Evaluation of Solar Space and Domestic Hot Water Heating House with Water and Air Systems

Koji Oba[1*], Mitsuhiro Udagawa[1], Takafumi Kusunoki[1] and Hyun-woo Roh[2]

[1]Kogakuin University, 1-24-2 Nishi-Shinjuku, Shinjuku-ku, Tokyo, 163-8677, JAPAN

[2]OM Solar, 4601, Murakushi-chou, Hamamatsunishi-ku, Hamamatsu-shi, Shizuoka, 431-1207, JAPAN

[*]Corresponding Author, dm09015@ns.kogakuin.ac.jp

Abstract

The whole building simulation was carried out for the two types of solar house built in cold district in Japan. The two types of the solar systems, a water heating system and an air heating system were evaluated. The solar heating processes are simulated using the building simulation program EESLISM. The results of the simulation show on the solar heat collection, the room thermal environment, the solar heating and the auxiliary heating. The effects of two solar space and DHW heating systems are also compared with the case without solar heating system.

Keywords: Solar heating, Simulation, Space heating, DHW heating

1. Introduction

The purpose of this study is to evaluate the two solar houses with water collector and air collector by using the simulation tool EESLISM. The model houses are provided with solar space heating and DHW supply coupled with solar collector. The effect on the space and DHW heating load reduction by the solar heating system is shown by using the same house without solar system.

2. Overview of the system

The floor plan of the house used in the series of simulation is shown in Figure 1. The model house is existing house which is the two storied wooden houses in cold climate area in Japan. The first floor area is 70.5 m^2 and the second floor area is 40 m^2. The first floor consists of entrance, LD room, kitchen, work space and bathroom, and the second floor consists of hall and two rooms. The LD room on the first floor and the hall on the second floor are connected by the void space. The phenolic foam thickness of 95mm is used for the insulation of the roof. The glass fiber 16K thickness of 100mm is used for the outside wall and the polystyrene foam thickness of 100mm is used for outside of the foundation. The windows are double-glazed. Table 1 and Table 2 show general description of the house.

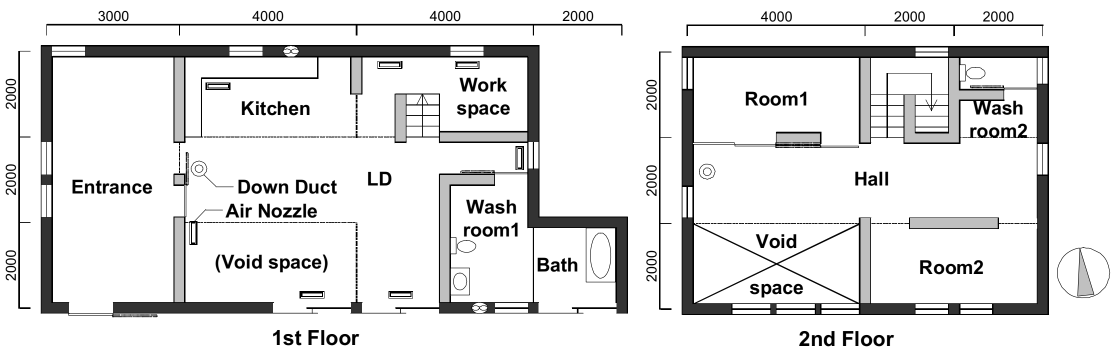

Fig.1. The floor plan of the house.

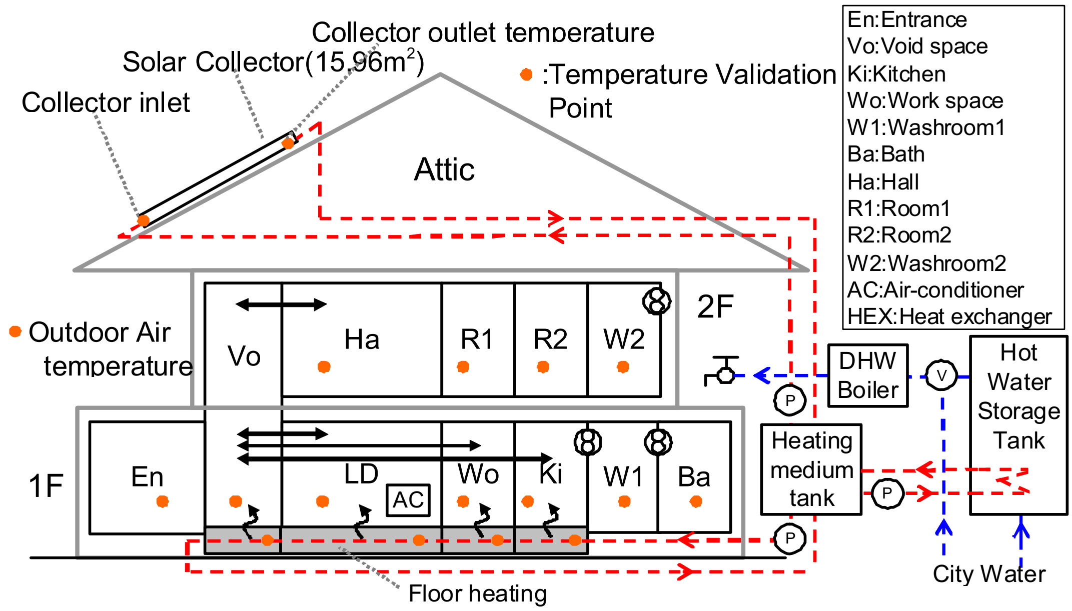

Fig.2. The system diagram of the solar system using water type collector.

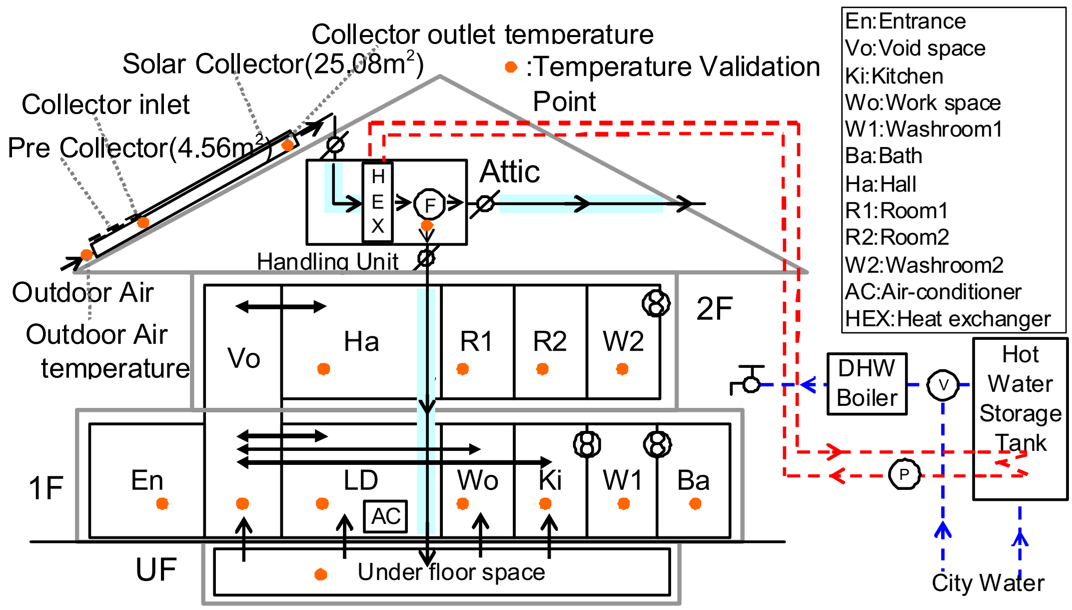

Fig.3. The system diagram of the solar system using air type collector.

Figure 2 and Figure 3 show the system diagram of the space heating and DHW heating system of the simulation model. Table 4 shows the solar systems used in the simulation.
Figure 2 shows the solar system using water type of collector. The standard operation of winter season is that the heating medium heated by collector circulates through the concrete floor for the heat and space heating and solar heat collection is used for the DHW heating.

Figure 3 shows the solar system using air type of collector. For a standard operation in winter, outdoor air taken from edge of the eaves is heated by the solar collector and the collected heat is delivered to the heat storage space below the floor. The heated air by solar collector heats the under floor space. The solar heated air is also used to heat DHW with the air to water heat exchanger.

The simulation data are created based on the components and materials of model houses. The solar heating systems are integrated into the model houses as shown in Figure 2 and 3.

Table 1. Specifications of the house.

Area	Maebashi-city, Gunma Pref. (36°N, 139°E)
Construction	Two stories wooden house
Southern roof angle	31 degrees
Azimuth of southern roof	7 degrees to West

Table 2. Specifications of the insulation.

Insulation of roof	Phenolic foam thickness of 95mm
Insulation of outside wall	Glass fiber 16K thickness of 100mm
Insulation of foundation	Polystyrene foam thickness of 100mm
Windows	Double-glazed glass

Table 3. Conditions of simulation.

Heating operation	Operative temperature 22 °C in 7:00-23:00
DHW operation	37 °C in 06:00-19:59 52 °C in 20:00-21:59
Simulation period	Novemver to March
Simulation interval	60 minutes

Table 4. Simulation cases.

Case 1	System using water type collector Solar collector : Single-glazed, Selective absorber Single-glazed area : 15.96m^2 Heating medium tank : 100 litters Storage tank : 300 litters
Case 2	System using air type collector Solar collector : Non-glazed, Single-glazed Non-glazed area(Pre-heating) : 4.56m^2 Single-glazed area : 25.08m^2 Storage tank : 300 litters
Case 3	System without solar

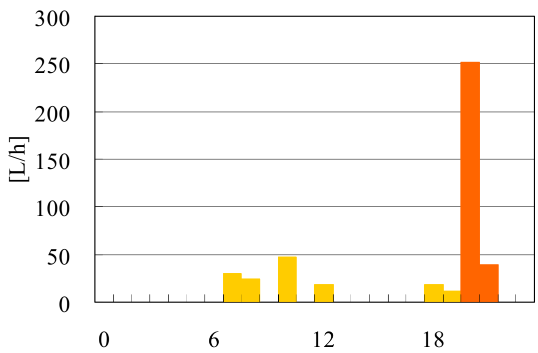

Fig 4. Schedule of supplying hot water.

The meteorological data of Maebashi City(36°N, 139°E), Gunma Prefecture is used, Maebashi City is the region where model house exists.

3. Condition of simulation

The simulation cases are three. Case 1 is the system using water type collector in Figure 2, Case 2 is the system using air type collector in Figure 3, and Case 3 is without solar system. There is a difference in the collector areas for the water collector(Case 1) and the air collector(Case 2). As the air collector is supposed to be roof integrate type assembled on site, the collector area is larger than the area of the water collector.

To examine the effect of the heating load reduction, the air conditioning unit of the LD room on the first floor is operated in 22 °C of the operative temperature setting. The operation hour of air conditioning unit is 7:00 to 23:00. The heating space are the LD room besides void space, kitchen and work space. The mutual ventilation is operated in the LD room and void space, kitchen, work space and void space and the second floor hall space. The auxiliary DHW boiler is operated for the supply temperature of 35 °C from 0:00 to 20:00 and 50 °C from 20:00 to 22:00.

In Case 1, the operation of the collector starts when the temperature difference of the sol-air temperature of the collector and the temperature of water under the storage tank is greater than 10 K. In Case 2, the operation of the collector starts when the sol-air temperature of the collector is higher than 30 °C, the DHW heating starts when the temperature difference of the sol-air temperature of the collector and the temperature of water under the storage tank is greater than 10 K.

To examine the effect of the space and DHW heating load reduction, the simulation is carried out from November to March. The time interval of simulation is 1 hour. To examine the effect of the solar space and DHW heating by using solar system, the case with solar system and the case without solar system are compared.

4. Results of simulation

4.1 Simulation results on typical days

Figures 5 to 10 show the simulation results on February 21 to 23 when the weather is clear.

Figure 6 and 7 show the temperature of collector and heat storage tank. The water type collector outlet temperature is 40.0 °C at the maximum. The air type collector inlet temperature is equal to the outdoor air temperature. The preliminary collector outlet temperature is 18.0 °C at the maximum. The glass covered collector outlet temperature is 69 °C at the maximum.

Figure 8 shows the simulation result of Case 1 (water type). The LD room temperature is 26.1 °C at the maximum. The heat storage floor temperature is 36.5 °C at the maximum. In February 23, the heating load of air conditioning unit is 9.0 kWh/day. The solar DHW heating, it covered 4.8 kWh/day among 11.8 kWh/day for DHW heating load.

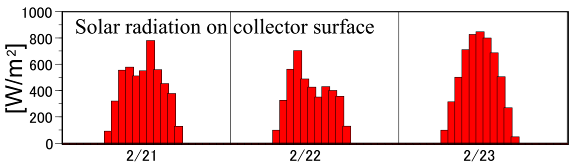

Fig 5. Weather condition in simulation.

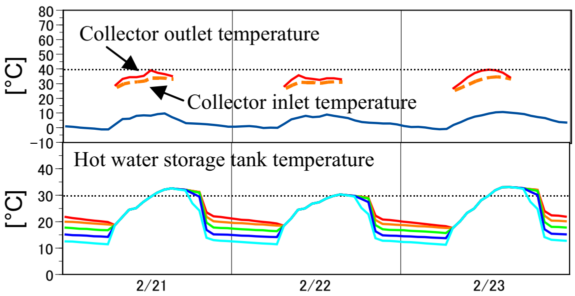

Fig 6. Temperature of water type collector(Case 1).

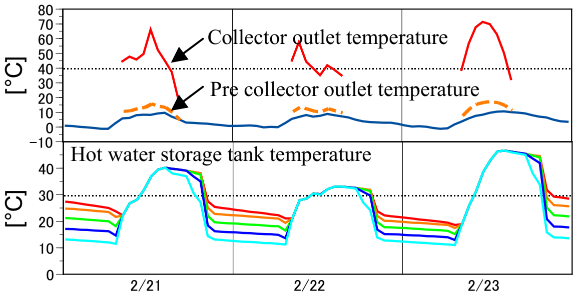

Fig 7. Temperature of air type collector(Case 2).

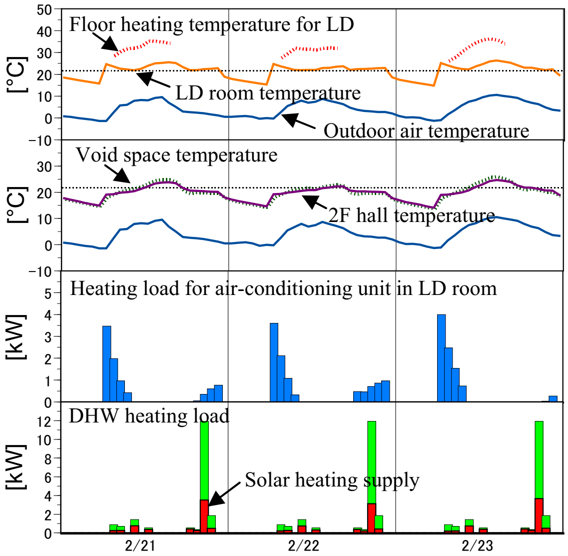

Fig 8. Results of Case 1(water type).

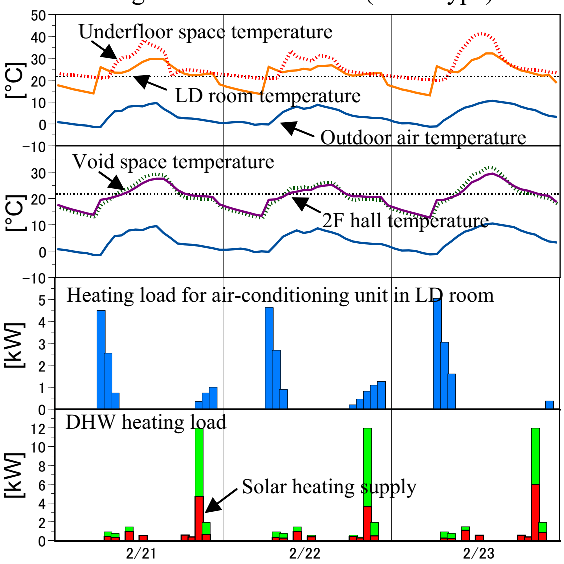

Fig 9. Results of Case 2(air type).

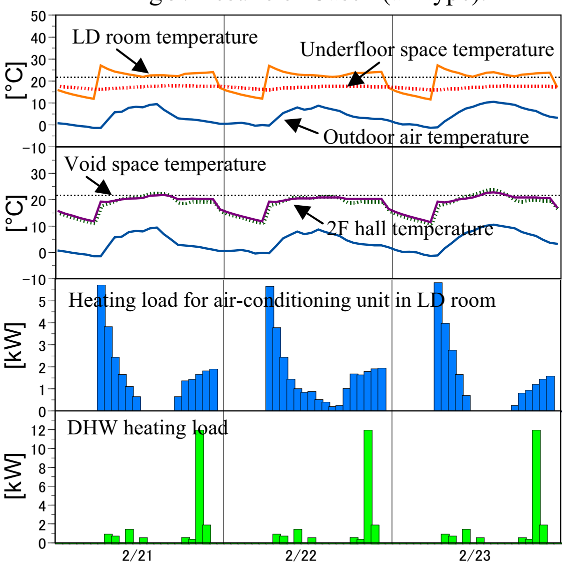

Fig 10. Results of Case 3(without solar system).

Figure 9 shows the simulation results of Case 2(air type). The LD room temperature is 31.9 °C at the maximum. The under floor space temperature is 41.6 °C at the maximum. In February 23, the heating load of air conditioning unit is 10.1 kWh/day. The solar DHW heating, it covered 9.9 kWh/day among 18.5 kWh/day for DHW heating load.

Figure 10 shows the simulation result of Case 3(without solar system). The LD room temperature is 26.9 °C at the maximum. The under floor space temperature is 18.2 °C at the maximum. In February 23, the heating load of air conditioning unit is 21.1 kWh/day. DHW heating load is 18.3 kWh/day.

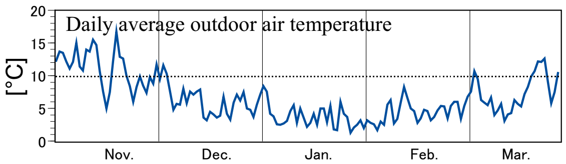

Fig 11. Weather condition in simulation.

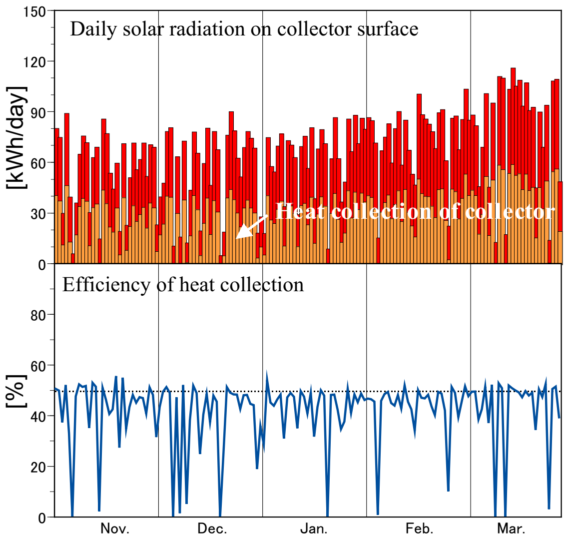

Fig 12. Efficiency of water type collector(Case 1).

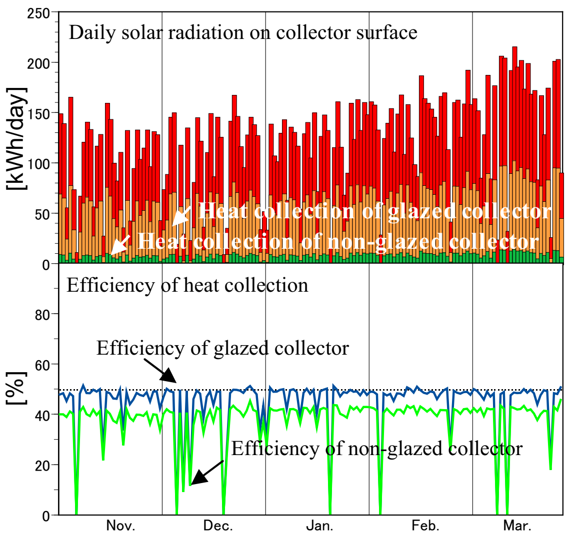

Fig 13. Efficiency of air type collector(Case 2).

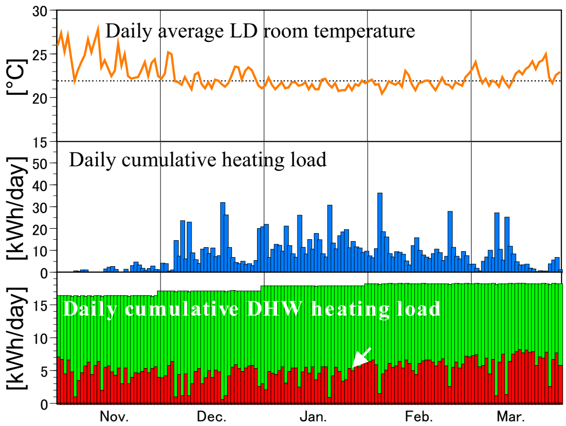

Fig 14. Results of Case1(water type).

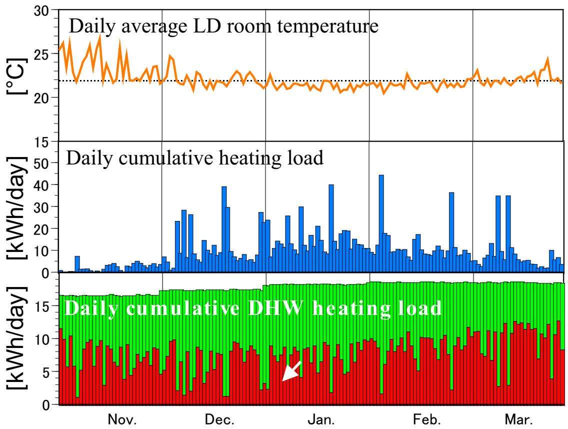

Fig 15. Results of Case2(air type).

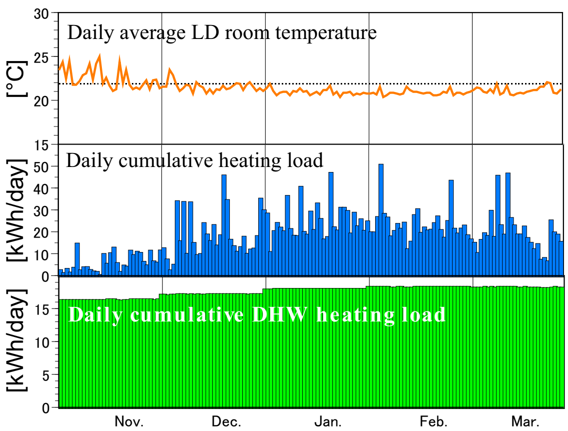

Fig 16. Results of Case3(without solar system).

Table 5. Seasonal system performance (November to March).[MWh/season]

	Solar space heating (A)	Auxiliary space heating load (B)	Space heating load (C)=(A)+(B)	Solar DHW heating (D)	DHW boiler load (E)	DHW heating load (F)=(D)+(E)	Total solar heating (G)=(A)+(D)	Total auxiliary load (H)=(B)+(E)	Total load (I)=(G)+(H)	Auxiliary space heating load reduction (J)	DHW boiler load reduction (K)	Auxiliary load reduction (L)	Space heating solar contribution (M)=(A)/(C) *100	DHW heating solar contribution (N)=(D)/(F) *100	Solar contribution (O)=(G)/(I) *100
Case 1 (Water type collector 15.96m^2)	3.2	1.2	4.4	0.8	1.9	2.7	4.0	3.1	7.1	56%*1	30%*3	43%*5	72%	29%	56%
Case 2 (Air type collector 25.08+4.56m^2)	1.6	1.5	3.1	1.2	1.5	2.7	2.8	3.0	5.8	47%*2	43%*4	45%*6	53%	43%	48%
Case 3 (Without solar system)	-	2.8	2.8	-	2.7	2.7	-	5.5	5.5	-	-	-	-	-	-

*1:{(3.B-1.B)/3.B}*100 *3:{(3.E)-1.E)/3.E}*100 *5:{(3.H-1.H)/3.H}*100
*2:{(3.B-2.B)/3.B}*100 *4:{(3.E)-2.E)/3.E}*100 *6:{(3.H-2.H)/3.H}*100

4.2 Simulation results in winter season

Figures 11 to 16 show the simulation results of November to March.

The heat collection efficiency of Case 1(water type) is 50%. The heat collection efficiency of Case 2(air type) is 50% in glass area, 40% in without glass area.

Table 5 shows the simulation results of the heating load, reduction and solar contribution in winter. Total load of Case 1(water type) is 43% less than Case 3(without solar system), and total load of Case 2(air type) is 45% less than Case 3(without solar system).

Solar contribution of Case 1(water type) is 56%. Solar contribution of Case2(air type) is 48%.

In Case 2(air type), as a result of all fresh air solar heating system, the ventilation rate is two air changes per hour. It seems that better indoor air quality, however the space heating load is greater than the Case 1 (water type) with the ventilation rate of 0.5 air changes per hour.

5. Conclusion

The solar heating system with water type and air type collector was simulated using EESLISM. The results of simulation show the thermal processes by solar heating systems with building thermal models and DHW heating. The effects of the solar heating systems were examined by the simulated results.

1) The auxiliary heating load of the water type solar heating system(Case 1) is 43% less than the case without solar system(Case 3). Meanwhile the auxiliary heating load of the air type heating system(Case 2) is 45% less than case without solar system(Case 3).

2) As the air type solar collector area is larger than the water type solar collector, the auxiliary heating load reduction of the solar type heating system(Case 2) is slightly greater than the water type solar system(Case 1). The reduction of air-conditioning unit of the water type solar heating system(Case 1) is 9% greater than the air type solar heating system(Case 2). Meanwhile the reduction of DHW heating load of the air type solar collector system(Case 2) is 13% greater than the water type solar heating system(Case 1).

3) The space heating solar contribution of the water type solar heating system(Case 1) is 19% greater than the air type solar heating system(Case 2). The DHW heating solar contribution of the air type solar collector system(Case 2) is 14% greater than the water type solar heating system(Case 1). For the total solar contribution, the water type solar heating system(Case 1) is higher than the air type solar collector system(Case 2).

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