ENERGY PERFORMANCE ANALYSIS TO REALIZE A ZERO ENERGY HOUSE,
‘ZENER HEIM’ IN KOREA

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ABSTRACT
According to the government’s plan, our company set up a goal, which we termed ‘Green Premium’. It involves realizing a zero energy house as a commercialized residential building by 2020.
In this paper, we present an example of a zero energy house (Zener Heim) applied to a house in an actual project in which people live. To realize the zero energy house, an energy simulation method was mainly utilized.
The total energy used by a building (not only the cooling and heating energy but also the energy for lighting, hot water, instruments, cooking and other purposes) can reach zero through energy production by geothermal, solar thermal, photovoltaic and fuel cell means.
Finally, we found that it is possible to predict the cooling and heating energy via an energy simulation method and to realize a zero energy house based on the result of the energy simulation.

INTRODUCTION
The Korean government announced on August 8th, 2009, the Carbon Reduction Target of 2020, which aims to reduce energy consumption by 30% compared to BAU (Business As Usual). The Korean government also suggested ‘Low Carbon Green Growth’. This is not the passive concept that reduces carbon but active concept that advances the growth of new power sources.
In building areas, an energy conservation roadmap has been suggested. This regulates the total energy consumption in 2010, aims to reduce the energy consumption of residential buildings by 30% in 2012 and by 60% in 2017. Another goal is a 60% reduction in the energy consumption of non-residential buildings by 2020 and finally the obligation of all buildings being zero energy buildings by 2025.
Korean construction companies compete for control in related industries. Our company suggested the ‘Green Premium’, which is an energy conservation roadmap for residential buildings. It outlines a plan for the commercialization of methods to realize a 30% reduction in energy consumption in 2010, 50% in 2011, 70% in 2014, with the final commercialization of zero energy houses in 2020.
This represents an advanced goal compared to the policy of the Korean government.
The purpose of this paper is to find the means to realize zero energy houses in residential buildings as they are actually constructed at commercial project sites.
To achieve these goals, we first conduct simulations of an early design based on Korean regulations to determine the correct amounts of heating and cooling energy required and to look for possibilities to conserve energy. Secondly, we used the early design at the passive house level to realize a zero energy house that minimized the energy production needs. Thirdly, we conduct simulations of the advanced design and calculate the necessary quantity of energy production.
Finally, we decided on a renewable energy system to realize a zero energy house considering the possible space, cost and other considerations.
Throughout this research, our company (Daewoo E&C) realized a zero energy house in 2010 which we termed ‘Zener Heim’. It is in Dong-tan, Korea. ‘Zener Heim’ is an amalgamation of the words ‘Zero ENERgy’ and ‘Heim’ (meaning ‘house’ in German).
‘Zener Heim’ as designed and constructed was successful and presented the possibility of meeting energy requirements without any fossil energy input.
We confirmed that it is possible to realize a zero energy house by the monitoring the energy consumption and production after construction.
On the basis of this experience, we realized the possibility to make the occupants of such houses comfortable while at the same time to decrease the amount of energy required so as to enhance the energy savings.

SIMULATION AND/OR EXPERIMENT
To realize a zero energy house and to apply the technologies and related items to actual buildings (not a test-bed building), we chose the project site of Dong-tan, Korea. Details are shown in Figure 1.
In its analysis of the energy performance, the simulation program took into account the transient characteristics of the building structure. Visual DOE was used for the simulation. It is based on DOE-2
and one of the most popular simulation tools for building energy analysis.

**Overview of the Early Design**

The early design was basically referenced from the Korean Energy Efficiency Level, including the Korean Building codes. The details are shown in Table 1. It is a two-story building and the useable residential area of the unit is about 188 square meters (See Figure 2).

**Overview of the Advanced Design**

The zero energy house is not a building with zero energy consumption but a building with minimized energy consumption capable of the self-production of energy without any fossil energy input. Because the cost of a renewable energy system is high and because it requires available space, the building’s energy consumption method needs to be minimized. This is accomplished with a passive energy conservation method that incorporates highly insulating materials and other strategies.

Thus, we advanced an early design to minimize energy consumption. The details are shown in Table 1 as compared to the early design. The plan of the advanced design is shown in Figure 3.

**Energy Consumption Factors of a Residential Building**

The energy used in buildings includes the energy for hot water, appliances, cooking and lighting as well as heating and cooling.

![Figure 1 Planning of the project site](image)

![Figure 2 Plan drawing of the early design](image)

![Figure 3 Plan drawing of the advanced design](image)

**Table 1 Comparison of thermal factors**

<table>
<thead>
<tr>
<th>Insulation</th>
<th>EARLY DESIGN (Korean Building Code)</th>
<th>ADVANCED DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>0.437 W/m²K</td>
<td>0.108 W/m²K</td>
</tr>
<tr>
<td>Roof</td>
<td>0.282 W/m²K</td>
<td>0.109 W/m²K</td>
</tr>
<tr>
<td>Bed 1</td>
<td>Reflective Low-E 24mm (2.5 W/m²K)</td>
<td></td>
</tr>
<tr>
<td>Bath 1-1</td>
<td>Vacuum 24mm + Reflective Low-E 24mm</td>
<td></td>
</tr>
<tr>
<td>Bath 1-2</td>
<td>Tempered 6mm + Vacuum 24mm</td>
<td></td>
</tr>
<tr>
<td>Living 1</td>
<td>Vacuum 24mm + Reflective Low-E 24mm</td>
<td></td>
</tr>
<tr>
<td>Living 2</td>
<td>High Performance</td>
<td></td>
</tr>
<tr>
<td>Dining</td>
<td>Low-E 24mm (2.682 W/m²K)</td>
<td></td>
</tr>
<tr>
<td>Utility</td>
<td>Vacuum 24mm + Reflective Low-E 24mm</td>
<td></td>
</tr>
<tr>
<td>Bed 2</td>
<td>Vacuum 24mm</td>
<td></td>
</tr>
<tr>
<td>Family 1</td>
<td>Vacuum 24mm</td>
<td></td>
</tr>
<tr>
<td>Family 2</td>
<td>Vacuum 24mm + Reflective Low-E 24mm</td>
<td></td>
</tr>
<tr>
<td>Bed 3</td>
<td>Tempered 6mm + Vacuum 24mm</td>
<td></td>
</tr>
<tr>
<td>Stair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bath 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-value</td>
<td>2.5-2.682 W/m²K</td>
<td>0.8-1.1 W/m²K</td>
</tr>
<tr>
<td>Solar Shading</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Lighting</td>
<td>Fluorescent lamp</td>
<td>LED lamp</td>
</tr>
<tr>
<td>Infiltration</td>
<td>0.2 times/hour</td>
<td>0.1 times/hour</td>
</tr>
</tbody>
</table>
Table 2 Percentage of energy consumption factors in residential building in Korea (Korea Energy Management Corporation, 2006)

<table>
<thead>
<tr>
<th>Heating</th>
<th>Appliance</th>
<th>Hot water</th>
<th>Cooking</th>
<th>Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>59%</td>
<td>14%</td>
<td>12%</td>
<td>11%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Table 2 shows the average percentage of the energy consumption factor in a residential building in Korea. Energy consumption for appliances, hot water and cooking is considered to be identical both in the early design and in the advanced design.

The amount of energy consumed by appliances, heating hot water and for cooking is calculated from the energy analysis result of the heating consumption in the early design. With this amount and the energy analysis result of the advanced design we determined the amount for the renewable system.

**DISCUSSION AND RESULT ANALYSIS**

First, we compared the heating and cooling load of the early design and the advanced design to determine the effect of an energy saving method.

Secondly, we compared the total energy consumption of the early design to that of the advanced design. Subsequently, we calculated the amount of renewable energy to be created by the system to realize a zero energy house.

Finally, we determined the specific type of renewable energy system and confirmed that it is possible to realize a zero energy house.

**Heating and Cooling load**

The load simulation results of the early design and the advanced design are shown in Figure 4. Throughout the advanced design, the heating and cooling load could be reduced by 68.7%.

**Total Energy Consumption**

The total energy consumption results of the early design and the advanced design are shown in Figure 5. The efficiency of the boiler is considered to be 80% and the COP (Coefficient of Performance) of the refrigerator is 3.0. The energy for hot water, the appliances and for cooking and lighting was calculated from the heating energy of the early design. These percentages are shown in Table 2.

The lighting energy for the advanced design is considered to be 70% of the lighting energy for the early design because LED lamps were used in the advanced design. An LED lamp can reduce energy use by 30% compared to a fluorescent lamp.

Energy for hot water, appliances and cooking should be identical in both designs as these factors are related to the occupant’s habits and because there are no other methods used to conserve energy.

As shown in Figure 6, heating and cooling energy could be reduced by 67.7% and the total energy consumption could be reduced by 44.1% with the advanced design.

In the advanced design, the total annual energy consumption is 12,570 kWh. To realize a zero energy house, more than 12,570 kWh should be produced by the renewable energy system without any fossil energy input.

**Determination of the Renewable Energy System**

There are several renewable energy systems that can produce energy in a building. As shown in Figure 1, the space available to install a renewable energy system is not sufficient. Considering its practical operation, we decided upon the following four renewable energy systems.

1) Geothermal energy system
- COP of cooling: 3.8, COP of heating: 3.2
- Electricity is necessary to operate the system
- Necessary electricity is supplied from photovoltaic and fuel cell
Table 3 Quantity of annual energy production by renewable energy system

<table>
<thead>
<tr>
<th>Renewable energy system</th>
<th>Production</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal</td>
<td>Heating(2,914kWh)</td>
<td>Saving</td>
</tr>
<tr>
<td></td>
<td>Cooling(155kWh)</td>
<td>Quantity</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>Hot water(3,736kWh)</td>
<td></td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>Electricity(4,032kWh)</td>
<td></td>
</tr>
<tr>
<td>Fuel cell</td>
<td>Electricity(6,912kWh)</td>
<td>LNG</td>
</tr>
<tr>
<td></td>
<td>Hot water(3,232kWh)</td>
<td>8,016kWh is needed</td>
</tr>
</tbody>
</table>

2) Solar thermal system
- Capacity : 60˚C hot water, 20,907 kcal/day

3) Photovoltaic
- Capacity : 5.2kW
- Size(mm) : 1,500(W) × 993(H) × 45(D)
- Annual production : 4,032 kWh/year

4) Fuel cell
- Using LNG at a rate of 0.25m³/h
- Production : electricity 1 kWh, hot water 60˚C, 30 liter/h

To prevent a waste of energy and to enhance efficiency, we applied the following hybrid systems:

- Hybrid heating system (See Figure 7)
  - Surplus hot water produced by solar thermal and fuel cells is supplied to the heating system
- Hybrid hot water system
  - A mix of hot water produced by solar thermal and fuel cells.

Figure 7 Hybrid heating system

With this renewable systems, we can expect the energy production levels shown in Table 3.

Realization of the Zero Energy House ‘Zener Heim’

We confirmed whether a zero energy house could be realized or not by combining the energy analysis result and decision of the renewable energy system.
As shown in Figure 8, using the advanced design, the total building energy consumption decreased considerably. However, there is still some energy being consumed. Thus, a renewable energy system is necessary.
Based on the result of the energy analysis, we determined the quantity of renewable energy system efficiently. ‘Zener Heim’ can produce 395 kWh/year more than it consumes. Thus, a zero energy house is realized.

Figure 8 Confirmation of a zero energy house
CONCLUSION

In this study, we simulated and analyzed the energy performance of a residential building to realize a zero energy house.

We found that the energy simulation method is a useful and essential tool for determining which renewable energy system would be necessary.

An energy monitoring system has been operating in ‘Zener Heim’ since the construction of this house, and we have confirmed that more energy is produced than consumed. We will report the result of the monitoring and analysis of this house in another paper.

REFERENCES


