ABSTRACT
This paper report refers to an indoor thermal environment and energy-saving characteristics of a small-scale nursing home in CHINO City, Nagano Prefecture, JAPAN (referred to as “S” nursing house) by means of measuring the temperature, humidity and electricity consumption. The city of CHINO, a very cold area in Japan, is allocated to Area II under the new energy-saving standard in Japan. This house is built with the EWIS for reinforced concrete structure. To ensure higher thermal insulation performance, the EPS boards with thickness of 300 mm are attached onto the wall building from outside. And two different high insulation and air-tight window systems with triple glazing are installed. Along with high insulation building materials, a full-time ventilation system with high efficient heat recovery function is also installed. As per the surface finish of EWIS, a vapor permeable synthetic plaster system is applied for good vapor diffusion and to avoid blistering, peeling and bubbling. This building is designed to use human body heat of the staff and customers as heat wastes, as well as lighting and electric devices. Service started in September 2006, any air-conditioning device has never been used until now (end of April 2007), except for use of dehumidifier during a few several hot days. The indoor amenity and energy-saving characteristics is highly expected throughout the year.

KEYWORDS
External wall insulation system (EWIS), Nursing home, Reinforced building with external thermal insulation.

INTRODUCTION
Some researches on the indoor thermal environment and energy use concerning the elder care facilities have been conducted[1] - [3], but medium-scale elder care facilities with reinforced thermal insulation efficiency are not sufficiently studied yet. In this research, we measure the elder care facility that improved insulation completely, and we examine whether it is possible to build a facility that maintains a constant temperature throughout the year and saves energy greatly. Since this measurement is still continued, this paper describes the actual measurement results from the start of the measurement in Aug., 2006 to Apr., 2007 as well as the results of the questionnaire conducted in winter, a heat load simulation, and an estimated total annual power consumption using multiplied regression analysis in order to study the above.

METHODS
Overview and Insulation Specification of the Building

1 Corresponding Author: Tel: 03-3341-1381, FAX: 03-3341-3820
E-mail address: futatsugi58117@watahan.co.jp
The building is located in CHINO City of Nagano Prefecture, which is in the Area II according to the area classification specified by the next-generation energy-saving standard. The 1st floor is used for the day-service and as the office and kitchen, and the 2nd floor for the short-stay service. The thermal insulation structure for the exterior wall is constructed by a method whereby the expanded polystyrene foam (hereinafter referred to as EPS), which is 300 mm thick and has moisture permeability, is attached to the RC wall outside and its exterior surface is finished thinly with permeable resin plaster. The EPS 400 mm thick is used for the thermal insulation of the RC surface which lies under the “Okiyane” (upper roof). The concrete basement is laid down under floor, which is covered with extruded polystyrene foam (referred to as XPS) of 100 mm in thick. In addition, the ventilation system with sensible heat exchanger, in which an auxiliary heating device integrated, is installed on each floor. Table 1 shows the overview of the building and Figure 1 shows plan of the building.

Measurement points
The measurement started on Aug. 12, 2006, and “S” nursing house started the operation on Sep., 1st. The measuring points are 56 points in total, including the indoor/outdoor air temperature and humidity, wall temperature of four points of the compass, temperature inside the heat exchanger ducts, amount of insolation, power consumption of the electric light etc, and power consumption of air conditioners/heat exchangers. The data is collected every one minute. Table 2 shows the brief description of the measurement.

RESULTS
Long-Term Variation in the Indoor/Outdoor air temperature and Relative Humidity
Figure 2 shows the average variation in the indoor/outdoor air temperature from the start of the measurement in Aug. 2006 to the end of Apr. 2007. Since this graph is used to understand the general
flow of the change in the indoor/outdoor air temperature, one plot in the data indicates the average of one week. This graph indicates that the outdoor air temperature varied largely during this period, but the room temperature didn’t change much and remained at around 20 deg C even in Jan., which is the coldest month of the year. It is confirmed that heat was discharged and ventilated by opening the windows at night, etc, and the air conditioners were used sometimes in summer. In winter, though the air conditioners were rarely used for air heating, auxiliary heater by the heat exchanger activated to keep the room temperature constant.

Figure 2 also shows the changes in the weekly average relative humidity from the start of the measurement to the end of Apr.2007. The room humidity dropped as the outdoor air temperature fell. Particularly, the relative humidity on the 1st floor fell below 20 % a few times between Jan. and Feb., which is a severely cold period.

Definition of the Hottest/Coldest Days
The business day when one minute data records the highest or lowest temperature and the horizontal insolation intensity is high, which allows the judgment of fair weather, is defined as the hottest day or coldest day.

Figure 3 shows the graph of the week that includes Sep. 4, or the hottest day. When the solar insolation was intensive, the external temperature exceeded 30 deg C, but the room temperature was kept at around 25 deg C. Figure 4 shows the graph of the week that includes Jan. 10th, or the coldest day. In most of the days during this week, the daytime high of the external temperature was only around 5 deg C, and the lowest temperature dropped to -10 deg C or below in the morning. On the other hand, the room temperature remained at around 20 deg C.
Daily Behaviors of the Hottest Day (Sep. 4) and Coldest Day (Jan. 10)

Figure 5 shows the graph of the hottest/coldest days. While the external temperature fluctuated by 13 deg C between the morning and daytime on the hottest day, first floor's temperature kept about 26 deg C. The fluctuation in the room temperature was about 4 deg C on the 1st floor, and about 2.5 deg C on the 2nd floor.

The increase in the temperature during daytime on the 1st floor is considered to be caused by the increase in the number of the elderly care receiver and in the internal heat generation due to this. Though the air conditioners were used this day, the highest room temperature was around 27 deg C even when the activities in “S” nursing house became active and the internal heat generation increased.

The relative humidity was kept about between 60 % and 40 % throughout the day, and maintained properly even during the activity time of the people.

While the lowest external temperature on the coldest day fell down to around -13 deg C at around 6:50 in the morning, the temperature on the 1st floor was kept at about 18 deg C even when there were no people, and the difference between the indoor and outdoor air temperature was about 31 deg C. Then, the room temperature started to rise at around 10:00 when the day service activities on the 1st floor started, and kept at around 20 deg C. On the other hand, the temperature on the 2nd floor where the short-stay elderly care receiver always stayed was kept at 20 deg C or higher almost throughout the day. The daily variation in the room temperature was small about 4.3 deg C on the 1st floor and about 3.0 deg C on the 2nd floor, which kept the environment whereby the elderly people were not physically burdened. The average relative humidity between 6:00 to 8:00 in the morning was about 13 % and the air was so dry. This is because the sensible heat exchangers were used and the indoor humidity was discharged outside. However, it increased from around 10:00 when more elderly care receiver visited “S” nursing house and a humidifier started to be used, and it was kept at 20 % or higher during daytime.

On the 2nd floor, the phenomenon whereby the relative humidity dropped in the morning was not observed and it was kept at between 20 % and 30 %.

Long-Term Variation in the Wall Surface Temperature

Figure 6 shows the relationship of the surface of the exterior thermal insulating material EPS whose temperature increases due to the solar insolation on the wall surface on the south side of the building, internal RC frame surface, and the outdoor air temperature from the start of the measurement to the end of Apr. 2007. The weekly average is used for each value in the graph. The graph indicates that the internal RC frame surface remained almost constant throughout the period despite the variation in the
temperature on the surface of the exterior thermal insulating material EPS. While the external temperature fluctuated from 25 deg C to -4 deg C throughout the year, the temperature on the internal RC frame surface only fluctuated by 9 deg C, from 26 deg C to 17 deg C. This is common to all the wall surfaces and shows clearly the properties of the exterior thermal insulation that receives no heat stress on the concrete throughout the year.

Subjective Evaluation by a Questionnaire about the Living Environment

A questionnaire was conducted in “S” nursing house about the living environment from Feb. 15 to 23 2007. The evaluation consists of three items; thermal sensation of each and entire portion of the body, indoor dryness, and overall comfort. Figure 7 shows the measure for evaluation of the thermal sensation. The purpose of this evaluation is to understand the thermal sensation, dryness, comfort of the staff during work, and those of the elderly care receiver during their stay. A simplified questionnaire was used for people who used the short stay service by reducing the measure for evaluation. Figure 8 shows the result of the thermal sensation of the entire body. This Figure shows that most of the staff and the elderly care receiver answered to it with the range of “Neutral” and “warm,” and the indoor thermal environment was basically fine. Among the staff, however, some of the care persons who performed heavy work answered as “hot,” while some elderly care receiver replied as “cold.” This reveals the existence of the difference in thermal sensation between the staff members and the elderly care receiver.

Figure 9 shows the indoor dryness. While 65 % or more staff replied that the room was dry, there were only 50 % or less elderly care receiver who replied so. 88 % of the entire respondents answered to the inquiry about the comfort with the range between “Neutral” and “comfortable.” (Not shown in the Figure above.)
Examination of the Annual Cooling and Heating Load using a simulation Software

The annual cooling and heating load was calculated using "SMASH," a simulation Software. The electric power Note 1) in the electric lights on floors, auxiliary heater and ventilation of the heat exchangers, and human body were set as the source of the internal heat generation. The exhaust heat by the hot-water supply system was excluded.

The simulation model of the "S" nursing house calculated the indoor space separated into the 1st and 2nd floors without the partitions of each room, and it was set that no heat was conducted to the machine room and the kitchen. Table 3 describes the detailed contents of the setting.

The internal heat generation was set each month, and the simulation on the human body was set from the schedule of the presence according to the hearing. The actual measurement was used for the electric lights, auxiliary heater and ventilation, and for the period when it was not available, values obtained using regression analysis from outdoor air temperature were used. Table 4 shows the daily internal heat generation of each month.

The calculation result is shown in Figure 10. No heating load was generated throughout the year, and the result was almost consistent with the actual measurement. The annual cooling and heating load calculated this time was 25.9 MJ/m², which is only 6.7 % of 390 MJ/m², or the Area II criteria under the next-generation energy-saving standard. This proves an extremely high energy-saving efficiency, but actually the internal heat generation shown in Table 4 was included. Therefore, when the electric lights on 1st and 2nd floors and the auxiliary heater and ventilation of the heat exchangers, excluding the heat generation of the human body from the internal heat generation set for the simulation, are also included in the cooling and heating load, 392 MJ/m² load is applied per year, which is 1.01 times of the next-generation energy-saving standard. That is to say, 1.01 times means lighting and heating expenses (ordinary expenses) plus heating and cooling load.

<table>
<thead>
<tr>
<th>Month</th>
<th>Sensible heat (Weekday)</th>
<th>Sensible heat (Holiday)</th>
<th>Latent heat (Weekday)</th>
<th>Latent heat (Holiday)</th>
</tr>
</thead>
<tbody>
<tr>
<td>September</td>
<td>217.1</td>
<td>193.0</td>
<td>27.5</td>
<td>29.3</td>
</tr>
<tr>
<td>October</td>
<td>294.8</td>
<td>239.8</td>
<td>27.3</td>
<td>18.0</td>
</tr>
<tr>
<td>November</td>
<td>429.3</td>
<td>284.9</td>
<td>27.7</td>
<td>17.9</td>
</tr>
<tr>
<td>December</td>
<td>429.3</td>
<td>325.5</td>
<td>27.3</td>
<td>18.0</td>
</tr>
<tr>
<td>January</td>
<td>429.3</td>
<td>325.5</td>
<td>27.3</td>
<td>18.0</td>
</tr>
<tr>
<td>February</td>
<td>429.3</td>
<td>325.5</td>
<td>27.3</td>
<td>18.0</td>
</tr>
<tr>
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<td>325.5</td>
<td>27.3</td>
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</tr>
<tr>
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</tr>
<tr>
<td>May</td>
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<td>18.0</td>
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<tr>
<td>June</td>
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<td>239.8</td>
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<tr>
<td>July</td>
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<tr>
<td>August</td>
<td>201.0</td>
<td>159.0</td>
<td>26.5</td>
<td>28.0</td>
</tr>
</tbody>
</table>

Table 4 Conditions of the monthly internal heat generation

![Figure 10 Simulation result](image-url)
Figure 11 shows the transition of the monthly power consumption from the start of the measurement to the end of April 2007. In the "Total Motive Power", power for air-conditioning and ventilation system with auxiliary heater is included. The care service started in September and the total power consumption increased after that and became highest in January when the outdoor air temperature was the lowest. Concerning its breakdown, the increase in the power consumption of the total electric power most affected the overall transition of the power consumption. This is caused by the actuation of the auxiliary heater of the heat exchangers. That is to say, auxiliary heater is main heating load in winter.

Examination of the Amount of the Internal Heat Generation to Realize the Energy-Saving Building without Heating System

The calculation period was from Feb. 1st to 6th, 2007 when "S" nursing house operated without using the heating and the external temperature dropped most during the period after the measurement of the power consumption of the auxiliary heater in the heat exchanger was started. Heat from the human body and electric power consumption of the electric lights, the auxiliary heater and ventilation of the heat exchanger on the both floors are regarded as the source of the internal heat generation and exhaust. The daily average of the amount of the internal heat generation was 443.7 Wh/m².

Estimated Total Annual Power Consumption

To estimate the total annual power consumption in "S" nursing house, multiplied regression analysis was used as data in summer are yet to be available. The explanatory variable used for the analysis was the difference of the measured temperatures in indoor and outdoor (daily average). The values in the Expanded AMEDAS Weather Data (Ver. 2000) were used for the period when the actual measurement of the outdoor air temperature was not available. The correlation coefficient of the predicted values obtained from the above and the actual measurement is 0.95, and the total annual power consumption is calculated to be 531.8 MJ/m². That is, when compared with the standard value of 390 MJ/m² for the Area II specified in the next-generation energy-saving standard, it is 1.36 times high. Therefore, this means that all the operational electric power was covered approximately by 1.4 times of the annual cooling and heating load standard. Besides analysis of annual measured power consumption, the comparison with other care facilities will be considered in future, but this can be said an amazing energy-saving efficiency.
CONCLUSIONS
The following findings were obtained from the results of this actual measurement and the simulation.
1) As a result of the full-scale exterior thermal insulation in which the insulating material of 300 mm in thick was used in the building of RC frame construction, the variation in the room temperature was small both in winter and summer, and a comfortable thermal environment was maintained.
2) By using the exterior thermal insulation, the variation in the temperature inside the wall can be reduced throughout the year, resulted in the reduction in the heat stress of the concrete.
3) The result of the questionnaire shows that the temperature whereby part of the elderly care receiver felt slightly cool made the staff who actually worked there feel hot. The staff felt more dryness than the elderly care receiver.
4) The simulation result shows that the annual cooling and heating load was 6.7 % of the Area II next-generation energy-saving standard. However, when the internal heat generation and exhaust heat excluding the human body are all added to the cooling and heating load, it will be 1.01 times of the standard.
5) This facility covers all the energies by electric power. The power consumption increases as the external temperature falls. Especially, this is largely affected by the increase in the power consumption due to the auxiliary heater of the ventilation system.
6) The internal heat generation and exhaust heat required to achieve the energy-saving system without using the heating during the severely cold period was 443.7 Wh/m² per day.
7) The calculation result using regression analysis shows that the annual electric power consumption required to manage “S” nursing house was about 1.4 times the cooling and heating load based on the next-generation energy-saving standard.

NOTE
Note 1): Since the power consumption is measured in the distribution board, it includes the consumption of electronic office equipments, besides the electric lights.
Note 2): The conversion rate to electric power is 3.6[MJ/kWh].

REFERENCES