A Study on BIM based Energy Efficient Design Improvement for Rural Standard Drawing and Specification in South Korea

Focusing on Using Buffer-Zone

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Abstract. *Throughout the world, global warming has been considered a severe problem, which has led to efforts being made for technical development to reduce greenhouse gases in the building sector. As more attention has been paid to energy consumption by residential housing in the building sector, policies and studies on domestic dwellings tend to focus on quality improvement and energy-efficient housing development rather than quantitative housing supply. Yet, policies and guidelines considering residential energy efficiency are inclined to focus on performance and lack in integrated consideration in connection with design. Hence, it seems necessary to compare and analyze design and energy efficiency and to study correlations between housing design and energy. Lately, BIM technology has been used in buildings domestically and proved reliable in respect of its features that enable overall comparison and prediction of housing design, performance and efficiency.*
The present study is to use the BIM technology to analyze energy consumption and the standard drawing schemes for rural areas to find ways to improve efficient design in singles housing sector and to suggest how to take advantage of buffer zones and how to improve housing design in favor of energy efficiency.
Keywords. *BIM; Energy Analysis Tool; Rural Standard Drawing; Buffer-Zone; Sustainable design.*

INTRODUCTION

Each country throughout the world has given top priority to greenhouse gas reduction by paying increasing attention to energy efficiency and renewable energy sources and boosted up policy implementation for greenhouse gas reduction. Currently, Korea's greenhouse gas emission from the perspective of international standard, according to the data published by IEA in 2009, has ranked the 6th place among OECD member states, and the 9th in emission per capita. Subsequently, the government has declared the green policy to reduce greenhouse gas emission and engaged in studies on mid- and long-term policy development.

The building sector takes up 24% of overall domestic energy consumption, which suggests that technical development for energy saving inside and outside buildings is crucial. The government has revised the 'criteria for standard housing construction' and promoted policies to renovate over one million old houses into green homes. Unfortunately, specific technical components are at a test-bed stage of referring to those used in the advanced countries, and relevant studies are limited to public office buildings, large building complexes, apartments and offices in urban areas.

Among residential buildings at home, there are as many single houses as apartment units. Energy consumption by single houses takes up 41% of all residential energy consumption. Therefore, to achieve the mid-term goal of energy saving by 2020, technical development to save energy consumed by single houses as well as apartment ones is a must. To put that plan into practice, BIM technology is adopted in the building sector. From architectural design to construction to management, the technology is capable of integrated analyses and prompt and convenient plan-cost relational analyses.

BIM-based annual energy saving efforts will be conducive to improving the quality of life at national and individual levels. Above all, it will prove a great help for better living conditions in rural areas with relatively lower economic capacity and for energy operation. Accordingly, this study is to seek how to design better energy-efficient single houses in rural areas.

BACKGROUND AND OBJECTIVES

The present study is to seek ways to save energy, specifically in relation to energy consumption for heating, which takes the highest percentage in overall energy consumption by residential houses. The buffer zones that have recently been installed in rural areas and residential housing are applied to new housing design and the resulting energy efficiency is comparatively experimented in regard of the types, placement, sizes and materials of the buffer zones to investigate the correlation between optional ranges applicable to design and efficiency.

For the experiment here, 76 types of the 'standard drawing schemes' suggested by the Korea Rural Development Corp. up to 2010 are chosen as the sample for energy simulation. As the modeling tool for the simulation, Revit Architecture2010 is used to model a target house following the standard drawing schemes. For energy consumption simulation, Autodesk's Ecotect 2010 is used to figure out how to reduce energy consumption of buildings.

CORRELATIONS BETWEEN THE STATUS OF RESIDENTIAL HOUSING AND ENERGY

According to the National Statistics Office's census, the number of single properties has decreased steadily since 1985, whereas that of apartment housing has been consistently on the rise. In 2000, apartment buildings took up a larger percentage than single housing as a result of apartments-oriented housing supply in lieu of single houses.

Table 1
Increase form of Drawing & Apartment

Increase form of Drawing & Apartment

Year	Drawing (%)	Apartment(%)
1985	77.3	13.5
1990	66.0	22.7
1995	47.1	37.5
2000	36.8	47.3
2005	32.2	52.7

In terms of energy consumption per residential housing type, energy consumption by single properties has gradually decreased since 1995, whereas annual energy consumption by apartment houses has steadily growing. Since 2001, energy consumption by apartment buildings has exceeded that by single properties.

Such changes resulted from new housing supplies focused on apartment buildings irrespective of existing housing and from the maintenance cost generated by apartments. As in the Table2 below, a single property compared to an apartment unit of the same size costs more for maintenance and energy consumption for heating.

Table 2
Heating Cost Comparison Drawing & Apartment

Heating Cost Comparison Drawing & Apartment		
Criteria	Drawing	Apartment
Monthly Average of Heating Cost on January	250,000won	145,000won
Security Cost	180,000won	15,000won

Moreover 41.2% of single properties are over 20 years old, and most of them were built without taking into account the heating and insulation. In contrast, most apartment housing was built relatively recently with more efforts exerted for energy security. For long-term energy saving, it is necessary to make appropriate efforts for improvement of existing residential buildings.

Overall, energy consumption per household is proportionate to income, whereas in view of correlations between income and energy consumption levels, the proportionate increase of energy consumption to income shows a downward tendency. Regardless of income levels, low-income households should bear a higher percentage of basic spending out of income.

RELEVANT DOMESTIC INSTITUTIONAL SYSTEMS

Domestic architectural energy-saving-related standards are enforced under the Acts on Building and the on Reasonable Energy Use. Currently stipulated under the Act on Building, the heat-loss prevention provision is largely concerned with the partial insulation criteria and the thermal performance criteria for energy-consuming buildings. In developed countries, by contrast to the belated efforts at home, since the emergence of the Climate Change Convention in the early 1990s, standards for energy-saving housing design have been tightened up to a great extent.

Recently, as studies on energy efficiency have been carried out actively at home, the BIM technology has emerged as an integrated object-oriented information modelling and analysis solution applied to the field of housing for information modeling, energy-environment analysis, construction cost estimation, construction period prediction, design error detection and construct-ability analysis. Still, as it has not been adopted domestically for long compared to the advanced counterparts, the technology is under active consideration and review to seek some localized development and application. Accordingly, applicable technical development in compliance with institutional environment lacks as of now. Hence, specific cases of eco-friendly design approaches and relevant data collection are far from reality as seen from the following study results recently reported. For faster and more active application, case studies on detailed environmental techniques and accurate definition are required.

STANDARD DESIGN DRAWING SCHEMES FOR RURAL AREAS AND BIM-BASED ENERGY PERFORMANCE ANALYSIS

Since 1995, the Ministry of Land, Transport and Maritime Affairs has provided free standard drawings for rural areas in an attempt to relieve building owners of cost and time burdens and help people to choose drawings suitable for their preferences. The standard drawings capitalized on mass production of standardized building materials to save cost of construction and provided a wide range of area (size)- based designs for families to choose. So far, a total of 76 types of standard drawings for rural areas have been developed and distributed 6 times. The following drawings, types and stories have been provided every year under the standard drawing scheme:

The following table delineates housing types as rectangular types, modified rectangular types, ㄱ-shaped types, ㄷ-shaped types and combined types. Rectangle-typed housing accounts for 64.5%, and average housing area is 92.95 m2.

Rectangular types of residential housing takes up 57.89%, which is a larger percentage than the modified rectangular types, ㄱ-shaped types,ㄷ-shaped types and combined types, In addition to the larger percentage of 57.89% compared to the other types, as a rule, unevenness in shapes leads to bigger housing sizes. Single-storied housing amounts to 84.21% in the standard drawings scheme. This is ascribable to economic conditions in rural areas, cost, social phenomena and the intent of the standard drawing scheme.

TARGETS AND CONDITIONS OF SIMULATION

Each process in energy performance analyses requires certain conditions. The following table concerns the overall thermal transmission coefficient among the property values of simulation targets and its rationale. And it is the basic condition for simulation commonly applicable to each energy performance analysis.

- Wall: Overall thermal transmission coefficient=0.4(revised standard for insulation design following Korea National Housing Corp.'s enhancement of criteria for insulation performance)
- Floor: Overall thermal transmission coefficient=0.5(Ministry of Land, Transport and Maritime Affairs' Notification # 2010-371-100608_ revised scheme on energy saving housing design criteria)
- Roof: Overall thermal transmission coefficient=0.25(Korea National Housing Corp.'s enhancement of insulation performance criteria for insulation practices_ Top-floor living-room ceiling exposed to the air)
- Glass: Overall thermal transmission coefficient=2.1(Ministry of Land, Transport and Maritime Affairs' Notification # 2010-371-100608_revised scheme on energy saving housing design criteria)

Table 3
outlines the targets for the simulation.

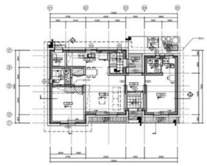
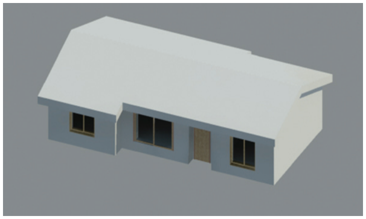
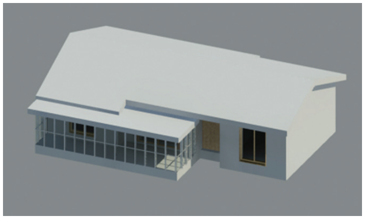
Criteria	Summary	Image	Plan
Orin Number of type	10-27-Na		
Structure	Masonry+Lightweight timber		
Building Area	85.22m2		
Floor	1 floor		
Ceiling Hight	2,400mm		

Table 4
Table Energy efficiency depending on buffer-zone

Criteria	None buffer-zone	Buffer-zone
Image		
Heating load (Wh/m2)	185,709	161,828
Heating load reduction (Wh/m2)	Buffer-zone reduces 12.85% of heating load	
Common element	Depth=2425mm, Height=2400mm, Width=8000mm	

SIMULATION USING ALTERNATIVE COMPONENTS

Greenhouse-based energy efficiency was compared in an experiment. As seen in the table below, the standard 'greenhouse type' suggested in the standard drawings was applied to the target model in the experiment. As a result, post-installation energy consumption for heating decreases by 12.85% per area of unit in contrast to pre-installation.

To maximize the greenhouse-based energy efficiency, the following alternative components in designs, types and materials of greenhouses should be considered:

- Analysis of different consumption of energy for heating per unit area at different depths of greenhouses;

Depth(mm) Heating load (Wh/m2)Heating load reduction (Wh/m2) Ratio of Heating load reduction

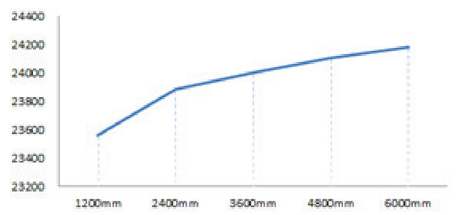
- Different energy consumption for heating per unit area at different heights of greenhouses;

Height (mm) Heating load (Wh/m2)Heating load reduction (Wh/m2) Ratio of Heating load reduction

- Different energy consumption for heating per unit area at different widths of greenhouses;

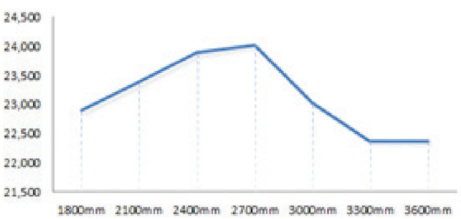
Width (m) Heating load (Wh/m2)Heating load reduction (Wh/m2) Ratio of Heating load reduction

- Different energy consumption for heating with different greenhouse designs.



Depth(mm)	Heating load (Wh/m2)	Heating load reduction (Wh/m2)	Ratio of Heating load reduction (Wh/1200mm)
1200	162150	23558	-
2400	161828	23881	-0.17
3600	161710	23998	-0.06
4800	161607	24101	-0.06
6000	161531	24177	-0.04

Table 5
Table Analysis of different consumption of energy for heating per unit area at different depths of greenhouses



Height (mm)	Heating load (Wh/m2)	Heating load reduction (Wh/m2)	Ratio of Heating load reduction (Wh/300mm)
None buffer-zone	185,709	-	
1800	162,812	22,897	-
2100	162,335	23,374	0.26
2400	161,828	23,881	0.27
2700	161,689	24,020	0.07
3000	162,694	23,015	-0.54
3300	163,327	22,382	-0.34
3600	163333	22376	0.00

Table 6
Different energy consumption for heating per unit area at different heights of greenhouses

Results of simulation using alternative components

- The deeper the greenhouse, the higher the energy efficiency. However, the increment in energy efficiency started to reduce at a certain depth. Using 1200mm mostly used in apartment buildings as a baseline to apply different depths, the efficiency was relatively higher when the depth was doubled to 2400mm. No further difference was found above that level.
- Energy consumption for heating around houses in rural areas was compared in an experiment by changing the heights of a greenhouses by 30cm(尺) starting from the height suggested in the standard drawings for rural areas. The decrement in energy consumption for heating rose in proportion to the heights of greenhouses, and then began to take a downturn at 3000mm. This finding indicates that a greenhouse should be installed within a certain range of heights for efficiency.
- Unlike in the experiment regarding the length, width and height of greenhouses, types usually found in ordinary housing were extracted for a simulation for performance analysis. 3 schemes were derived as alternatives for comparison:

1. Alternative 1 - A greenhouses with a slant-line roof similar to that of a house;
2. Alternative 2 - Low walls surrounding a greenhouse; and
3. Alternative 3 - A greenhouse with a glass roof.

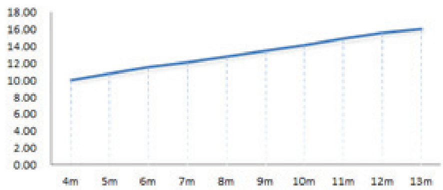
Those three types were compared with the existing greenhouses. As a result, alternatives 1 and 2 were found to produce efficiencies of 12,62% and12.64%, respectively, which were similar to the existing model. By contrast, the glass roof showed a low efficiency of 4.8% due to wider area exposed to the air. This suggests that the roof of a greenhouse should follow the existing one for efficiency, which is an important component in design selection.

DERIVING BETTER DESIGN FOR A BUFFER ZONE

An optimal alternative centering on efficiency was examined on the basis of numeric data derived through an energy performance analysis tool using the alternative component of a greenhouse.

With other control components being equal, the depth of a greenhouse showed higher efficiency

Table 7
Different energy consumption for heating per unit area at different widths of greenhouses



Width (m)	Heating load (Wh/m2)	Heating load reduction (Wh/m2)	Ratio of Heating load reduction (Wh/1m)
None buffer-zone	185,709	-	-
4	166,991	18,718	10.08
5	165,609	20,100	10.82
6	164,223	21,486	11.57
7	163,128	22,581	12.16
8	161,828	23,881	12.86
9	160,476	25,233	13.59
10	159,237	26,472	14.25
11	157,965	27,744	14.94
12	156,628	29,081	15.66
13	155,682	30,027	16.17

values compared to other alternatives when it increased from 1200mm to 2400mm. When the height of the greenhouse was changed by 30 centimeters starting from 2400mm for the target model, the highest efficiency was found at 2700mm. In terms of the length of the greenhouse increased by 1 meters, nearly consistent increase in efficiency was found, suggesting that the optimal alternative should be to install a greenhouse facing south. Finally, given conditions affecting the energy performance analysis, 3 representative types of greenhouses used in practice were chosen and compared with the target model. In sum, the highest efficiency was gained when the roof of the greenhouse was built with the same materials used for the target model with 3 sides fitted with glass panels.

The simulation found that the optimal alternative resulted in 16.39% of efficiency over the case where no greenhouse was installed.

CONCLUSION

The present study attempted to verify the greenhouse-based energy saving effects around single houses and to elicit optimal alternatives based on components determining the types of buffer zones. From the standard architectural drawings in practical use nationwide, average values in terms of frequency, stories and areas were derived, and a target

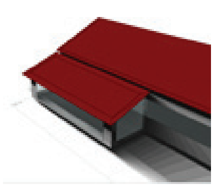
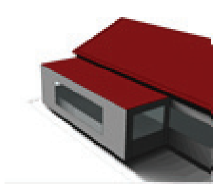
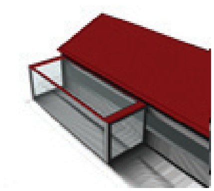
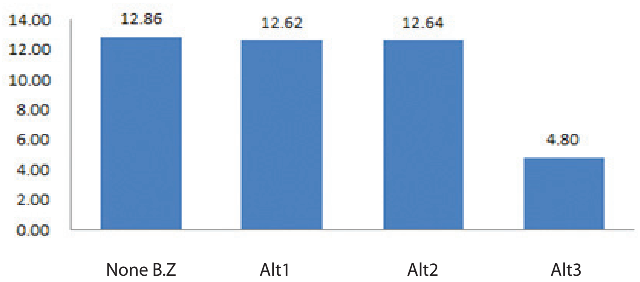
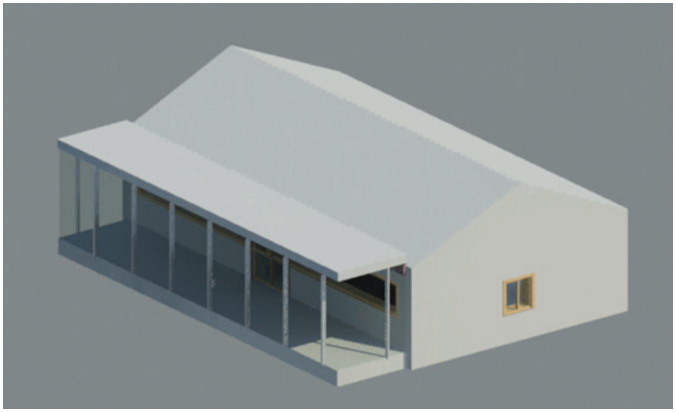
<table>
<tr><th>Criteria</th><th>Alt1</th><th>Alt2</th><th>Alt3</th></tr>
<tr><td>Image</td><td></td><td></td><td></td></tr>
<tr><td>Chart</td><td colspan="3">
</td></tr>
<tr><td>/</td><td>Heating load (Wh/m2)</td><td>Heating load reduction (Wh/m2)</td><td>Ratio of Heating load reduction (%)</td></tr>
<tr><td>None buffer-zone</td><td>185,709</td><td>-</td><td>-</td></tr>
<tr><td>Referance house</td><td>161,828</td><td>23,881</td><td>12.86</td></tr>
<tr><td>Alt1</td><td>162,266</td><td>23,443</td><td>12.62</td></tr>
<tr><td>Alt2</td><td>162,237</td><td>23,472</td><td>12.64</td></tr>
<tr><td>Alt3</td><td>176,795</td><td>8,914</td><td>4.80</td></tr>
</table>

Table 8
Different energy consumption for heating with different greenhouse designsa

Table 9
Optimization alternative simulation

Criteria	Optimization alternative		
Image			
/	Heating load (Wh/m2)	Heating load reduction (Wh/m2)	Ratio of Heating load reduction (%)
None buffer-zone	185,709	-	-
Optimum of depth alternative	161,828	23,881	12.62
Optimum of height alternative	161,689	24,020	0.07
Optimum of width alternative	155,682	30,027	16.17
Optimum of type alternative	161,828	23,881	12.86
Optimization alternative	155,253	30,456	16.39

model was chosen to build a model applied with the property values in drawings based on the BIM modeler. With such approaches to change the types of buffer zones and with the energy performance analysis tool, the analyses here on correlations with energy efficiency found the following conclusions.

- The higher the values of depth in the reference house, the less the energy consumption for heating per unit area. However, the decrement was found to drop sharply when it was in excess of 2400mm.
- Appropriate height for the reference house was found 2700mm. The reference house was applied with 2400mm, but the analysis on decrement and increment in 30cm(尺) found that the energy consumption for heating per area of unit began to rise at 3000mm .
- Energy efficiency against the length of a greenhouse was found to have a proportional relation. Decreased energy efficiency as per increased length showed relatively high values compared to other components.
- As for the alternative design referring to a greenhouse, three types of improved houses mostly seen in domestic rural areas underwent energy performance analyses, which found that in terms of elevation the more the permeable materials were used, the further the efficiency dropped, and that higher insulation performance on the roofs with non-permeable materials led to higher energy efficiency. This seems attributable to high-temperature air diffusing

through the top as its density lowers.

Based on the aforementioned resulting values, an optimal alternative was developed and its energy performance was analyzed. As a result, compared to the reference house, energy consumption for heating per unit area ended up in 16.39% of efficiency generated. This resulting value should be taken as a relative value rather than an absolute one given the energy performance analysis tool's incomplete reliability. Further, diverse in-depth studies need carrying out by considering opportunity cost and correlations with other design components. Still, the present study is arguably meaningful in that it took advantage of the buffer zones and defined their relations with energy performance based on performance analyses with specific approaches. Hopefully, this study will build a base to establish correlations between energy efficiency and design components.

ACKNOWLEDGEMENTS

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