. Realistically, much greater energy saving is required for a zero-energy house, and the performance of the thermal insulation must be improved at first. In this section, we discuss the next steps, comparing room temperature and the energy consumption of each house.

5.1. Ranges of living room temperature and the energy consumption of room air-conditioner

To clarify the cause of the difference in energy consumption among the houses, we examined room temperatures in winter and in summer. Box-and-whisker plots of room temperature with the electric consumption of air conditioner in the living room in winter (January and February in 2015) and in summer (July and August in 2015) are shown in Fig. 9.

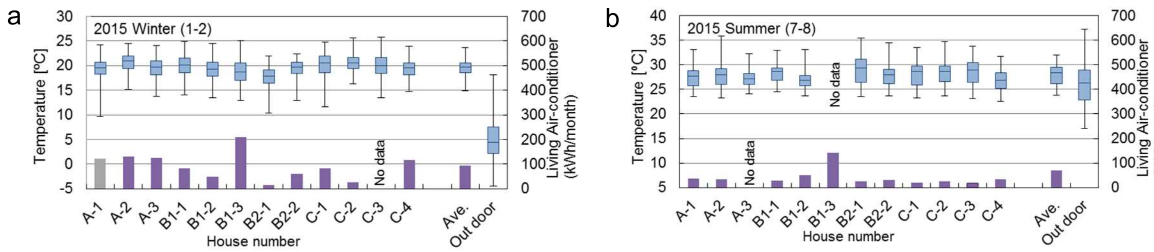

Fig. 9. Room temperature and energy consumption of air-conditioner in living room (a) winter; (b) summer

In winter the room temperatures of each house are comfortable, with a median of 18–20°C, against a median outdoor temperature of 4.5°C. There is no definite relationship between room temperature and electricity consumption. The maximum temperatures of House B2-1 and House B2-2 range 22–23°C and are lower than that of other houses. The cause of this is that the living rooms of these houses are located on the upper floor, where the effect of solar floor heating is lower than on the ground floor. Another reason for the lower temperature in House B2-1 is a reduced use of the air conditioner. In summer, the third quartile of room temperature is lower than 30°C, except in Houses B2-1 and C-3. The electric consumptions of Houses B1-2 and C-4 are higher than other houses, but there is no definite relationship between room temperature and electricity consumption.

5.2. Relationship between outdoor temperature and energy consumption

Fig. 10 shows the relationship between the average monthly outdoor temperature and monthly total energy consumption (Fig. 10a), and monthly energy consumption per person (Fig. 10b).

From Fig. 10a, we can see the consumption of House C-2 is the highest and that of House B2-2 is higher than that of remaining houses. On the contrary, the consumption of House B1-1 is very less, and its increases in rate in the winter are low. The consumption of House A-1 is lesser than others, at a temperature of approximately 10°C, because the kerosene consumption is not considered in the total energy consumption, except for from December to February.

In Fig. 10b illustrates monthly energy consumption per person. Consumption in House B2-2, House C-4, House C-2 (at over 14°C) and House B1-3 (in winter) are higher than that in others. House B1-1, which has the lowest total consumption, is same as other houses per person.

The causes for smaller and bigger consumption in Houses B1-1, B1-3, B2-2 and C-2 have been mentioned in section 4.1 and 4.2. With regard to House C-4, the following reason was received from residents:

- House C-4: an electric oil heater was used in winter. Afterwards this was changed to air-conditioner.

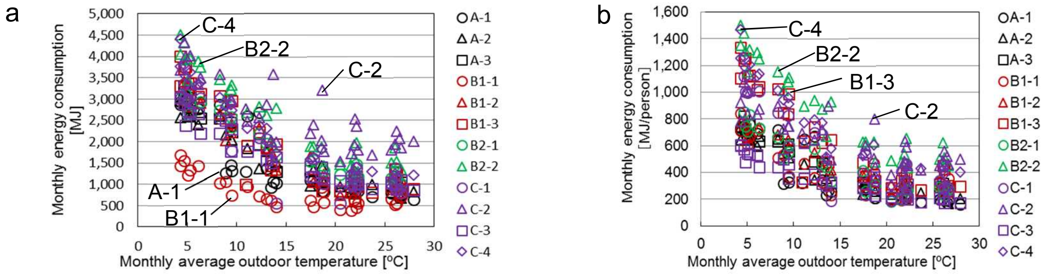

Fig. 10. Relationship between outdoor temperature and monthly energy consumption of each house
(a) total energy consumption; (b) consumption per person

5.3. PV power generation and collected solar heat energy

The annual PV electric power generation for each house is shown in Fig. 11. The electricity generation capacity is 2.69 kW for A-type houses and 3.02–3.13 kW for other houses. The total power generation for A-type houses is 2800–3000 kWh, less than that of other houses, which is over 3200 kWh. The PV power consumed in the house is almost identical for the houses, with the exception of House C-2. Therefore, the difference in PV power capacity does not influence PV power consumed in the house. In House C-2 the PV power consumed is about twice that of other houses, owing to the use of the electric carpet, an old refrigerator and other factors mentioned earlier.

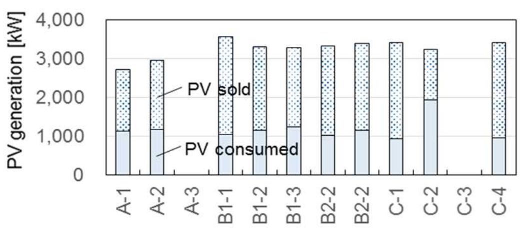

Fig. 11. Electricity generated by PV power system (2014.10-2015.9)

Fig. 12 shows monthly collected heat energy by solar system in winter (2015.1) and in summer (2015.8). In winter (Fig. 12a), almost all the heat collected was used for floor heating. Houses B1-3 and B2-2 are about half the size of the other houses. This lower solar heat collection is the main cause of the increase of the energy consumption of these houses in winter, shown in Fig.10b. Additionally, the cause of the reduced solar heat collection is inferred to be due to the missing changeover of the operating mode of the solar heating and hot-water systems by residents.

In the summer (Fig. 12b), all collected heat is used for heating water. The amount of heat collected is lesser than that in winter because the temperature of hot-water, set at 54°C, is higher than that of floor heating, set at 30°C. There are variations in the heat collected in summer for each house. The amount of heat collected in Houses A-2, B1-3, C-1 and C-4 are lower than that collected in other houses. In summer, the heat collected is only used for heating water and the remaining heat is discharged from the house. Therefore the cause of difference should be clear, in order to increase the amount of collected heat.

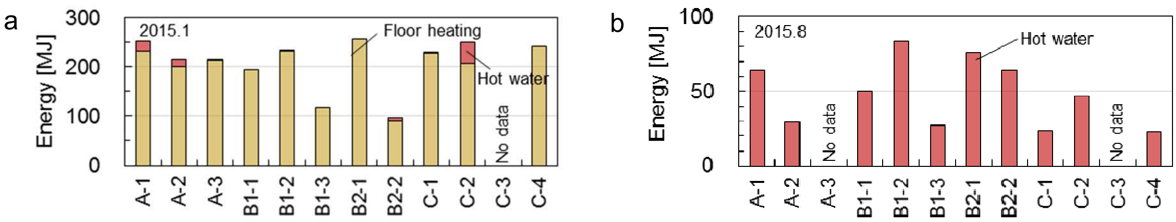

Fig. 12. Collected heat energy by solar system (a) winter (2015.1); (b) summer (2015.8)

5.4. Summary of each house feature

The distinctive features of each house in energy consumption and room temperature can be summarized as follows.

As factors in building services, the following items have been clarified:

- The energy consumption of ST Fuchu houses is lower than that of other high-performance houses, which have no solar heating systems; in particular, gas consumption in summer is very less. Therefore, it is clear that solar heating and the hot-water systems contribute considerably to saving energy.
- The PV power generation of A-type houses is approximately 10% less than that of other houses, but the difference in PV generation capacity does not influence the PV power consumed in the house.
- There are two houses in which the amount of heat collected by the solar system is about half of other houses; they should be improved to acquire the proper amount of collected heat.

Regarding the lifestyle factors concerning greater energy consumption, the following items are listed:

- House B1-3: The room temperature in summer was lower than that of others, because the residents keep pets and used an air conditioner. Additionally, the lower solar heat collection is the main cause of the increase of the energy consumption in winter
- House C-2: The room temperature was higher than that in other houses because the residents used an electric carpet for their pets. Their electric consumption was higher than that of the others. The reasons for this are the usage of the electric carpet and presence of much electric equipment and an old refrigerator. There is also a resident who leaves equipment turned on.
- House C-4: An electric oil heater was used in winter. Afterwards this was changed to an electric air conditioner.
- House B2-2: The gas consumption was higher. A person in this family is very sensitive to cold, and thus, hot-water consumption was higher. Another cause is reduced collection of solar heat.

Therefore, for better energy saving, changing the heating equipment and electric devices to high-energy-efficiency goods and improving life practices are necessary.

On the other hand, the followings are mentioned as examples of lower energy consumption:

- House B1-1: Here the number of residents is two, which is lesser than the average number of residents in the households, 3.4. Another reason for low consumption is that gas consumption, i.e. hot-water consumption, is very low, although the reason of this is not clear.

- House B2-1: Room temperature is lower in winter and higher in summer than that in others. The living room is located on the first (upper) floor, and it is sufficiently warm without the air conditioner. It is hot in summer, but the residents remained on the ground floor for a long time.

To clarify the reason for the low gas consumption of House B1-1 is needed for further energy saving. The lifestyle of House B2-1 is reasonable; thus, the advantages and disadvantages need to be clarified in having a living room on the upper floor in a detached house.

6. Conclusion

It is clarified the energy consumption of houses in Solar Town Fuchu is about half of the ordinary houses and the carbon dioxide emissions is over 75% lesser than the ordinary houses. It amply clears the target of this model project. Also it is highlighted the solar heating and hot-water system is effective. In order to fulfill ZEH with the current level of PV, about 3 kW, further energy saving is necessary by improving the living way, making solar water heating systems usable all year and further improving the insulation performance of houses.

We must work hard to become the high-performance houses like ST Fuchu or ZEH popular as soon as possible in the world. And also solar water heating systems should be spread immediately for existing houses.

Acknowledgements

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Appendix A. Conversion coefficient

The following conversion coefficients to secondary energy and CO_2 emission are used in this paper.

- Secondary energy; Electricity 3.6MJ/kWh, Gas 44.8MJ/m^3, LPG 50.8MJ/kg, Kerosene 36.7MJ/L [5]
- CO_2 emission; Electricity 0.53kg-CO_2/kWh, Gas 2.21kg-CO_2/m^3N, LPG=0.059kg-CO_2/MJ, Kerosene 2.489kg-CO_2/L [7]

References

[1] Ministry of Land, Infrastructure, Transport and Tourism, Outline of 2013 revision of energy saving standard, http://www.mlit.go.jp/common/001012880.pdf (Japanese)

[2] Tokyo Metropolitan Government, Master Plan of Tokyo after 10 years, http://www.metro.tokyo.jp/INET/CHOUSA/2011/12/60lcf100.htm (Japanese)

[3] Tokyo Metropolitan Government's "Model project of eco-friendly long-life houses", http://www.toshiseibi.metro.tokyo.jp/juutaku_seisaku/chojyumyou/index.html (Japanese);

[4] Eiko Kumakura, Nobuyuki Sunaga, et.al, Influence of Detached House Residents' Behavior on The Thermal Environment of a Common Garden Path in Summer, Proc. of the 31th PLEA International Conference, (2015.9) Paper_0135

[5] Agency for Natural Resources and Energy, National Report of energy consumption (Consumer use edition), (2013.3), p63 (Japanese)

[6] Yasuhiko Hata, Nobuyuki Sunaga et.al., Study on the Energy-Saving Action in Home Part.1.-Part.5., Summaries of Technical Papers of Annual Meeting, D-2, Architectural Institute of Japan, Tokyo, (2014), pp.587-596 (Japanese)

[7] Websites of Tokyo Electric Power Company holdings Inc., Tokyo Gas Co. LTD, Japan LP Gas Association, Ministry of the Environment.