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Design Proposal for Low Energy Buildings using Energy Simulation Program

Goopyo Hong[1], Hye Jin Kim[1] and Byungseon Sean Kim[1]

[1] Yonsei University, Seoul (Korea)

Abstract

The use of energy performance software will become a necessity in the early design stages to quantitatively verify the energy consumption of buildings. In this research, a simulation tool was used in designing a zero energy senior community center for an apartment complex. After comparing and evaluating case 1 (code) and case 2 (current design trend), each load element was analyzed to derive the low energy design for case 3. For case 3, the thermal performance of the insulation and windows as well as the lighting efficiency improved. In addition, photovoltaic solar power was considered as the renewable energy. For heating, the percentage of heat loss from opaque surfaces is 52%, while that from infiltration is 31% and that from window systems is 17%, demonstrating that the envelope has a significant effect on heat loss. For cooling, the percentage of heat gain due to window systems is 43%, while that due to lighting is 33%, that due to people is 17%, and that due to equipment is 7%, demonstrating that the internal and solar heat gain account for most of the energy loss, while the envelope has an insignificant effect. Photovoltaic solar panels were included as a source of renewable energy for the low energy design of case 3 to offset the heating and cooling energy consumption. It was found that using renewable energy would result in an energy surplus of 3,438kWh/year.

Keywords: *energy performance software, early design stage, zero energy design, renewable energy, PV*

1. Introduction

Buildings with improved energy consumption in Korea are being designed and constructed according to the Building Energy Conservation Design Standards (BECDS). The BECDS is categorized into sectors including construction, machinery, electricity, and renewable energy, and is applied to insulation, windows, high-efficiency mechanical and electric equipment, and renewable energy systems. Although the use of these materials is regarded as energy saving, it is difficult to quantify the amount of energy consumption. Thus, the standards are prescriptive requirements, not performance requirements. Also, the Korean government announced its goal to achieve the passive house standard by 2017 and zero energy standard by 2025. Likewise, Europe's target year for achieving zero energy houses is 2020 and that of the U.S. is 2025. In the future, building regulations will become more stringent in order to achieve low energy or zero energy buildings, and this will be a challenge for designers. As a result, architectural designers have focused on building geometry and envelope when designing low energy or zero energy buildings (Shady Attia et al., 2012).

In practice, a high level of expertise is required to apply passive and active techniques in the early design stages, since verifying energy performance is difficult, complex, and time consuming. The use of energy performance software will become a necessity in the early design stages of buildings in order to quantitatively verify energy consumption. In this research, EnergyPlus (Version 8.2) was used in designing a zero energy senior community center for an apartment complex. The energy consumption for designs adhering to the Korean government regulations and current design trends was verified. The purpose of this research is to analyze the technical elements used and determine the effects of energy demand. The findings

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could be considered and applied to future designs for low energy buildings.

2. Methods

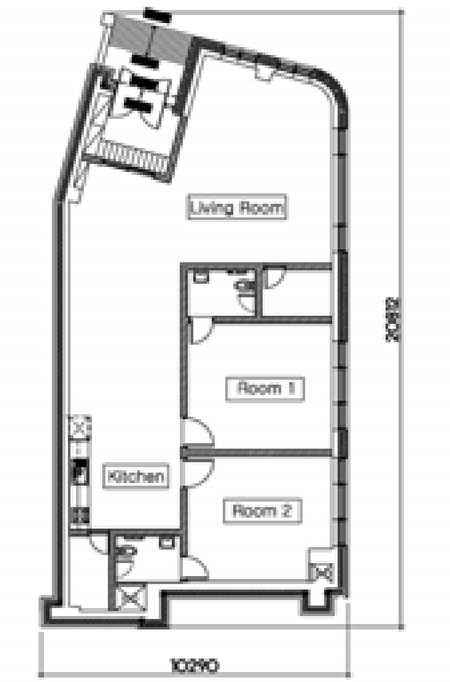
Utilizing the senior community center as the subject building, EnergyPlus was used in this research to analyze and compare case 1 (code), which complied with the building code, and case 2 (design), which followed the current design trend. The elements affecting energy in case 1 were verified.

After evaluating and comparing case 1 and case 2, each load element was analyzed to derive the low energy design for case 3. Case 3 showed improved thermal performance of the insulation and windows. The only renewable energy source considered was solar power generation.

2.1 Case study

The subject building for this research is the senior community center within an apartment complex. Figure 1 shows the floor plan of the community center, with the living room, grandfather's room (Room 1), grandmother's room (Room 2), restrooms, kitchen, and storage rooms.

The heating system is floor heating via district heating. The cooling system consists of four air conditioners fitted to the ceilings in the living room, kitchen, and Rooms 1 and 2.



(b) view of the senior community center

(a) Floor plan **(c) seniors who are taking a rest in the living room**

Fig. 1: Plan and photos of case study

2.2 Energy Simulation Program - EnergyPlus

Developed by the U.S. Department of Energy, EnergyPlus is a program that uses climatological data for load calculation and analysis of energy consumption characteristics. It combines the advantages of DOE-2 and BLAST and has several new functions. It is a simulation to have input and output text files. Users can set a time-step to calculate the loads of a building. EnergyPlus then calculates the heating and cooling system and the requirements of the plant, and predicts the accurate space temperature and humidity as well as occupant comfort (Crawley et al. 2008).

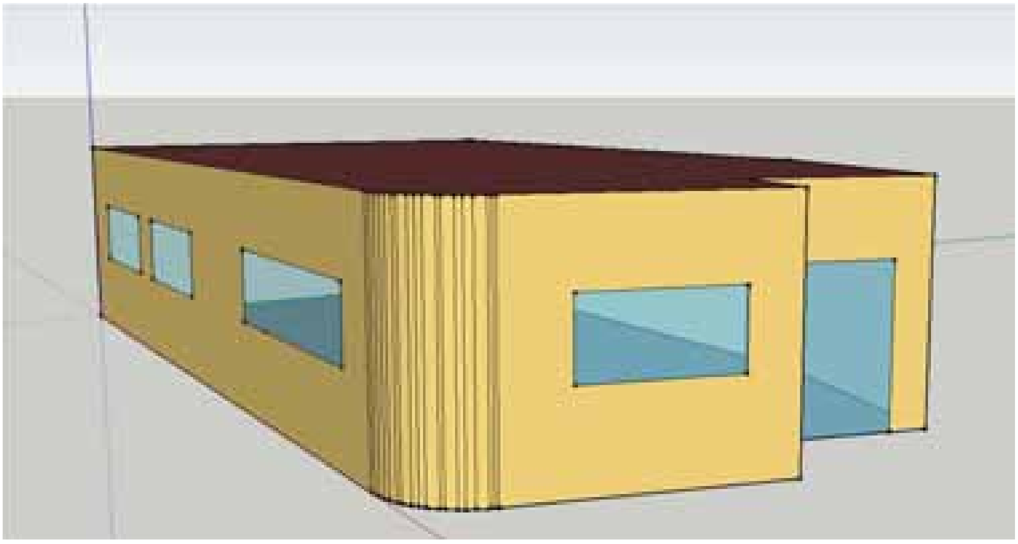


Fig. 2: Modelling using Sketchup

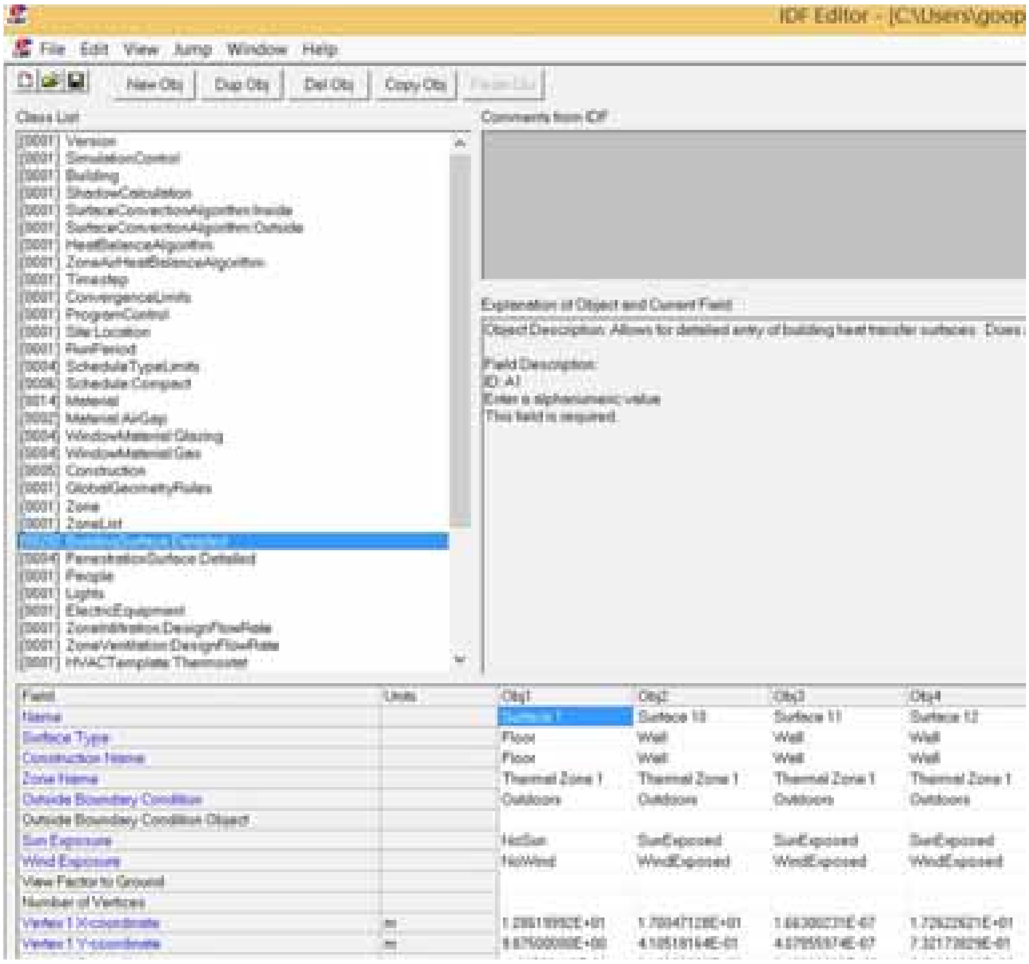


Fig. 3: Image of the EnergyPlus Input data

2.3 Model Conditions

Sketchup was used to model the subject building, as shown in Figure 2, and the model's data was entered into EnergyPlus. Figure 3 shows the values entered into the modeling wall of EnergyPlus. One zone was designated for the heating and cooling for the entire senior community center.

Table 1 shows the necessary elements for the building energy analysis of case 1 and case 2. The BECDS values from the middle region of Korea are shown in case 1. The data for case 2 reflect the values that are commonly used during construction. For the architectural sector, the thermal conductance of the roof, walls, floor, and window systems were calculated and entered. This was then repeated for the lighting, ventilation devices, and household appliances of the electrical sector. For the equipment sector, the district heating system installed was assumed to consist of an individual heating system, while the cooling system was assumed to consist of four air conditioners, each installed in the four main rooms. The number of occupants was 17, while the set point temperature for heating and cooling was set to 23℃ and 26℃, respectively. The amount of infiltration was presumed to be 0.1 h-1(ACH) and the ventilation was designed to be 0.5 h-1 (ACH).

Tab. 1: Condition of the case 1 & case 2

Contents		Case 1	Case 2
U-value (W/m^2 K)	Roof	0.29	0.23
	Wall	0.48	0.32
	Floor	0.34	0.29
	Window	2.70 (SHGC : 0.75)	1.76 (SHGC : 0.52)
	Door	3.70	3.26
Electric	Light	$10W/m^2$	
	Ventilation	0.5 ACH	
	Misc.	Equipment-television, refrigerator	
System	Boiler	Efficiency : 90%	
	System Air Condition	Capacity : 23kW	
Etc.	Occupants	17 people (0.1 person / m^2)	
	Infiltration	0.1 ACH	

2.4 Schedule

A major factor in determining the energy consumption of a building is scheduling. It is important to set a reasonable schedule that considers occupant time, lighting, running time of household electric appliances, and the hours of operation of the building's systems for weekdays, weekends, and holidays. The time period set for this research was one year, starting on January 1st and ending on December 31st, with hours of occupation set from 7:00 AM to 9:00 PM. The contents of the schedule are shown in Table 2.

Tab. 2: Schedules

Content	Total / Week	Total/ Year
Occupancy	98 hours	5,096 hours
Appliances	98 hours	5,096 hours
Lighting	84 hours	4,368 hours
Ventilation	84 hours	4,368 hours

3. Results

3.1 Comparing case 1 and case 2

A simulation was used to verify the energy consumption for case 1 and case 2, with a focus on heating and cooling. Figure 4 shows the monthly heating and cooling energy consumption for case 1 and case 2.

The heating energy consumption of case 1 was 5,861kWh/year and that of case 2 was 4,722 kWh/year, which is 20% less than case 1. The use of improved materials that complied with the thermal conductance code for both insulation and windows system, led to approximately a 24% and 35% reduction in thermal performance, respectively. The cooling energy consumption of case 1 was 6,367 kWh and that of case 2 was 6,086 kWh, which is about 4% less than case 1. Therefore, enhancing the thermal performance of the insulation and window systems has a significant impact on heating energy consumption, but a minimal impact on cooling energy consumption.

According to the simulation results, case 2, which follows the current design trends in Korea, consumes 12% less heating and cooling energy than buildings that follow the BECDS (case1).

(a) Monthly Heating Energy **(b) Monthly Cooling Energy**

Fig. 4: Comparison of case 1 and case 2

3.2 Low Energy Design Elements

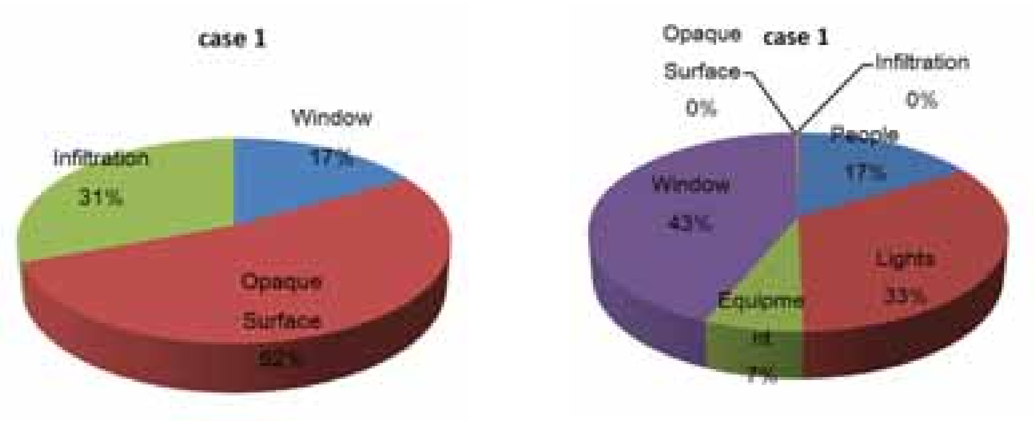
Figure 5 quantitatively shows the heating and cooling elements of case 1 according to load ratio. The heat loss through opaque surfaces was 52%, infiltration 31%, and window system 17%. This shows that the envelope has a significant effect on heat loss.

For cooling, heat gain due to window systems is 43%, lighting 33%, people 17%, and equipment (household electric appliances) 7%, which shows that the opaque surface has a minimal effect However, the window system, which is a major factor in solar heat gain, and other factors contributing to internal heat gain including people, lighting, and equipment, have a significant effect on the overall heat gain. It follows that the slight reduction of 4% in cooling energy consumption from case 1 to case 2 is due to the lack of change in the factors for internal heat gain.

The analysis shows that in order to reduce the heating load, the insulation for the walls, roof, and flooring must be improved. Infiltration is also a significant factor; insulation tape will thus be used during construction to reduce heat loss.

In order to reduce the cooling load, the solar heat gain through the window systems must be reduced by installing glazing with a low solar heat gain coefficient (SHGC). The internal heat gain factors such as people and equipment (household electric appliances) cannot be changed so it is more important to have highly efficient lighting.

Each factor for the load categories of case 1 was analyzed to reduce the energy consumption for the senior community center's design. The important objectives were to reduce the heating energy by enhancing the thermal conductance of the walls and window systems and to reduce the cooling energy by installing windows with low SHGC glass and by installing LEDs.



(a) Heat loss **(b) Heat gain**

Fig. 5: Analysis of the load elements

Table 3 shows the factors contributing to the low energy design for case 3. Compared to case 1, the thermal conductance for insulation decreased by 57%, while the thermal performance for window systems significantly improved by 60%, with a drastic decrease in the SHGC value and a 20% decrease in light density. In addition, solar panels were added to the plans for a zero energy design with renewable energy.

Tab 3. Condition of the case 1 & case 3

Contents		Case 1	Case 3
U-value (W/㎡ K)	Roof	0.29	0.17
	Wall	0.48	0.11
	Floor	0.34	0.16
	Window	2.70 (SHGC : 0.75)	1.03 (SHGC : 0.13)
	Door	3.70	2.1
Electric	Light	10W/㎡	8W/㎡
Renewable	PV system	-	8kW x 4hr/day

3.3 Energy Consumption-case 3

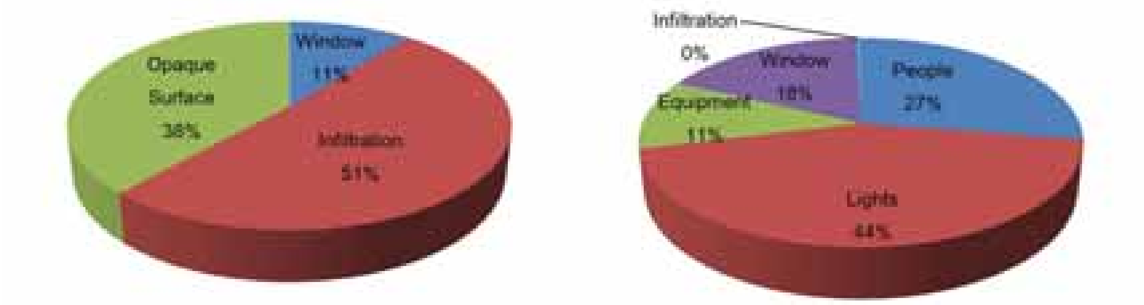
Figure 6 compares the heating and cooling energy consumption of case 1 and case 3. The heating energy consumption of case 3 was calculated to be 3,929kWh/year, which is 33% less than case 1, while the cooling energy consumption of case 3 was 4,313kWh/year, which is 31% less than case 1.

It was determined that the 33% reduction in heating energy consumption was due to the increase in the insulation of the wall and in the thermal conductance of the window systems. The cooling energy consumption was reduced by 31% by utilizing glass with an SHGC value of 0.134 for glazing, achieving a light density of 8w/㎡, and using LED lighting wherever possible.

To further reduce the energy consumption of case 3, the case 3 load ratios were analyzed, as shown in Figure 7. For heating, the infiltration was reduced and the insulation for the wall was improved. For cooling, the lighting density was reduced. However, since reducing light density can increase the heating load, it is necessary to calculate the lowest light density that does not fall below the recommended level of indoor illuminance.

(a) Heating Energy (b) Cooling Energy

Fig. 6: Comparison of case 1 and case 3



(a) Heat loss (b) Heat gain

Fig. 8: Analysis of the load elements in case 3

3.4 Photovoltaic using of renewable energy

Photovoltaic solar cells were included in case 3 to meet the need for renewable energy in a zero energy design. Figure 10 shows that the combined heating and cooling energy consumption is 8,242 kWh/year, while the solar panels produce 11,600 kWh/year. Therefore, by using renewable energy, the zero energy design is feasible and can result in a surplus of 3,438kWh/year.

(a) Photo of the installed PV system (b) monitor of PV generation in the senior center

Fig. 9: Analysis of the load elements in case 3

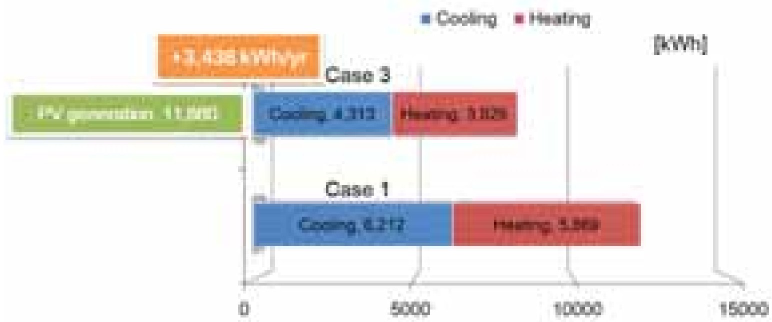


Fig. 10: Energy consumption and energy generation

4. Conclusions

An energy simulation was conducted to design a zero energy building accommodating a senior community center within apartment complexes in Korea. Case 1 was designed according to the Building Energy Conservation Design Standards (BECDS) and case 2 reflected the common designs of Korean construction companies. By analyzing the factors that affect heating and cooling in case 1, low energy design factors were derived to calculate the energy consumption for case 3, as shown below.

- Heating energy consumption was 5,861kWh/year for case 1, 4,722 kWh/year for case 2, and 3,929 kWh/year for case 3. Compared to case 1, case 2 and case 3 showed a 20% and 33% reduction, respectively.
- Cooling energy consumption was 6,367kWh/year for case 1, 6,086 kWh/year for case 2, and 4,313 kWh/year for case 3. Compared to case 1, case 2 and case 3 showed a 4% and 31% reduction, respectively.
- Analyzing the factors that affect heating and cooling for case 1 shows that 1) for heating, opaque surfaces are responsible for 52%, infiltration is responsible for 31%, and window systems are responsible for 17% of heat loss, which shows that the envelope has a significant effect on heat loss; 2) for cooling, window systems are responsible for 43% of the heat gain, lighting is responsible for 33%, people are responsible for 17%, and equipment is responsible for 7%, which shows that internal and solar heat gain account for most of the energy loss, while the envelope has an insignificant effect.
- Photovoltaic solar panels were included in the design as a source of renewable energy to offset the heating and cooling energy consumption of the low energy design of case 3. Using renewable energy would result in an energy surplus of 3,438kWh/year.

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