Study on Renovation to Solar Houses with Air Collector
Part 2 House N – Renovation of the Typical Two Storied House

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Abstract

In this study, the development of housing renovation method and related element technologies for the solar house with air collector suitable for a typical two storied house is described. The house, House N is located at a suburb of Nagoya (35.17 N, 136.97 E). While the house has been lived by a family of four peoples, after the renovation, the house is supposed to be live by an elderly couple who will mainly use the spaces on the first floor (ground floor). Therefore, the renovation was limited for the first floor. In order to increase the thermal resistance, the envelopes have been replaced by the well insulated exterior walls and ceilings and the double pane windows. The first floor roof is provided with the glazed air collectors of 37m^2 to be used for space heating and domestic hot water heating in heating season. In summer, the solar collectors are used for only domestic hot water heating. The heat pump air conditioners are used for auxiliary space heating and cooling. The gas boiler is also used for auxiliary domestic hot water heating. The simulation study with a generalized simulator tool EESLISM was carried out in the design process of the renovation. The simulation results showed that the total heat loads of space heating, cooling and domestic hot water heating of the renovated house will be reduced by 55% for the existing house.

1. Introduction

In this study, for the typical wooden two storied house for the family of 4 or 5 persons in the suburbs, the renovation to improve the energy efficiency and the thermal comfort and the renovation to the solar house technology with the air collector is studied. The house (House N) is located at a suburb of Nagoya (35.17 N, 136.97 E) and it was a modern traditional house built approximately 20 years ago. House N is the two storied house with a total floor area of 195m^2 as shown in Figure 1. Using the renovation technology, the house was considered to be converted into an energy efficient and comfortable solar house using solar thermal system with passive solar technologies [1].

2. Renovating House

As shown in Figure 1, front of the house is faced to western south. The thermal insulation of the house is shown in table 1. The insulation thickness of the outside walls was 50mm and the ceiling was insulated with 50mm thick insulation. Single pane windows were used. The insulation of the house was poor and renovation of the envelope was necessary to improve the thermal comfort of the room and to reduce the energy use by space heating.

Space heating was provided with a heat pump room air conditioner and an electric heater for the auxiliary. As the space cooling is necessary in summer, a heat pump room air conditioner was used. For the domestic hot water heating, a gas boiler was used. The house was occupied with a family of four with two adult children.

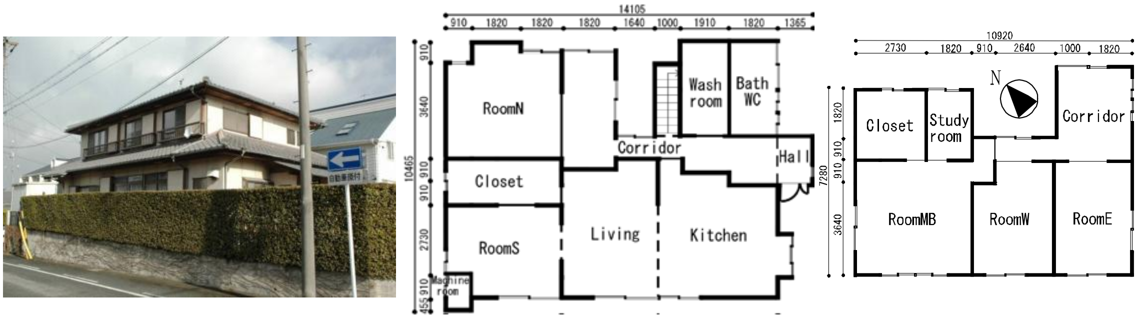

Figure 1. Floor plan and outside view of House N before renovation.

Table 1. Thermal insulation of House N.

Before renovation	After renovation
Roof: glass wool 50mm	Roof: glass wool 50mm
Ceiling: glass wool 50mm	Ceiling: glass wool 50mm Cellulose fiber 200mm
Floor: glass wool 50mm	Foundation: polystyrene foam 80mm
Outside wall: glass wool 50mm	Outside wall: glass wool 50mm Cellulose fiber 200mm
Window: single pane	Window: low-e double pane U=2.08W/m^{2}K

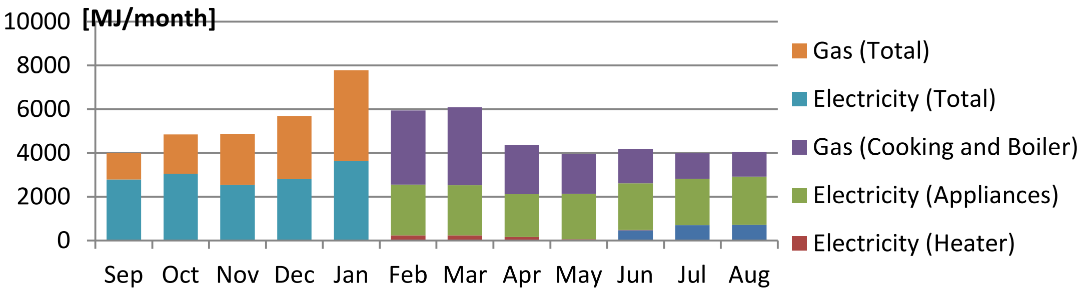

Figure 2. Energy use of House N before renovation (September, 2010 – August, 2011).

The energy use and lived environment of the house had been monitored from February 2011 to July 2011 when the renovation of the house started. The energy used in the house was electricity from the grid and city gas. The electricity use and the city gas flow rate were accumulated at a time interval of 10 minutes by the monitoring system. The room air temperatures and the domestic hot water temperatures and hot water flow rates were also measured.

Figure 2 shows the energy use of the house for a year. In Figure 2, while the monthly energy use started from September, the data from September to January were estimated from the invoices of the purchased electricity and city gas, since the monitoring started from February, 2011. The annual energy use of the house before renovation was estimated to be approximately 60 GJ/year.

3. Renovation Design

Recently, there were two major purposes for the house renovating project in Japan. One is to improve the energy performance, reduce the energy use and CO2 emission and the other is to improve the earthquake resistant. While to improve the earthquake resistance is important, this paper focuses on the renovation to improve the energy performance using the passive and active solar energy use. The renovation to improve the thermal insulation of the house envelopes was the basic method of reducing the energy use for space heating and to improve thermal comfort of the rooms.

The floor plan and section of the renovated house are shown in Figures 3 and 4. The outside view of the house after renovation is shown in Figure 5. The total floor area was slightly increased. The corridor is extended. The envelope of the house was completely replaced by the insulated exterior walls of 250 mm thick insulation and ceilings of 250 mm thick insulation. The double pane windows were provided. The insulation of the envelopes is summarized in Table 1. The first floor roof was modified to mount the solar air collectors.

Air heating collectors are used to heat the air supplied for space heating and also to heat the domestic hot water using an air-to-water heat exchanger is also used as shown Figure 4. The air collector system is an all fresh air heating system with glazed air collector. All collectors are roof integrated type. The collector areas are shown in Table 2.

For the space heating, the heated air is introduced into the under floor space surrounded by concrete foundation walls and foundation floor slab. In order to increase the heat capacity of the under floor space, foundation floor concrete slab is added by 50 mm thick. The room air conditioners are mounted in the living room and rooms S and N. The room air conditioners are air source heat pump unit which are used for the auxiliary space heating and also for cooling in summer.

The domestic hot water is preheated by the solar energy and the gas boiler is used for the auxiliary water heating. The renovation was completed in February, 2012.

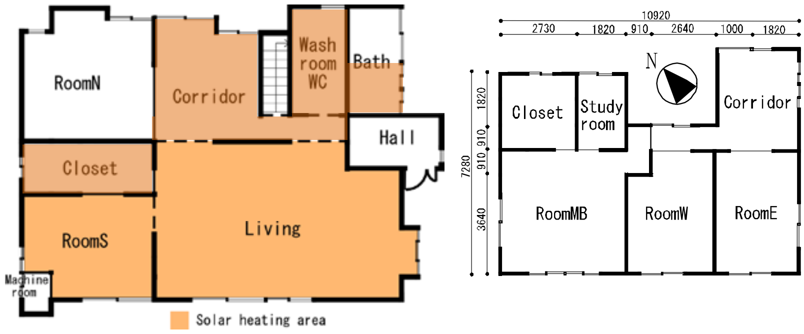

Figure 3. Floor plan of House N after renovation.

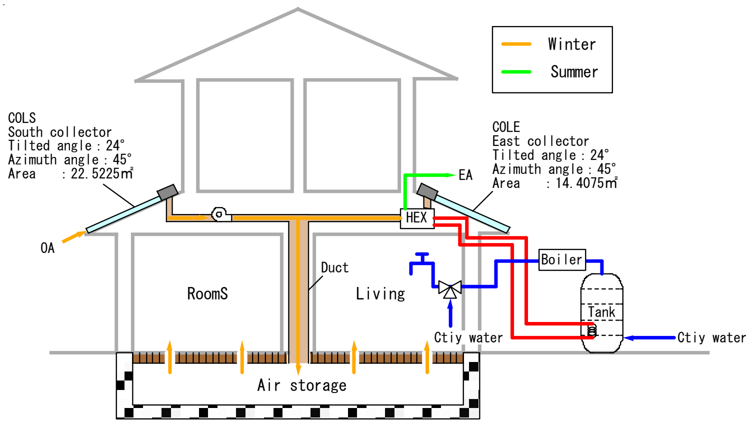

Figure 4.Solar thermal system of House N after renovation.

Figure 5. Outside view of House N after renovation.

Table 2. Heating, cooling and domestic hot water heating system of House N after renovation.

Air heating collector -Total collector area 37 m^2	1) South (glazed) 23 m^2 24 degrees 2) East (glazed) 14 m^2 24 degrees
Domestic hot water heating (DHW)	1) Solar heated tank, 300 litters 2) Gas boiler , eff.=0.94
Space heating and cooling	Heat pump air conditioner, COP=4.0

4. Improvement of Energy Performance

The simulation study with a generalized simulator tool EESLISM was carried out to examine the renovated performance of the house. The weather data at Nagoya weather station in the housing site. The room thermal conditions, the use of household equipment and the domestic hot water use were assumed based on the monitored data of the house before renovation. In the heating season, the room set point for space heating is 18 degree C of the operative temperature defined by the mean of a room air temperature and a mean radiant temperature of a room. The space heating system is assumed to be operated from early morning to midnight. The solar heating provides basic heating and the room air conditioners are used for the auxiliary.

The domestic hot water heating load is based on the hot water use of 450-330 litters and the hot water temperatures of 50 degrees C for the bath room and 35 degrees C for other hot water demand. The gas boiler is operated when temperature of the solar heated hot water is lower than the required hot water temperature.

Figure 6 shows the monitoring result and the simulation results of the annual energy use for the house before and after the renovation. The total heat loads of space heating, cooling and domestic hot water heating supplied by the solar energy and the auxiliary heating systems after renovation. After renovation, the energy consumption for the total heat loads of space heating, cooling and domestic hot water heating will be reduced by 55%. The simulation results showed that the energy uses of total heat loads (space heating, cooling and DHW heating) were 31.2 GJ/year for before the renovation and 14.1 GJ/year for after the renovation

Figure 6 and Table 3 show the summary of the annual performance based on the secondary energy. The simulation results showed that total purchased energy is 41.2 GJ/year. The annual energy use of the house before renovation was 59.7 GJ/year. Therefore, after the renovation, total energy consumption of the house will be reduced by 31%.

Table 3. Comparison of annual performance in secondary (purchased) energy.

Before the renovation (Sep. 2010 to Aug. 2011)	After the renovation (Prediction by simulation)
Electricity 32.4GJ /year (9.0MWh/year)	Electricity 28.8GJ/year (8.0MWh/year) Space heating 1.21GJ Space cooling 0.50GJ Cocking 1.25GJ Appliances, Lighting 25.88GJ
Gas 27.3GJ/year (7.6MWh/year)	Gas 12.4GJ/year (3.4MWh/year) Domestic hot water(DHW) 12.43GJ
Total 59.7 GJ/year (16.6MWh/year)	Total 41.2GJ/year (11.4MWh/year)

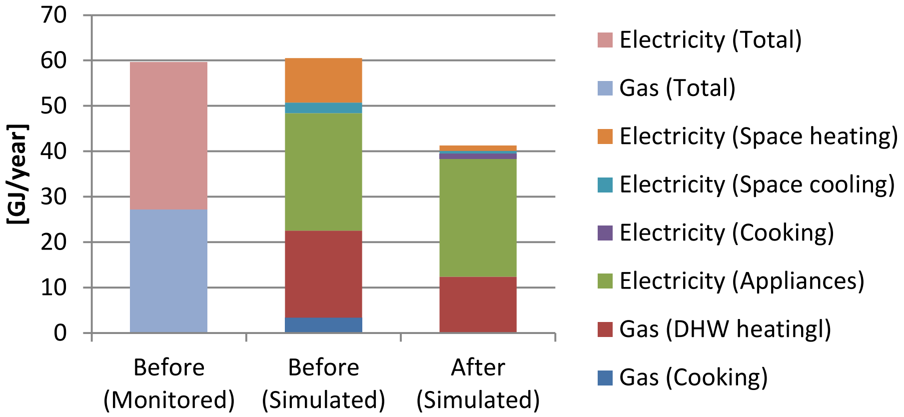

Figure 6. Monitored and simulated results of House N for an year.

5. Conclusion

In this study, the simulation for the total energy performance of the typical wooden two storied house was carried out. As the simulation results, it was found that the renovation is very efficient. It is expected that total energy use of the renovated house will reduce to 31% compared to the house before the renovation. The monitoring of the house after the renovation is conducting to examine the simulation results.

Acknowledgment

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