Energy Consumption and the Power Saving Potential of a University in Korea: Using a Field Survey

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Abstract
With its rapid economic development Korea is faced with the problems of energy consumption and environmental destruction that are in need of urgent solutions. Since buildings account for 25% of Korea's total energy consumption they are the key target in the reduction of carbon dioxide, the principal culprit of global warming. This paper focused on the thoughtless energy waste in universities and researched the characteristics of campus buildings, surveying the energy consumption patterns identified in accordance with the number of users and the period of use. In addition, this paper also established an optimized limitation of future energy consumption by forecasting the trend of growing consumption after examining the kinds and quantities of energy installations being utilized in campus buildings.

Keywords: energy consumption; energy saving potential; energy intensity; university; field survey

1. Introduction
A university, where the highest level of education is offered, can be referred to as a 'small society' made up of various interactions among people involved in education, industries, culture, and housing¹¹. In particular, as rapid improvement is made in the quality of life, a quantitative and qualitative increase in education has also caused schools to bear an increasing environmental load. Many renowned universities in the world have already realized the severity of the environmental load caused by universities and have taken active measures to reduce it through energy production on campus, while at the same time raising awareness about excessive energy consumption and the need for efficient energy facilities.

Universities in Korea, too, have begun to discuss energy use on campus. Particularly, electricity rates for educational institutions, applied to campuses, are cheaper than those for other uses and thus such energy is being used on campuses. The '2007 Energy Use Statistics' published by the Korea Energy Management Corporation has reported that the amount of energy used by Korean universities increased to 240,000 TOE in 2007 from 130,000 TOE in 2000, an 84.9% increase in only 7 years. This increase is about 4 times larger than that of the total amount of energy use in Korea which increased by 22.5% during the same period²². For this reason, universities have been aware of the deep concern regarding environmental problems and started to make low-carbon campuses through the greenization of their land such as by turfing or planting trees. Yet, a more fundamental solution lies in radical changes in energy consumption and immediate reduction in the environmental load, by developing more effective energy plans for campuses. Furthermore, it would be easier for universities to make concrete efforts to save energy if the details of energy-saving rates were presented.

This paper examined the energy consumption patterns of university buildings in Korea, developed greenhouse gas reduction plans, and presented their energy-saving potential. Based on the data collected in this research, the areas in which energy consumption reaches the highest level and the energy source used frequently were identified to present a detailed energy saving plan.

2. University Characteristics
A university is made up of a variety of facilities such as school land, school buildings, libraries, student union building, research buildings, dorms,
A university is largely divided into a school of humanities and a school of science and engineering. And each school (or department) has its related facilities. The residential area may include dorms while the office area includes the administration buildings. Various other buildings such as museums or gyms can be added, making it difficult to classify the energy consumption patterns of a university. Thus the characteristics of a university's energy consumption have to be more general and comprehensive.

It is not easy to ascertain the energy consumption patterns of universities in Korea. Although each university is required to report to the Korea Energy Management Corporation on their energy consumption, that would reveal the status of their energy use and may lead to criticism over environmental issues making power consumption a highly sensitive matter. Nevertheless, the 2006 data shows that a total of 190 high-energy-consumption organizations in the nation included 23 universities, and their energy use revealed a much more serious problem than others.

Kyungpook National University (KNU), analyzed in this research, is located in Daegu, Korea and consists of a total of 112 buildings. Fig.1. shows the KNU campus.

![Campus Map of KNU](image)

As shown in Fig.2., the annual energy consumption of KNU is ranked 6th among the 23 Korean university campuses, slightly higher than the average consumption of 35,477kWh.

KNU's land area is 2.6 million square meters and its floor area 0.46 million m², and they are used by 25,000 students and school personnel as shown in Table 1.

| Area (m²) | Ground area | Building area | Total floor area |
|----------|-------------|---------------|-----------------|
| 2,600,000 | 149,543 | 466,409 |

The facilities were examined to investigate the campus's energy consumption pattern.

KNU was using the 1-cable power supply type, which is simple and economical and suitable for small and medium size buildings. However, it is not very reliable because it takes a long time to recover in the case of a power failure. Therefore, the university installed an extra cable to prepare for such an emergency.

For the HVAC systems, the single duct type (CAV), the fan coil unit and the package types were used. For the cooling and heating facilities, moreover, most central cooling and heating systems used the city gas, in particular the heating devices used gas more than the cooling devices. Table 2. shows the types and the number of central type heating and cooling equipments being used on the campus.

![Annual Electricity Consumption of Universities in Korea](image)

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| Equipment Type | Number | Capacity of rated out (MW) | Total rated out (MW) |
|----------------|--------|----------------------------|----------------------|
| Heating resource equipment | Steam boiler | 13 | 50.7 | 58.1 |
| | Once-through boiler | 4 | 4.8 | 58.1 |
| | Hot-water boiler | 10 | 2.5 | 58.1 |
| Cooling resource equipment | Chiller-heater | 10 | 9.6 | 17.3 |
| | GHP | 118 | 7.7 | 17.3 |

3. Analysis of Energy Consumption

The energy consumption of the KNU campus was examined between 2005 and 2008. Based on the data obtained from the analysis conducted prior to making energy reduction plans, the hourly, monthly, and yearly energy consumption pattern per energy sources of electricity and city gas was analyzed. The energy intensity was calculated as follows to compare energy consumption.

\[ EI (J/m^2) = I_E (J/m^2) + I_F (J/m^2) \] (1)
$I_E$: Electricity Intensity ($J/m^2$), $I_F$: Fuel Intensity ($J/m^2$), $EI$: Energy Intensity ($J/m^2$)

The major energy sources of the campus were electricity and city gas while the use of oil has been decreasing since 2005 until it has become, with a few exceptions, very rare now. Thus, oil consumption was excluded in this research. In fact, the statistics show that 55% of the energy used by universities in Korea is electricity, 40% gas, and only 5% oil\(^2\). Therefore, it was decided that an analysis of electricity and gas was sufficient to show the energy consumption state of a university.

### 3.1 Hourly Energy consumption

An electricity meter was installed in buildings to ascertain the campus' energy consumption in real time and the hours during which the electricity load increased. The data on hourly consumption was collected on a weekday randomly chosen date before/after the summer/winter vacations and during the midterm exam day when the weather was clear.

The energy consumption reached the highest level during the semester in summer, followed by the summer vacation, winter semester, and midseason (spring and autumn) as shown in Fig.3.

Also, the energy consumption increased between 8:00 am (when students begin to arrive at school) and 10:00 pm, slightly decreased at lunchtime, and reached the highest level between 1:00 pm and 3:00 pm. This pattern was more evident in summer possibly because cooling devices were in operation, for the temperature rises to the highest degree around 2:00 pm\(^14\). Yet, as depicted in Fig.4., there is almost no difference in the loads factor between the semester days and vacation days.

Electricity load per building varied greatly from building to building\(^13\). On the campus not only educational-use buildings but also residential buildings such as a dorm and offices were located. The office buildings and the science school buildings showed energy consumption patterns different from the humanities school buildings. Fig.5. shows the hourly energy consumption patterns of the library, the dorms, the information center, and the main administration office buildings as well as the buildings of the engineering/agricultural/domestic science/natural science departments. The greatest energy consumption was observed in the library used by many people, and in the engineering department building whose equipment consumes more electricity. Although most people used more energy during the daytime, the dorm's energy consumption began to rise in the afternoon.

### 3.2 Monthly Energy consumption

As depicted in Fig.6., the monthly electricity consumption pattern was similar in summer and winter, which indicates that cooling and heating accounted for most of the electricity consumption.
In particular, electricity use was higher in summer than in winter probably because the heating area is greater than the cooling area and that electricity consumption per floor area is greater. Also, this may be because other additional heating devices such as an electric stove are used together in winter. Therefore, building repair/maintenance that enhances insulation would be effective in saving energy.

The overall city gas consumption was higher in winter but lowest between May and June and between September and October. Particularly, as shown in Table 2., the energy source was concentrated on heating, which means that the heating load is greater than the cooling load regarding this energy source. The gas consumption is higher in summer than in the midseason because of the use of GHP that utilizes gas for both heating and cooling. GHP was being used in the library and several other buildings.

### 3.3 Yearly Energy consumption

The amount of electricity used in 2005 was 759.6MJ/m², however it continued to rise and reached 909.5MJ/m² in 2008, especially because of the increasing number of heating equipments that used electricity only. The energy consumption of the buildings increases in proportion to the expansion of the floor area, but it is also affected by annual weather.

As shown in Fig. 7., the electricity intensity increased in 2006 compared to the previous year because of higher monthly average temperatures in the summer, which resulted in heavier use of air-conditioners. In contrast, gas showed a significantly lower energy intensity, and its increase after 2006 is relatively small (308.8MJ/m² in 2005 and 339.5MJ/m² in 2006). Hence, the energy intensity of the campus depends on electricity.

### 3.4 Energy consumption per occupants

The University users include undergraduate students, graduate students, faculty and staff personnel. As Table 1. shows, the number of KNU students is 23,000~25,000 and the faculty and staff 1,000. While the number of users gradually increased, the energy consumption per user also rose. Fig. 8. shows the electricity and gas energy intensity per user on the campus.

### 4. Analysis of Greenhouse Gas Emission

Most CO₂ emissions resulted from the use of electricity and LNG or fossil fuel for heating[7]. The annual amount of electricity used on the campus produced about 20,000 tCO₂eq and about 8,000 tCO₂eq in city gas.

A further analysis of the CO₂ emission according to energy sources revealed that electricity produced 0.0204 tCO₂eq per floor area in 2005 but increased to 0.0245 tCO₂eq in 2008. CO₂ emission caused by electricity per user also increased to 0.442 tCO₂eq (2008) from 0.364 tCO₂eq (2005). On the other hand, gas produced 0.0172 tCO₂eq per floor area in 2005 and slightly increased to 0.0189 tCO₂eq in 2006, showing little variation. Similarly, CO₂ emission by gas per user showed an insignificant change (Table 3.). These findings led to the conclusion that electricity use plays a major role in CO₂ emission on the campus[5, 9].

### 5. Energy Saving Potential

#### 5.1 Baseline and estimation of energy demand

Although it is possible to save energy through the energy saving education programs or energy saving campaigns by surveying the normal energy consumption behavior on a university campus, this paper focused on the amount of energy that can be saved by introducing new energy installations to the campus buildings and by increasing energy efficiency internally on the basis of the energy consumption pattern in the campus buildings. To reduce energy consumption in a university, an actual target for energy saving has to be established after analyzing the energy consumption pattern on the campus[8]. the baseline and the volume for energy saving have to be established for the above purpose. A survey of the energy consumption pattern between 2005 and 2008 revealed a big increase
of energy consumption between 2005 and 2006 caused by the newly built facilities and extension of existing buildings. Since then, the KNU’s gas consumption has been almost stable, while the total energy consumption has increased by more than 5% every year because the electricity consumption has largely increased. Nearly all oil heating was changed to gas or electricity heating in 2007 because of the high oil price. Since there was no significant change in KNU’s city gas consumption, an increase in energy consumption in the future would mean an increase in electricity consumption. Thus this paper proposes a concrete heating and cooling alternative to reduce the forecasted energy consumption of 2015 to the energy consumption level of 2006. A diversified variance should be considered for analyzing the reason for increasing energy consumption on the campus\(^{(4)}\). According to the report on energy consumption in public buildings\(^{(3)}\), the increase in manpower, heating installation and electricity installation has been the main reason for increasing energy consumption compared to the former year. So the limitation of expected volume for gas and electricity energy was calculated based on the following formula.

\[
\begin{align*}
V_s &= I_f \text{ (The average for recent 2 years)} \\
&\times (1 + R_{AC} + R_{man} + R_p) \tag{2} \\
V_e &= I_f \text{ (The average for recent 2 years)} \\
&\times (1 + R_x + R_{man} + R_p) \tag{3} \\
R_{man} &= R_p \times R_s \tag{4}
\end{align*}
\]

*The Average annual growth rate since 2000 is 2.1%.

\(V_s\): Estimated volume for the increase of gas (J)

\(V_e\): Expected volume for the increase of electricity (kWh)

\(R_{AC}\): Ratio of increased air conditioning area (%)

\(R_{man}\): Ratio for the increase of energy on increased manpower (%)

\(R_x\): Ratio for the increase of heating installation (%)

\(R_p\): Ratio of population increase (%)

\(R_{man}\): Ratio for the increase of total area (%)

\(R_e\): Ratio of electricity installation (%)

\(R_{man}\): Ratio for the increase of total area (%)

The average gas consumption of KNU for the last 2 years (2007, 2008) was 335.9MJ/m\(^2\), and the average electricity consumption was 887.7MJ/m\(^2\). Additionally, heating installation and electricity have increased on average 2% and 5% respectively every year because of the increased installations, the expansion of air-conditioning equipment and the increase in research equipment. The rate of population increase has been 3.3% every year. Although the ratio for the increase of energy installation could be different when a stable figure being increased but not exceeding the above figure is assumed, gas would be expected to be around 389.9MJ/m\(^2\) and electricity around 1,309.7MJ/m\(^2\) in 2015.

5.2 Energy saving scenarios

In this paper, the costs concerning possible installation of equipment and its exchange and maintenance were not considered. First of all, when equipment is introduced how much energy and cost can be saved\(^{(1)}\).

Therefore, this paper tried to establish some concrete plans and their limitations by preparing scenarios for energy saving through the introduction of available new installations to reduce the energy consumption expected in 2015 at the maximum\(^{(1)}\).

5.2.1 Scenario 1(S1): Building performance improvement for reduction of energy demand

The ratio of average reduction surveyed from the example of improving a building’s energy demand was applied and the energy reduction by reviewing insulation enhancement, greening of exterior coverings and cooling by the intake of outside air in scenario 1 was calculated. In the case of KNU that has many old buildings, insufficient insulation for windows and single window panes caused a great deal of heat loss. Thus improving the performance of insulation could achieve the maximum effect at minimum cost.

Table 4. presents a guideline for the ratio of heat transmission by the kind of windows designed based on the standard of energy saving type construction.

The university buildings were built with simple double windows, and the existing heat transmission...
is 12,552 J/m²·h·°C. By applying glasses with heat transmission of only 8,619 J/m²·h·°C, the buildings could reduce heat transmission and improve the insulation performance.

\[
E(\%) = \left(\frac{k_1 - k_2}{k_1}\right) \times \frac{q_1}{Q} \times R_h \times 100
\]

**E**: Rates of energy saving (%)

\(k_1\): Heat transmission coefficient before exchange (J/m²·h·°C)

\(k_2\): Heat transmission coefficient after exchange (J/m²·h·°C)

The window areas occupy about 20% of the university buildings, and the heating energy would decreased by 6% if the windows were replaced with low heat transmission windows. Use of the construction technology available for energy reduction in buildings is the best method because it has an environment friendly concept to reduce the energy demand of buildings. The method of greening walls or rooftops has recently proved to be not only economical but also most effective because it can reduce the indoor heat load in consideration of the heat environment of university buildings. An analysis of energy performance revealed that greening the exterior coverings of typical university buildings - greening the walls, greening the rooftops, and greening walls and rooftops together - could save heating energy by 1.2%, 3.1%, and 4%, respectively. As the medium and small size buildings in the university are mostly installed with air-conditioning systems that utilize electricity as a fuel, greening the walls and rooftops can reduce the electrical energy required for cooling.

KNU has been cooling the computer rooms or rooms where IT equipment is installed throughout the year including the cold winter months. This paper proposes a natural cooling method that can save up to 1.2% of energy by infusing into the cooling system the outside air that is lower than room temperature during the winter months.

**5.2.2 Scenario 2(S2): Efficiency improvement of energy facilities**

S2 is a scenario designed to save energy through planned improvements in the efficiency of energy utilizing equipment such as the main heating sources, lighting instruments, power equipment, air conditioning equipment, and cooling & heating equipment installed in the existing buildings.

First, in the case of lighting, the normal reflectors of fluorescent lamps are painted with white enamel, and even the products made of abraded aluminum or stainless steel, etc., have no protective covering. As a result, they cause a loss of light because they can be eroded by oxides of sulfur, nitrogen, etc. The SSR (Sterling Silver Reflector) has ultra power saving performance, and maximizes efficiency regarding power saving and is capable of maintaining brightness and improving illumination by reviving lost light through its excellent reflectance and durability owing to its material characteristics. It also has good durability through its excellent resistance to corrosion by ultraviolet rays and pollution. If the normal reflector is replaced with a high illumination reflector, 2 lights of 20W can provide the same illumination as 4 lights of 20W. In the case of a school using 2 lights of 40W, they can be reduced to 1 light. When a normal reflector is replaced with a high illumination reflector, 2.5% of energy can be saved every year.

The current use status of the transformer indicates that it has been run beyond its normal capacity except for the summer season of July through October. However energy can be saved by 6.4% if unnecessary loss is reduced by suspending the use of the lighting panels and summer power panels of the transformer and if the power factor is improved.

A further 2.6% of energy can be saved by applying the following methods. If the flow of refrigerant in a freezer is interrupted or the cooling performance in a compressor is decreased due to wet compression, the performance of cooling equipment can be decreased. To prevent these situations, the COP of cooling equipment should be improved by maintaining the cooling equipment efficiently by replacing the old compressor, by replacing grease or filling the refrigerant into the part that is deficient in it in order to maintain the proper pressure.

Especially in the summer season, the water cooler and heater discharge waste heat of 200 kWh or higher. Therefore energy saving of 4% can be expected when the heat of gas from the water cooler, heater and boiler is used to supply warm water to buildings such as dormitories during all seasons.

**5.2.3 Scenario 3(S3): Installation of renewable energy system**

Universities themselves could adopt a more aggressive approach concerning the production of renewable energy compared with the relatively inefficient and wasteful energy supplied by the Korean Electricity Power Corporation and Korean Gas Corporation resulting from energy loss caused by long distance delivery. Though this scenario cannot reduce energy consumption itself, it can reduce the use of fossil fuel. It is an environment friendly and most advanced method of reducing the emission of carbon dioxide.

KNU is currently generating electricity through a 123kW photovoltaic (PV) system - 40kW in 1 dormitory, 50kW in the dormitory restaurant, 30kW in the central library, and 3kW in the fountain.

A solar thermal system is in operation for the dormitory. A fuel cell with a 3kW capacity is installed, but its efficiency is low because of warm water treatment and the problem is that it is used in the summer season only. The average wind velocity
is 2.2m/s in Daegu, so wind power systems are not suitable for the KNU. The geothermal heat pump system is not recommended because it is difficult to install in preexisting buildings.

If a renewable energy system is additionally installed, the PV system seems to be the most reasonable choice, because electricity occupies 70% of all energy consumption sources at KNU, and is an excellent alternative because it can be easily built on the existing building’s rooftop.

In the case of installing the PV system, the following should be considered in calculating the capacity for installation and power generation.

1) The total construction area within KNU is 120,065 m², and the buildings available for installation of PV systems in this area, each building’s orientation toward the sun, core of the roof and roof shape were considered.

2) To calculate the capacity of the PV system to be installed, the base load of electricity and the area of the rooftop were considered.

As for the architectural elements of the buildings of KNU, 10% are considered suitable for adopting the PV system. In the case of total power load, 1MW can be made available through the PV system when the actual power generation per day is considered. Thus KNU is capable of installing the PV system with a power generation capacity of about 300kW when its construction area and the possible installation area and power generation not exceeding the base load are considered. Power generation from the PV system was estimated using the data of the PV system currently in operation at KNU.

6. Result and Discussion

This paper examined three alternatives to save energy and bring the KNU’s energy consumption level down to the level of 2006 by the year 2015 (1) by introducing new technologies that reduce energy demands of buildings, (2) by maximizing the efficiency of the existing energy consuming equipment, and (3) by introducing renewable energies.

S1 is expected to save 6% of heating load through insulation. S2 is expected to save 4% of hot water load through waste heat recovery and 2.6% of heating load (city gas) by improving the COP of cooling equipment. S3 can save 3% of hot water load by supplying hot water through the heat collected by a solar thermal system.

When the energy saving rates of all three alternatives are added up, the sum may not meet the 35% which is the anticipated increase of electricity by 2015, but the proposed alternatives will reduce the forecasted electricity consumption by about 18%. Though gas
consumption is expected to increase by about 13%, the proposed alternatives would reduce the forecasted gas consumption by about 6% (Fig.11.).

7. Conclusion
To make effective plans for reducing energy consumption and carbon dioxide emission on the campuses of large Korean universities, the authors selected KNU which is classified as the sixth largest energy consuming university in Korea and analyzed its energy consumption pattern. From the results of their analysis, the authors reached the following conclusions.

1) KNU's electricity intensity was 846.0MJ/m² and its gas intensity 330.0MJ/m², unlike the gas consumption that showed a stable increase rate, electricity consumption has shown an increase rate of more than 5% every year since 2006. This increase in electricity consumption occupies the biggest portion in the total increase in the energy consumption on the campus. Because of the increase in the annual average temperature, the increasing cooling load seems to be the biggest factor responsible for the increase in the energy consumption.

2) The authors' analysis showed that KNU is discharging 0.0432 tCO₂eq/m² and 0.7803 tCO₂eq/person.

3) To create a low carbon campus by 2015 reducing energy consumption to the 2006 energy consumption level, KNU must reduce 35% of its electricity consumption and 13% less gas consumption with reference to year 2006.

4) In the case of Scenario 1, it is expected that introduction of technologies capable of reducing the energy demand of the existing buildings can reduce the demand of energy in buildings: 5.2% cooling load and 6% heating load in the field of electricity, and 6% heating load in the field of gas.

In the case of Scenario 2, it is also expected that improvement of the efficiency of energy using equipment can save 2.6% cooling load and 9% lighting and equipment in the field of electricity, 4% hot water and 2.6% cooling load in the field of gas.

In the case of Scenario 3, introduction of the renewable energy systems on the campus can replace a portion of the energy consumption. It can save 10% for lighting and applications in the field of electricity and 3% for hot water in the field of gas.

When the energy saving rates of all three alternatives are added up, the sum may not meet the 35% which is the anticipated increase of electricity by 2015, but the proposed alternatives will reduce the forecasted electricity consumption by about 18%. Though gas consumption is expected to increase by about 13%, the proposed alternatives would reduce its forecasted consumption by about 6%.

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