Abstract
This study aims to develop a system-integrated design prototype for realizing zero emission buildings (ZEBs) and to apply the same to standard-model buildings in order to demonstrate the feasibility of ZEBs. Toward this end, we analyzed the energy consumption/CO$_2$ emission performance of various design strategies and component technologies. Residential buildings, office buildings, and school buildings were selected as the building types that will have the greatest ripple effect from the viewpoint of realizing ZEBs. Prototype models using various architectural planning elements, facility planning elements, and renewable energy systems were proposed for each type, and the CO$_2$ emissions reductions were evaluated through an energy performance analysis. The reductions in CO$_2$ emissions for these building types decreased in the order of school buildings (58.6%) > office buildings (46.1%) > residential buildings (36.6%). This study is significant in that currently available technologies were employed as element technologies, and CO$_2$ emissions were evaluated based on the most common buildings.

Keywords: zero emission building; CO$_2$ emission; residential building; office building; school building; integrated design

1. Introduction
Greenhouse gas emissions have become an issue of grave concern worldwide because of the role they play in global warming and other related effects. Attempts are therefore being made to reduce emissions from various sources. An important source that has been targeted in recent years is buildings in developed countries (Suzuki, 1998; Wiel, 1998; Petersdorff, 2006). In fact, in 2007, the 4th report of the Intergovernmental Panel on Climate Change (IPCC) suggested that reducing greenhouse gas emissions from buildings was the most economic and efficient way to reduce emissions (IPCC, 2007). Accordingly, innovative approaches have been devised toward this end in developed countries, and the concept of "sustainable buildings" has gained footing. Energy consumption and CO$_2$ emissions are the most important factors used for evaluating eco-friendly buildings.

In recent years, many government-led projects have focused on realizing eco-friendly buildings and cities in developed countries (NSTC, 2008; AIA, 2007: Johnston, 2005). A zero emission building (ZEB), which aims for "zero" CO$_2$ and greenhouse gas emissions throughout its entire life, has become the global standard for eco-friendly buildings (Smith, 2003 & Hernandez, 2010). However, such projects are only focusing on improving the energy performance of buildings without adequate emphasis being laid on reducing CO$_2$ emissions. To realize a truly "zero" emission building, both aspects need to be dealt with (Marszala, 2010). Furthermore, existing ZEBs have been constructed using only prototype technologies, and practical and economically feasible technologies have yet to be developed (Turner, 2008).

In this study, we propose a practical approach for realizing ZEBs by selecting building types that will have the greatest ripple effect in order to enable the construction sector to meet the government's emissions reduction targets. Toward this end, greenhouse gas emissions from standard buildings have first been evaluated. Then, the CO$_2$ emissions reductions in the prototype buildings after applying architectural planning elements, facility planning elements, and renewable energy systems have been evaluated.
aims to reduce 30% of its business-as-usual (BAU) greenhouse gas emissions by 2020 in order to conform to the United Nations Framework Convention on Climate Change (UNFCCC). To meet this target, a 26.9% reduction in emissions from the construction sector has been targeted. This will necessitate the reduction of emissions from all types of buildings.

However, the easiest and most effective way of meeting this target is to determine types of buildings that are common, have relatively limited sizes and forms, and are closely related to people's daily lives (Todorovic, 2010). Applying simple and common technologies for reducing CO$_2$ emissions from such buildings would produce a great ripple effect. The most obvious examples of such buildings are residential buildings, office buildings, and school buildings. According to the Korean statistical information service, residential buildings, especially high-rise apartments, have the highest ratio of residential building stock in Korea. And people spend the most time in residential, office, and school buildings.

A prototype selection process was carried out as follows. First, the data such as size, shape, and placement of the building were collected from statistics. If statistical data could not be obtained, case studies were conducted. The shape of the prototype was then selected based on the most common type. The details such as structural type, shading and $U$-value were determined through a survey of the literature and relevant regulations.

Table 1. shows an overview of the prototypes for residential, office and school buildings. The prototype of residential buildings was decided using statistics based on the current state of apartments of the Korean Statistical Information Service concerning building size, the framework act on fire services (NEMA, 2008) and building energy conservation design standards concerning building structure (MCT, 2001),

| Table 1. Overview of Prototypes |
|---------------------------------|
| **Categorization** | **Design Element** | **Residential Building** | **Office Building** | **School Building** |
| Scale | Gross floor area (m$^2$) | 8,090 | 16,200 | 9,431 |
| | Typical floor area (m$^2$) | 539 | 1,800 | 2,001 |
| | Number of stories | 15 | 7 | 4–5 |
| Figuration | Finess ratio | 1:1.1 | 1:3 | - |
| Orientation | Southern exposure | Southern exposure | Southern exposure |
| Plane | Core type | Staircase | Eccentricity core | Eccentricity core |
| Elevation | Floor height | 2.8 m | 4 m | 4 m |
| | Ceiling height | 2.6 m | 2.8 m | 2.8 m |
| | Ratio of window area (%) | 80% (Front side), 36% (Back side) | 50% | 43% (Classroom) |
| Shading | None | None | None |
| Structure | Roof insulation (W/m$^2$K) | 0.29 | 0.4 | 0.29 |
| | Basement insulation (W/m$^2$K) | 0.35 | 0.58 | 0.41 |
| | Wall insulation (W/m$^2$K) | 0.47 | 0.58 | 0.47 |
| Fenestration | Window performance (W/m$^2$K) | 3.12 | 3.16 | 3.84 |
| | Shading Factor | 0.70 | 0.76 | 0.76 |
| Etc. | Balcony expansion | - | - |

Fig.1. Prototype of Residential Buildings

Fig.2. Prototype of Office Buildings
and literature review for other details (Song, 2010a; Lee, 2008). The shape of the office prototype was determined based on 33 case studies. Other criteria for office buildings refer to the research paper (KICT, 1997), design standards (MCT, 2001) and other surveys (Youm 2010; Kim, 2012a). The authors used the search service of the Seoul education statistical year book for the prototype of a school building. This website posts information on school buildings in Seoul such as scale, height, number of classrooms and so on. Other criteria

Table 2. Case Studies

| Categorization | Residential Buildings | Office Buildings | School Buildings |
|----------------|----------------------|------------------|-----------------|
|                | Green Home 3L House  | Heifer International Headquarters | Training Center in Bukhara |
|                | BalZEDO Solar Umbrella | Hawaii Gateway Energy Center | Shangri La Botanical Gardens |
|                | Super E Gish ART     | Mercator Center Liubiana | Training Center in Bukhara |
|                |                      | Manitoba Hyo Head Office | Shangri La Botanical Gardens |
| Architectural design elements | Exterior wall insulation | Office Buildings | School Buildings |
|                | Window insulation    | Office Buildings | School Buildings |
|                | Daylighting          | Office Buildings | School Buildings |
|                | Thermal mass         | Office Buildings | School Buildings |
|                | Shading              | Office Buildings | School Buildings |
|                | Natural ventilation  | Office Buildings | School Buildings |
|                | Green roof           | Office Buildings | School Buildings |
|                | Light-shelf &       | Office Buildings | School Buildings |
|                | daylight duct        | Office Buildings | School Buildings |
|                | Façade design        | Office Buildings | School Buildings |
|                | Environmental        | Office Buildings | School Buildings |
|                | materials            | Office Buildings | School Buildings |
|                | Cool ceiling         | Office Buildings | School Buildings |
| Facility elements | Rainwater harvesting | Office Buildings | School Buildings |
|                | LED Dimming control  | Office Buildings | School Buildings |
|                | High-efficiency      | Office Buildings | School Buildings |
|                | equipment            | Office Buildings | School Buildings |
|                | Heat exchanger       | Office Buildings | School Buildings |
|                | Floor air distribution | Office Buildings | School Buildings |
| Renewable energy | Photovoltaics         | Office Buildings | School Buildings |
|                | Solar heating        | Office Buildings | School Buildings |
|                | GSHP                 | Office Buildings | School Buildings |
|                | Cogeneration system  | Office Buildings | School Buildings |
|                | Wind system          | Office Buildings | School Buildings |
|                | Bio-energy           | Office Buildings | School Buildings |

Fig. 3. Prototype of School Buildings
3. Case Studies and Deduction of Energy Saving Factor

In order to realize ZEBs, case studies have been carried out based on 20 buildings to determine feasible element technologies; these have been classified into architectural design elements, facility elements, and renewable energy elements, as shown in Table 2.

Architectural design elements applied to residential buildings include insulation in outer walls, windows and doors, greening, and natural light; furthermore, the cooling load could be reduced by using sunshadings to block solar heat, effective window designs to improve natural light and ventilation, and even solar heating systems. In office buildings, the insulation in outer walls, windows and doors, and natural light were commonly applied, along with air regenerators, the façade, maximization of natural light using light shelves, solar chimneys, and natural ventilation using nocturnal cooling. In school buildings, the insulation in outer walls, windows and doors, and air regenerators were applied, and in particular, eco-friendly building materials were used from the viewpoint of the students’ health. Facility elements used in residential buildings included excellent recycling systems, total heat exchangers, and high-efficiency lamps. In office buildings, excellent recycling systems, high-efficiency lamps, floor air distribution systems, lighting controlling systems, and other high-efficiency equipment were used. In school buildings, excellent recycling systems and lighting controlling systems were commonly used. Renewable energy elements used included photovoltaic systems, along with solar heating systems, geothermal systems, and cogeneration systems.

4. Analysis of CO2 Emissions from Prototype Buildings

The CO2 emissions from the prototype buildings, hypothesized to be proportional to their energy consumption, were calculated by analyzing their energy performance. The energy consumption of each building was analyzed according to its type of heat source and air-conditioning system. To interpret the energy consumption, EnergyPlus, in which an energy balance equation is used in conjunction with a conduction transfer function for dynamic heat transfer analysis, was used. The system interpretation of EnergyPlus is based on the DOE-2 algorithm, and its loading parts are based on the BLAST algorithm. The weather conditions were set based on the typical meteorological weather data for Seoul, Korea. This weather file was derived from the Korea Solar Energy Society and contains a year of hourly data synthesized to represent 20 years of statistical trends and patterns. A type of surrounding terrain was set as a city.

Table 3. shows the annual primary energy consumption and CO2 emission of the prototype buildings. The estimated energy consumption data was 412.2 kWh/m2-yr in a residential building, 366.4 kWh/m2-yr in an office building and 161.6 kWh/m2-yr in a school building. To verify the data from the simulation program, the simulated data was compared with the measured one. The simulated data has a margin of error of 7.6~14.7%. According to the EUMMOT (2012), the acceptable tolerance is ±15% between the annual measured energy consumption and the simulated one. Therefore, the reliability of the simulated data was verified.

CO2 emission from the apartment building was 518.3 tCO2/yr, with the building elements having maximum emissions being, in decreasing order, the heating system, equipment, and hot water heating system. That of the office building was 786.8 tCO2/yr, with the building elements having maximum emissions being, in decreasing order, the lighting, equipment, and air-conditioning system. That of the school building was 120.6 tCO2/yr, with the building elements having maximum emissions being, in decreasing order, the heating system, lighting, and air-conditioning system. Because the form of the greenhouse gas emission of each building was different, element technologies were introduced to reduce the effects of elements with high CO2 emissions.

| Load type | Residential Building (kWh/m2-yr) | Office Building (kWh/m2-yr) | School Building (kWh/m2-yr) | CO2 Emissions (tCO2/yr) |
|-----------|---------------------------------|----------------------------|----------------------------|------------------------|
| Heating   | 155.3                           | 31.7                       | 80.5                       | 209.7                  |
| Water heating | 72.8                           | 5.6                        | 9                           | 85.6                   |
| Cooling   | 20.0                            | 44.3                       | 16.8                       | 24.2                   |
| Lighting  | 32.2                            | 125.4                      | 47.3                       | 39.0                   |
| Equipment | 130.3                           | 90                          | 8                          | 157.8                 |
| Total     | 412.2                           | 366.4                      | 161.6                      | 518.3                  |

Table 3. Annual Primary Energy Consumption and CO2 Emission of Prototype Buildings
Table 4. Comparison between Measured & Simulated Data

| Type of building | Measured data (kWh/m² yr) | Simulated data (kWh/m² yr) | Error rate (%) | Reference |
|------------------|---------------------------|-----------------------------|----------------|-----------|
| Residential building | 352.0 | 412.2 | 14.7 | Lee (2007) |
| Office building | 396.5 | 366.4 | 7.6 | KEEI (2012) |
| School building | 142.0 | 161.6 | 13.8 | Kim (2011) |

5. Energy Saving Design for Prototype Buildings

The prototype building is designed in three stages. In order, and in the respective stages, the reduction of CO₂ emissions is evaluated by changing architectural design elements such as the form and arrangement of buildings and the plans for building parts; by using facility planning elements such as automatic controlling systems and by improving the efficiency of the facility, and by applying renewable energy elements such as photovoltaic systems, solar water heating systems, and geothermal systems. In the last stage, the performance of feasible element technologies is also evaluated.

Table 5. shows the available planning elements for each stage. Basically, design elements refer to passive house standards issued by the International Passive House Association. Different elements are applied depending on the load characteristics of each building. Elements are changed if there are no present standards or if more energy conservational items are available. According to Kim (2012a), the window wall ratio is most efficient when based on 50% of the available. According to earlier studies, the infiltration rate ranges from 0.025 to 0.5 ACH (Thormark, 2002; Sadineni, 2011; Molin, 2011; Kim, 2012a). To reduce the loads, an extremely airtight building envelope is estimated to give an infiltration rate of only 0.1 ACH. The authors used actual data from the website of Hanglas (a Korean window manufacturer) for the solar heat gain coefficient (SHGC) of windows. Shading devices are planned to reduce cooling loads and to improve visual comfort in offices and school buildings. The school building in particular was designed with an atrium to provide a buffer space, while a heating and cooling system was used to save energy. The lighting system replaced fluorescent bulbs (32W) with LED luminaires (25W). Lighting density was set according to the room area (Shin 2008). Dimming controls were used to maximize natural light because the office and school buildings had high light density during the day (Li 2006; Juliana 1982; Guyon, 2006).

A type of renewable energy system was chosen based on load characteristics, and a capacity of systems was determined based on the applicable area. Photovoltaic systems and solar water heating systems were installed in the building and a geothermal system was installed in the other areas except a building footprint.

Residential buildings were simulated under the condition that the building envelope could be improved in a passive house and that high-efficiency equipment with other building types, the window wall ratio of the south façade was increased to 64% and that of the north façade was decreased to only 16%. Heat transfer coefficients refer to passive house standards. According to earlier studies, the infiltration rate ranges from 0.025 to 0.5 ACH (Thormark, 2002; Sadineni, 2011; Molin, 2011; Kim, 2012a).

Table 5. Applied Design Elements

| Categorization | Design Elements | Residential Building | Office Building | School Building |
|----------------|-----------------|----------------------|----------------|----------------|
| Architectural design elements | Window wall ratio according to orientation Insulation | South 64%, North 16% | S, E, W 50%, N 30% | S, E, W 50%, N 30% |
| | Roof, Exterior wall, Lowest floor | 0.15 W/m² K | 0.15 W/m² K | 0.15 W/m² K |
| | Windows | 0.8 W/m² K | 0.8 W/m² K | 1.5 W/m² K |
| | Green Roof | - | - | 1.03 m² |
| | Infiltration (airtightness) | 0.1 ACH | 0.1 ACH | 0.3 ACH |
| | SHGC | - | South 0.5, North 0.3 | Classroom, Corridor 0.75 |
| | | | | Atrium 0.55 |
| Natural ventilation | Ratio of windows operation | Available | 20% | Available |
| Daylighting (Shading) | South | - | Horizontal shading | Horizontal shading |
| | East & West | - | - | Vertical shading |
| | | - | - | Atrium plan |
| Change of Zoning | | | | |
| Facility elements | Improvement of facility efficiency | Heat recovery ventilator system (0.7 ACH) | Heat recovery ventilator system (0.7 ACH) | Heating COP3, Cooling COP4 |
| | High-efficiency equipment (facilities) | 3.24 W/m² | 13.7 W/m² | 4 W/m² |
| | High-efficiency light fixtures | | | |
| | Dimming control system | - | Work surface 500 lx | Work surface 300 lx |
| Renewable energy elements | Photovoltaic system | - | Rooftop 83 kW | Rooftop & Atrium |
| | Solar water heating system | Balcony 540 m² | Façade 67 kW | Roof & Atrium |
| | Geothermal heat pump | 84RT | 366RT | 200RT |

JAABE vol.12 no.1 May 2013 Min Hee Chung 137
and a total heat exchanger to reduce the load of internal equipment were used in order to reduce the heating energy consumption. Furthermore, the use of a geothermal heat pump system to reduce heating energy and a hot water solar heating system to reduce the energy consumption for hot water was proposed.

For office buildings, a building envelope performance similar to that in the case of residential buildings was applied, and natural light was actively used to reduce the energy for air-conditioning and lighting by having 50% of the windows facing south and by using horizontal shading devices. The solar heat gain coefficient (SHGC) of windows was reduced, and the operation ratio of windows during in-between seasons was increased to 20% to reduce the energy required for air-conditioning. Renewable energy was focused on electricity production because 90% of the total energy consumption was in the form of electricity, and therefore, a photovoltaic system was used on the rooftop and façade.

For school buildings, the area of the building envelope was minimized and an atrium was planned. The insulation performance of the building envelope of each part was improved, and windows and doors with an SHGC of 0.75 were applied. The atrium was designed to have an SHGC of 0.55 to reduce the air-conditioning load. The infiltration rate of the building was determined to be 0.3 air changes per hour (ACH). 30% and 50% of the windows faced north and south-east, respectively. Horizontal and vertical shading devices were installed in the south- and east-west-facing windows, respectively, at intervals of 0.5 m. The high-efficiency EHP system was used for air conditioning (Lee, 2012). LED lighting was used to reduce the lighting load, and a lighting control system was applied at a light density of 4 W/m². The renewable energy systems applied included a 200RT geothermal heating and air-conditioning system, a 48.75 m² hot water solar heating system, and a 60 kW photovoltaic system.
6. Results

The standard models were determined and the reductions in their CO₂ emissions were analyzed through the energy saving plans for each building in order to examine the feasibility of a ZEB.

In prototype residential buildings, the use of architectural planning elements such as windows and insulation was found to reduce CO₂ emissions by 21.7%. The use of facility planning elements such as a ventilation system reduced emissions by 19.3%, which was less than those using architectural planning elements only. This was because the emissions from the ventilation system were not considered because of the absence of a ventilation frequency for apartment buildings. However, a ventilation system is required to realize 0.7 ACH of ventilation owing to recent regulations regarding air quality. Therefore, the energy loss was reduced by installing a total heat exchanger. Moreover, the use of renewable energy systems reduced emissions by 17.3%. Overall, CO₂ emissions were reduced by ~36.6% when feasible element technologies were applied to standard-model apartment buildings.

In prototype office buildings, the use of architectural planning elements to improve the performance of the building envelope and reduce air leakage through windows and doors depending on their direction reduced CO₂ emissions by 11.6%. The use of facility planning elements such as lighting control reduced emissions by 23.1%, which was greater than those using architectural planning elements only. This was because the internal loads such as lighting and equipment contributed more greatly to emissions. The use of renewable energy systems reduced emissions by 23%. Overall, CO₂ emissions could be reduced by 46.1%.

In school buildings, the use of architectural planning elements and facility planning elements reduced CO₂ emissions by 23.4% and 33.1%, respectively. This was because the heating system contributed greatly to emissions, and a high-efficiency air-leakage and insulation system reduced the energy consumption, leading to reduced emissions. The use of renewable energy systems reduced emissions by 25.5%. Schools had a lower building density than the other types of buildings, and this increased the feasibility of renewable energy systems such as photovoltaic systems and geothermal systems. Overall, CO₂ emissions could be reduced by 58.6%.

7. Conclusion

Residential buildings, office buildings, and school buildings were selected as the building types that will have the greatest ripple effect from the viewpoint of realizing ZEBs. Therefore, standard models were established for each building type, and the CO₂ emissions were evaluated through an energy performance analysis.

Reductions in CO₂ emissions through the use of architectural planning elements, facility planning elements, and renewable energy systems were analyzed to evaluate the feasibility of reducing the CO₂ emissions of the standard models. The reductions in CO₂ emissions for these building types decreased in the order of school buildings (58.6%) > office buildings (46.1%) > residential buildings (36.6%). The different levels of reduction were attributable to the fact that the available technologies and their applicability differed for each type of building depending on its characteristics. The results showed that the reduction was relatively greater in low-rise buildings that had greater roof areas and a greater percentage of window area.

This study is significant in that currently available technologies were employed as element technologies, and CO₂ emissions were evaluated based on the most common buildings, although a ZEB was not realized. Building types and sizes should be determined from the beginning during the planning stage in order to realize effective ZEBs.

In the future, planning standards and guidelines should be used from the beginning during the planning stage in order to realize ZEBs and thus effectively reduce CO₂ emissions, which should contribute greatly to the construction sector satisfying the government's emissions reduction targets.

Acknowledgments

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MEST) (No. 2012-0000136).

References

1) American Institute of Architects (AIA). (2007). Sustainability 2030.
2) EcoBuildings. www.ecobuildings.info
3) Electric Utility Marketing Managers of Texas (EUMMOT). Commercial standard offer program Measurement and verification guidelines for retrofit and new construction project, Retrieved September 3, 2012 form http://www.xcelefficiency.com/TX/COMM_COMMV_Guidelines_2012_05222012.pdf
4) Greenhouse Gas Inventory & Research Center of Korea (GIR). (2011). Roadmap for low carbon green society 2020, Korea Development Institute.
5) Guyon, D. (2006). Daylight Dividends Case Study: Smith Middle School, Chapel Hill, N. C. Journal of Green Building: Winter 2006, 1(1), pp.33-38.
6) Hanglas website, Retrieved January 15, 2012 from http://www.hanglas.co.kr/products/flatglass.asp
7) Hernandez, P. & Kenny, P. (2010). From net energy to Zero Energy Buildings: defining life cycle Zero Energy Buildings (LC-ZEB), Energy and Buildings 42(6), pp.815-821.
8) Intergovernmental Panel on Climate Change (IPCC). (2007). IPCC 4th Assessment Report Working Group III “Mitigation of Climate Change”
9) International Passive House Association, Retrieved August 25, 2012 form http://www.passivehouse-international.org.
10) Johnston, D., Lowe, R. J. & Bell, M. (2005). An exploration of the technical feasibility of achieving CO2 emission reductions in excess of 60% within the UK housing stock by the year 2050. Energy Policy, p.33.
11) Juliana, W. G. & McLeanb, P. S. (1982). Criteria for the Selection of Dimming Equipment in Schools, Architectural Science Review, 25(2), pp.37-40.
12) Kim, S. M. (2012a). A study of zero emission design strategies in public office building, Master thesis of Chung-Ang University, Korea.
13) Kim, K. H. (2012b). A study on the application of integrated renewable energy systems to the elementary school, Master thesis of Chung-Ang University, Korea.
14) Kim, K. S., Park, J. W., Yoon, J. H. & Shin, U. C. (2011) A case study of characteristics of energy consumption of a high school education facilities, Journal of the Korea Solar Energy Society, 31(5), pp.99-104.
15) Korea Energy Economics Institute (KEEI) (2012) 2011 Energy consumption survey, Ministry of Energy and Resources.
16) Korea Energy Management Corporation (KEMC), (2011). 2011 Handbook of Energy Saving & Economic Statistics in Korea.
17) Korea Institute of Construction Technology (KICT) (1997). Report on the design guideline development for public the standardization of public buildings, Ministry of Construction & Transportation (MCT).
18) Korean Statistical Information Service(KOSIS), Retrieved January 25, 2012 form http://Kosis.kr
19) Lee, H. L. (2012). A case study on zero emission elementary school building design, Master thesis of Chung-Ang University, Korea.
20) Lee, J. S. (2008). A study on the performance assessment of the sustainable buildings technologies for multi-family residential buildings, Master thesis of Chung-Ang University, Korea.
21) Lee, K. G. (2007) A study on heat islands mitigation according to thermal environment distribution of urban, Dissertation of Kyungpook National University, Daegu, Korea.
22) Li, D. H. W. Lam, T. N. T & Wong, S. L. (2006). Lighting and energy performance for an office using high frequency dimming controls, Energy Conversion and Management, 47(9–10), pp.1133-1145.
23) Marszala, A.J., Heiselberga, P., Bourrelleb, J. S., Musalla, E., Vosc, K., Sartorid, I. & Napolitanoe, A. (2010). Zero Energy Building – A review of definitions and calculation methodologies, Energy and Buildings, 43(4), pp.971-979.
24) Molin, A., Rohdin, P. & Moshfegh, B. (2011). Investigation of energy performance of newly built low-energy buildings in Sweden, Energy and Buildings, 43(10), pp.2822-2831.
25) Ministry of Construction & Transportation (MCT) (2001). Building energy conservation design standards.
26) National Emergency Management Agency (NEMA) (2008). Framework Act on Fire Services.
27) National Science and Technology Council (NSTC) (2008). Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Building.
28) Petersdorff, C., Boermans, T., Harnisch, J. (2006). Mitigation of CO2 emissions from the EU-15 building stock. Beyond the EU directive on the energy performance of buildings, Environmental Science and Pollution Research, 13(5), pp.350-358.
29) Sadineni, S. B., Madala, S. & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components, Renewable and sustainable Energy Reviews, 15(8), pp.3617-3631.
30) The Search service for Seoul education statistical year book Retrieved August 31, 2011 form http://statistics.sen.go.kr/
31) Shin, Y. S. & Eo, I. S. (2008, July). Lighting design of lecture room by using Relux. Paper presented at the 40th Biannual Conference of the Korean Institute of Electrical Engineers, Hoengseong, Korea.
32) Smith, P. F. (2003). Sustainability at the cutting edge : emerging technologies for low energy buildings, Oxford, Architectural Press.
33) Song, S. Y., Choi, Y. O., Choi, J. W. & Choi, M. H. (2010a). Comparative study on building arrangement determinants of educational facilities using attitude survey in the elementary school, Journal of the Architectural institute of Korea Planning & Design, 26(9), pp.57-64.
34) Song, S. Y., Koo, B. K. & Lee, S. J. (2010b). Cost efficiency analysis of design variables for energy-efficient apartment complexes, Journal of Asian Architecture and Building Engineering, 9(2), pp.515-522.
35) Suzuki, M. & Oka, T. (1998). Estimation of life cycle energy consumption and CO2 emission of office buildings in Japan, Energy and Buildings, 28(1), pp.33-41.
36) Thornmark, C. (2002). A low energy building in a life cycle? its embodied energy, energy need for operation and recycling potential, Building and Environment, 37(4), pp.429-435.
37) Todorovic, M. S. & Olivera, E. D. (2010). Multidisciplinary engineering assessment to approach sustainable ZE-ECO-settlement, Passive and Low Energy Cooling –PALENC 2010, Rhodos.
38) EnergyPlus. Whole building energy simulation program, U.S. DOE, Building Technologies Program. Internet website, Retrieved December 27, 2011 form http://apps1.eere.energy.gov/
39) Turner, C. & Frankel, M. (2008). Energy performance of LEED for New construction buildings, report for USGBC.
40) Wiel, S., Martin, N., Levine, M., Price, L. & Sathaye, J. (1998). The role of building energy efficiency in managing atmospheric carbon dioxide, Environmental Science & Policy, 1(1), pp.27-38.
41) Youn, C. H. & Lim, H. S. (2010). Establishment of architectural process design guideline for public office buildings, Research paper of AURI, 2010(2).