A Study on Energy Efficiency and Data Energy-based Knowledge Information Accumulation and Library Operation Direction

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ABSTRACT

The research focuses on the changes in the energy field following the Fourth Industrial Revolution, and aims to propose a direction for library operation based on energy efficiency and data energy reflecting this. To this end, this study conducted a case study related to energy efficiency. As a result of the study, detailed measures and guidelines for promoting energy efficiency in the library include 1) the need for policy changes to promote energy efficiency, 2) zero energy and high efficiency for new building renovation, 3) establishment of a high efficiency smart library environment, 4) seeking directions for energy efficiency at the library level, 5) interconnection between the library and the region, 6) establishment of an energy center, and 7) the improvement of awareness and education of employees and local residents, etc., which seem to require discussions.

1. Introduction

The Green New Deal is summarized into and interpreted as the idea of causing innovations which encompass employment and labor by adjusting in all respects the energy structure by building an eco-friendly renewable energy industry's infrastructures and fostering related businesses (Wikipedia, 2021). Such idea already was conceived in the 1970s, yet following the inauguration of the Biden administration of the United States, the eco-friendly policies have gained momentum, and at the same time, gaining attention from the international community once again as a way to overcome the COVID-19 crisis (Kwon, 2021; Yeo 2020).

As such, since the importance of energy efficiency has garnered much attention, industry, transportation, household and commerce, and public sector which consume the final energy are seeking and introducing the appropriate measures for each sector for the efficient use of energy. For instance, in the case of the sector of household, IoT and AI technologies are combined with home appliances used for the residential spaces, or in the case of the industrial sector including factories, smart

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factories and process automation which apply automatic energy control, real time monitoring of the use of energy, and sensor monitoring occupancy, etc., are implemented.

Among the final energy consumption by sector, the public sector consumes 435,000 tons as of September 2020, which accounts for 2.4% of the total of 17,856,000 tons, or the lowest consumption relative to other sectors. Notwithstanding which, the energy efficiency improvement for the public sector is evaluated to have made such a significant contribution to leading the national energy savings initiatives and spreading the energy savings perception (Ministry of Trade, Industry and Energy, 2013). Accordingly, a total of KRW 2.1 trillion are invested for the energy R&D for the public sector in 2020, including KRW 916.3 billion of the government and KRW 1.2232 trillion of the public energy enterprises (Lee, 2020), and when new buildings are constructed for public institutions, it is required to acquire building energy efficiency ratings of "1" in accordance with the Regulations on the Building Energy Efficiency Rating Certifications (official announcement of the Ministry of Knowledge Economy and the Ministry of Land, Transport and Maritime Affairs) (Ministry of Trade, Industry and Energy, 2013). Furthermore, in accordance with the amendment of the Act on the Promotion of the Development, Use and Diffusion of New Energy and Renewable Energy, new and renewable facilities are required for supplying 30% or more of the expected use of energy when public institutions are newly constructed, expanded, or reconstructed from 2020, and by making the installation of new and renewable energy facilities mandatory, and by raising the mandatory ratio of new and renewable energy supply for the public sector to 40% by 2030, public institutions are playing a leading role in promoting the supply of new and renewable energy (Jeong, 2020).

As public buildings, since the 1980s, discussions have taken place regarding the eco-friendliness such as the libraries and the environment, the green library's librarians, establishment of an environmental information source, development of libraries as an environmental subject, and the green library. For instance, a study was conducted to compare the domestic and foreign eco-friendly building certification systems such as LEED or evaluating the eco-friendly characteristics of specific libraries based on such a certification system (Mikkelsen, 2007; Ahn et al., 2012; Lee et al., 2006). Furthermore, references and case studies on the green libraries or the green libraries referring to the libraries carring out the activities related to energy and eco-friendliness (Ahn et al., 2013; Hong & Noh, 2014; Zhu et al., 2010) and the studies (Schaper, 2010), etc., presenting the strategies for building such green libraries have been conducted.

Furthermore, innumerable sites at the libraries have already applied the green paradigm. The relevant categories include all forms of eco-friendly activities, ranging from the activities which provide various programs on climate changes, such as those by the British Library, to those of the Whistler Library, which utilizes renewable energy including the solar and geothermal energies. Recently, the Central Library of the City of Asan became the first library in the country to acquire "This Certification (ZEB 5)" which is certified by the Korea Energey Agency through the "Zero Energy Building Certification System" enforced by the Ministry of Land, Infrastructure and Transport for contributing to the national greenhouse gas reductions and the energy consumption reductions, while promoting them as an innovative growth engine for the construction sector in response to the fourth industrial revolution (Seong, 2018).

As such, libraries are pursuing eco-friendliness by utilizing convenient locations for transportation in the center of cities, water resources conservation and their efficient use, computer controlled windows and light control for the energy efficiency, and the automatic lighting systems, etc., or by introducing architectural elements including the low energy glass windows and reflective membrane roofs, and automatic heating and cooling through undertaking such activities as the quality control of the indoor environment and reuse of the materials and resources through the air circulation system. Among which, this study has focused on the changes in the energy field following the fourth industrial revolution, and reflecting which, it is intended to propose a library energy savings plan based on the energy efficiency and the data energy.

2. Theoretical Background

2.1. Energy efficiency

Energy refers to the input factors for the production of energy services such as heating, lighting, and power (Gillingham et al., 2009), while efficiency basically means the concept of output versus input. The energy efficiency (symbol η), combining the two concepts, means the ratio of the available energy for the input energy in the broad sense of the meaning, and in the narrow sense of the meaning, it means the ratio of how much energy is recovered among the reacted energy (Wikipedia). Furthermore, the International Electrotechnical Commission (IEC) defines it as the ratio or quantitative relationship between the performance of a work or service product or energy and the energy input.

Overall, the energy efficiency may be viewed as the ability to use less input energy for the same production (Lee & So, 2018). There are largely 3 main ways to achieve such goal of energy efficiency. First, less energy is consumed to achieve the same performance (high efficiency), and second, the same amount of energy is consumed to achieve better performance (high efficiency), and third, conversion efficiency is improved towards the final energy from the primary energy (reduction of energy conversion losses), which, for instance, means the improvement of the power generation efficiency through the application of the high efficiency technologies (Lee & So, 2018).

2.2. Fourth industrial revolution and the energy innovations

During the era of the fourth industrial revolution, alongside the development of the ICT technology, countries around the globe are making a great deal of effort to prepare various technologies and policies to help reduce the carbon dioxide and improve the energy efficiencies. Korea is also stressing on the importance of the energy industry in connection with the fourth industrial revolution such as the development of the Renewable Energy 3020 Performance Plan. Such fourth industrial revolution refers to the “ICT and Service Development of the Manufacturing Industry” through the automation of the existing manufacturing industry and the convergence with the service industry, which is materialized by the core widely used technologies of the fourth industrial revolution including the IoT, Mobile and 5G, Cloud computing, Big Data, and AI. The changes of the energy sector following the fourth industrial revolution are largely classified into six major aspects, and are introduced as follows.

Table 1. Six Changes of the Energy Sector Following the Fourth Industrial Revolution.

Classification	Details
Demand for a lot more energy sources	• Alongside new changes of the fourth industrial revolution, more energy sources are required than before, with positive effects such as smartization of energy related facilities. • Sensors attached to each object, network equipment required for communication between sensors, and storage and analytical systems for the generated and accumulated data are all equipments using power as energy sources. • Hence, the increase in sensors and devices requiring power act as a factor causing the energy consumption in the industrial sector to increase significantly.
Convergence of energy technology and ICT innovation technology	• The existing industrial revolution is characterized by the emergence of new energy resources including coal, oil, and electricity, and an increase in productivity based on them. • However, under the fourth industrial revolution, it has been predicted that new energy will cause new changes via the convergence of existing energy technologies with innovative technologies in related fields including information and communication, chemistry, and biotechnology rather than a completely different new energy source. • That is, the fourth industrial revolution technology is expected to create a new market via the convergence of energy and ICT technology along with the expansion of eco-friendly and distributed energy sources.
Accompanied changes in the market structure	• Following the technological convergence of existing energy technologies and the core widely used technologies of the fourth industrial revolution, innovations in energy production and supply are not limited, yet the entire industry is likely to be structured and operated in a different system. • That is, not only the increased demand for eco-friendly and distributed energy sources, the convergence of ICT technology and energy, etc., but also the provision of energy related services, operation of demand devices, intelligent management of demand, optimization of supply to meet the increased demand, etc. and transformation of the existing business model and market structure will be accompanied. • For instance, in the management of energy infrastructure and major facilities such as transmission towers and nuclear power plants, the collection and repair of data will be processed via drones and robots, and the energy management system (EMS) data, by applying machine learning, etc., thereby radically changing the necessary prediction and optimization compared to the current level.
Energy optimization for the sectors of demand	• The management system for visualization, optimization, and efficiency of the energy flow and use for the consumption sector may be divided into households, buildings, factories, and communities.
Energy optimization for the sectors of supply	• Overall changes are also expected in terms of the energy supply. If the core widely used technologies of the fourth industrial revolution related to data measurement, analysis, and information exchange are applied to the distributed energy sector, the dependence on the current centralized energy supply will gradually decrease, and the quantity of power transported by using the transmission line will decrease, such as the transmission cost, etc., are expected to decline. • Furthermore, if an analysis based on the real time data acquisition via the IoT is realized, it would be possible to optimize the operation of solar and wind power generation according to environmental conditions such as weather, which will likely maximize supply and usage efficiency and minimize the system variability

Improvement of efficiency for the energy related equipments and facilities	• Energy is used via equipments and facilities, and hence, improving the efficiency of equipments and facilities is among the core tasks for energy savings. • As the era of the fourth industrial revolution and the Internet of Things (IoT) are in place, the effects of energy savings are also increasing via the rapid smartization of such energy industry equipments and the establishment of efficient systems (Hongshik Choi, 2019).

Source: Lee & So. (2018).

Considering the changes following the fourth industrial revolution, they may be understood to have made such a significant impact on the energy using equipments, and consequently, they are expected to significantly affect energy, particularly, the demand for electricity.

2.3. Performance achievement of the energy efficiency management system

The trends in the evolution of the energy using equipments following the convergence of the fourth industrial revolution technologies are summarized in five directions as follows (Lee & So, 2018). Each of the equipments is linked and systemized through the IoT, and the real time monitoring and remote control will become possible in connection with the mobile equipments. Furthermore, the data generated on a real time basis are accumulated in the Cloud, and it is expected that the autonomous control and the optimization of energy consumption will be materialized through the application of technologies such as the Big Data analysis and artificial intelligence.

1) Energy data available for utilization

The efficiency related information generated on a real time basis from various sensors may be utilized. With the data generated in the environment of actual use, it will be possible to acquire high quality data which are more realistic than the information generated in a laboratory. Furthermore, it will possible to measure time by hour or in the unit of minute, making it quantitatively sufficient or better. The existing energy efficiency management system was designed based on the efficiency related data of the energy using equipments acquired at the laboratories, and has been managed by selecting the subjects for each equipment. In addition, once the system was designed, it was maintained without undergoing any separate evaluation for the efficiency of the equipments until the equipments included were existed or until the system went down. However, due to the impact of the fourth industrial revolution, conditions are formed to design an energy efficiency management system based on the more accurate information, and the preparations are underway for an environment where the effectiveness may be accurately evaluated and more cost effectively improved during the implementation of the system.

2) Real-time confirmation of the information

The users of energy equipments will be able to directly verify the efficiency related information of individual equipment or system on a real time basis. Utilizing which, it will become possible to design various policy measures which can induce behavioral changes of the users of energy equipments. Until now, it is at the level of inducing behavioral changes of the users through publicity or education. For instance, a system which induces changes in the consumer behaviors through benchmarking by diversifying the information provided on the monthly electricity bills is evaluated as relatively innovative. Moving forward, however, in a situation where the consumers can directly verify various uses of the energy information on a real time basis and adjust their consumption patterns immediately with ease through the remote control, the effectiveness of the systems and policies inducing behavioral changes is likely to rise.

3) Expansion of the importance of the roles of service businesses

The role of the service providers for the sector of energy efficiency management is likely to become increasingly important. In particular, the role of the service providers is expected to be significant until technological development and dissemination of the autonomous control systems for optimization are expanded. Taking on the case of BEMS or FEMS, for instance, a substantial energy savings can may be achieved only by interpreting the information generated from such and utilizing the same for the optimization. However, major businesses to date have remained at the role of installing them. The substantive energy management takes place only when the service providers providing consulting for optimization and energy management services have a role. Hence, the effectiveness of energy efficiency management can be raised by expanding the scope of such business operators.

4) Increase in the complexity of the system design

Until now, the energy efficiency management system was designed and operated to manage each individual energy using equipment, yet moving forward, it is expected that the complexity of the system design will increase as the energy using equipments become systematized. For instance, the energy efficiency management considering not only individual equipments forming the system, but also those added for the construction and operation of the entire system, such as sensors or devices forming the IoT, and the energy required for optimization or autonomous control must be considered to design and operate the energy efficiency management system. Optimization has the effect of reducing the energy consumption. Whereas, the devices added to configure and operate the system have the effect of increasing the energy consumption, and whichever system that does not comprehensively consider such has the possibility of committing the mistake of aggravating the energy efficiency of the overall system.

5) Preparation of policy directions from a long-term perspective

If the systemization of the energy using equipments evolves to the point where it can be optimized through the autonomous control following the influence of the fourth industrial revolution, then rather than a policy of inducing changes in consumer behaviors, it seems that the effectiveness of efficiency management can be improved through a policy of encouraging the accommodation of such system. This is because it will become possible for the system to autonomously optimize without changing consumer behaviors. Therefore, it seems that it will be crucial to have directions such as the technological development for systematization, policies for market creation to enhance the initial technology acceptance, and policies to induce the reduction of manufacturing costs, etc.

3. Methodology

The purpose of this study is to present directions for the energy saving and efficiency of libraries in that the energy efficiency advancement of the public sector is evaluated to have led the national energy savings practice and contributed to the expansion of the energy savings perception. The research procedure and research system diagram for achieving the purpose of this study are as follows (refer to **Table. 1**).

Table 1. Research Procedures and the Research System Diagram

Phase	Details of the Study	Analytical Method
Phase 1: Theoretical study	• Setting of the research purpose and research questions • Theoretical study and the investigation of related previous studies	• Investigation of references
Phase 2: Case study	• Investigated and studied the energy efficiency related cases	• Investigation of cases
Phase 3: Derivation of implication	• Derivation of implications via the results of case analysis • Comparison of energy saving and efficiency of the existing library community and the current energy efficiency trends and cases	• Investigation of cases
Phase 4: Derivation of result	• Presentation of the directions of energy efficiency for the libraries	• Presentation of directions for improvement

4. Cases of the Introduction of Energy Efficiency System

4.1. Similar cases applicable for libraries

1) Development of an energy efficiency platform integrating new technologies

Recently, LS Electric completed an energy efficiency platform which integrates new technologies such as Big Data and artificial intelligence (AI) with smart energy solutions, and launched commercialization (JoongAng Ilbo, 2017). The LS Electric R&D Campus has been evaluated as having achieved a paradigm shift by inducing a rational energy consumption to prevent energy wastes, and has also been evaluated to have integrated smart technologies of LS Electric including the energy storage devices, solar power generation (PV), and smart meters based on the automatic building control.

Table 2. LS Electric's R&D Campus

Classification	Details
Purpose of introduction of the relevant technology	• Energy efficiency
Operational status of the relevant technology	• Introduced the AI based Big Data technology for smart energy solutions such as ESS (Energy Storage System) and BEMS (Building Energy Management System). • LSIS's smart technologies such as energy storage devices, solar power generation (PV), and smart meters are utilized based on the automatic building control. • Power was consumed via the energy storage system (ESS) battery and power conversion system (PCS). • In the 3rd basement floor of the building are the 1MWh-class ESS battery, which is the core of BEMS, and the PCS developed by LS Electric. • A power management system (PMS) monitoring and controling PCS and batteries and analyzing effects including cost reduction is also located at the center. • - PMS is responsible for controlling and directing the energy of this building. If EMS is a broad concept of managing all matters related to energy, PMS refers to the managing and controlling of small units of energy by further classifying areas. • For system construction, sensors which can control and communicate are attached to all facilities using energy to receive and store data every 5 minutes.
Provision of services via the relevant technology	• The optimal energy management, such as by minimizing power consumption, is possible by automatically controlling heating and cooling and lighting in empty offices and conference rooms by detecting the user's location.
Plan for managing the relevant technology	• (Control Tower) Energy management control room on the 1st basement floor of LS Electric's Anyang R&D Campus • - Various numbers showing the energy flowchart of the entire building at a glance emerge. • - The quantity of power used by the building, quantity of power from KEPCO, and the quantity of power produced by the photovoltaic system on the roof of the building are displayed in real time. • This building consumes power via energy storage system (ESS) battery and power conversion system (PCS). The general situation room also displays the charging and discharging status of the ESS battery in real time. The quantity of power which is always in stock for emergencies and the quantity of power used by frequent charging is separated and managed. The four elements of this building of the energy production, energy charging and discharging, energy saving, and the energy management are all controlled here.
Advantages and improvements via the introduction of technology	• By measuring and analyzing the power consumption of the building, it leads to the optimal energy usage pattern and achieves the effect of reducing electricity bills by 19% relative to the existing (appriximately KRW 650 million). • LS Electric uses its own developed MW (megawatt) class, large capacity ESS to charge power at night when the electricity rates are relatively cheap and use it during the daytime, when it is at the maximum load. In such a manner, approximately KRW 50 million of electricity bills are saved each year.

Source: https://news.mt.co.kr/mtview.php?no=2019031809285456249

2) Cases of building energy saving activities

Korea University prepared various countermeasures with the goal of completing the "Energy Saving Company (ESCO)" from 2012 to 2017. In March 2012, the building energy management system (BEMS) was established to implement the effective energy savings policies including the implementation of the power goal management system for each individual college and power peak management.

Table 3. Korea University

Classification	Details
Purpose of introduction of the relevant technology	• Energy efficiency
Operational status of the relevant technology	• 35,000 units of LED fluorescent lamps were replaced, toilet and parking lot lighting control devices were installed, and integrated automatic control system were installed.
Provision of services via the relevant technology	• A large sized screen is installed allowing people to view the real time energy usage and power peak values of 40 some buildings at a glance. • Through which, when the demand for power exceeds 90% of the peak power, individual air conditioners are sequentially operated and the room temperature is controlled, and when the power exceeds 95% of the peak power, the number of cold and hot water heaters is controlled, and the minimum control is made for the supply, and when it exceeds 97% of the peak power, the risk is immediately notified by text message to the staffs in charge, and the power of the cold and hot water unit will be cut off.
Plan for managing the relevant technology	• (Formation of a Dedicated Organization) Korea University has Energy Crisis Management Response Team and Green Campus Committee for the organization dedicated to saving energy in buildings. • The Energy Crisis Management Response Team is responsible for establishing and promoting the green campus and managing greenhouse gases. The Green Campus Committee prepares a master plan for establishing the green campus and manages the budget required thereby, and is also responsible for developing the internal and external evaluation indicators and statistical management.
Advantages and improvements via the introduction of technology	• As a result of replacing 35,000 units of fluorescent lamps with LEDs and installing lighting control devices at bathrooms and parking lots, school power consumption declined from 65,381MWh in 2011 to 63,990MWh in 2012.

In October 2008, Seoul National University also made the "Sustainable SNU Declaration," while establishing the five action goals and preparing specific action plans. Since it announced the "Sustainable and Eco-Friendly Seoul National University" in 2008, Seoul National University has developed a model for creating a "sustainable green campus" for 10 years. The formation and operation of the Seoul National University's sustainable green campus are largely introduced as 1) the energy visualization through the monitoring of energy consumption, 2) support for the green campus student activities, 3) formation of an eco-friendly campus, and 4) the university staffs' education, etc.

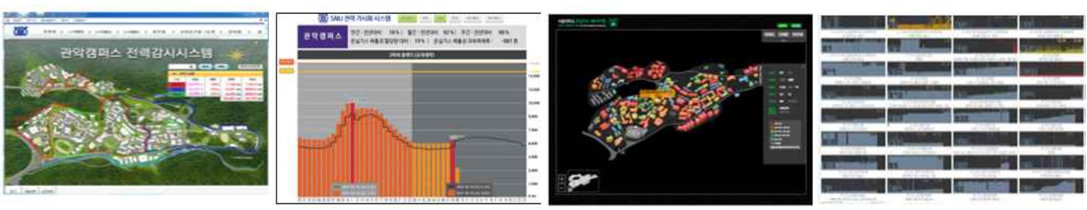
Table 4. Seoul National University

Classification	Details
Purpose of introduction of the relevant technology	• Seoul National University established quantitative goals and practical plans by building the greenhouse gas inventory in 2009 to reduce the CO2 emission per unit area of a building by half of the 2009 standard by 2030, and reduce the quantity of wastes to half the current level by 2020.

Operational status of the relevant technology	• According to which, the transformer's integration and closing, installation of lighting for human body detection sensor, high efficiency LED lighting installation, desk top power saving tap installation, and the real time promotion of campus power use, etc., were implemented.
Provision of services via the relevant technology	• As a part of the ESCO project in 2010, the entire Gwanak Campus was replaced with a heating and cooling system. • The “2013 Seoul National University's Climate Change Response Implementation Plan” was published by the Headquarters' Facilities Management Bureau and the Greenhouse Gas Energy Management Center.
Plan for managing the relevant technology	• (Dedicated Organization) At the Seoul National University Council, the proposal for the enactment of the greenhouse gas and energy goal management operation regulations were approved, and detailed regulations were prepared (November 2012). • Greenhouse gas reduction management and sustainable green campus activities were included among the university operation performance goals • By establishing the Greenhouse Gas and Energy Comprehensive Management Center, the University is systematically promoting the response to the national emission trading system and support for student participation on the Green Campus. • By developing educational programs for students and faculty, the University is actively engaged in the regular training of university members. • The Green Campus activities involving local communities are continuing via the Green Campus program with local residents.
Advantages and improvements via the introduction of technology	• Efforts were made to reduce greenhouse gas emissions of universities, which are among the major sources of greenhouse gas emissions in Korea. • Various supports were received via the selection of green campus development support projects : Support for the development of eco-friendly curriculum for fostering green talents, support for the establishment of a greenhouse gas inventory and establishment of a strategy for reducing greenhouse gases, support for the university’s eco-friendly life practice campaign, holding of eco-friendly contests, and support for green campus environmental clubs, etc.

Source: https://www.gihoo.or.kr/greencampus/univ/viewUniv2017.do

First, in the case of the energy visualization through the monitoring of energy consumption, Seoul National University is equipped with the power monitoring system, power visualization system, and the automatic monitoring system for gas and water consumption. Furthermore, an integrated management system for greenhouse gas which can measure the greenhouse gas emissions by institution and building is in operation.



Power monitoring system	Power visualization system's portal site posting screen	Greenhouse gas monitoring system	Main UI of issue detection program

Fig. 1. Seoul National University’s Energy Visualization Through the Monitoring of Energy Consumption.

Second, by providing support for the student activities on the green campus, the University encourages the participation of members by supporting the student organizations taking the lead in the creation of the green campus. For instance, there are the sustainable and eco-friendly Seoul National University Student Council, eco-friendly student club “Pium,” and Seoul National University’s “SNUCSR NETWORK,” etc. By holding green campaign events (2015, 2016, 2017), the students' eco-friendly awareness about the greenhouse gas reduction and energy conservation is enhanced. Through the Greenhouse Gas Energy Infographic Contest, the information on the Seoul National University's greenhouse gas and energy is delivered graphically to enhance the awareness and promote the participation of the members.

Operation of the 2016 Experiential Booth for Green Campaign | Green Formation Project of “Pium,” an Eco-Friendly Club

Fig. 2. Support for the Green Campus Student Activities

Third, the University promotes the insulation reinforcement facilities, improvement of the heating and cooling facilities, improvement of the lighting environment, reduction of the water consumption and utilization of water resources by creating an eco-friendly campus, etc. As for the insulation reinforcement facilities, an insulation reinforcement work was performed for 8 buildings (for a total insulation area of 9,941㎥), and the city gas was saved by 136,189N㎥ per year by improving the heating and cooling facilities such as by installing high efficiency boilers. Furthermore, 682,014 kWh of power is saved per year by improving the lighting environment, such as by replacing the LED lighting. In the case of the water consumption reduction and the water resource utilization, water resources are utilized such as through ① the water consumption reduction plan such as by strengthening the management organization operation, establishing the water management master plan, and establishing the infrastructure expansion plan, and ② the rainwater storage facility (approximately 60 tons), rainwater collection facilities (approximately 20㎥), and the rainwater-heavy water hybrid system (approximately 250㎥).

tatus of the installation of large capacity green rain-water storage facilities

Remodeling of interior windows of the Administrative Building

Fig. 3. Formation of the Eco-Friendly Campus

Fourth, the University conducts the education of the University members. In 2016 alone, 25 environment and sustainability related liberal arts courses were launched, green leadership courses were operated to form the green curriculum, faculty seminars for strengthening the capacity to manage the greenhouse gas emission facilities, and sustainability education for staffs such as those in charge of green life operation and management.

3) Green campus based on the greenhouse gas reduction

The Harvard Office for Sustainability (OFS) was officially reorganized while setting new goals in 2008 based on the Harvard Green Campus Initiative (HGCI), an existing institution formed in 1999 by the faculty and students to discuss the sustainability of Harvard University. Based on the HGCI's past performance achievements, since 2008, it has aimed to transform the campus into a living laboratory for innovation in conjunction with service groups across the campus. Harvard University has officially disclosed its responsibilities and special obligations of responding to climate changes and environmental impact with a view to reduce the greenhouse gas emissions by 30% relative to 2006 by 2016.

Accordingly, the Green Building Standards (established in 2007 and amended in 2009) were prepared including the total costs of life cycle, energy modeling, setting of the performance targets, 34% of energy efficiency, and operation management guidelines. By applying the LEED, which evaluates the performance of each building, a feedback system was established for evaluating and managing each building. Initially, it began with a $70,000 fund, which expanded with a $3 million loan program in 2001, and increased to as much as $12 million with a Green Loan Fund (GLF) in 2006, respectively. As the funds for Harvard's environmental projects, the GLF selects the projects related to the high performance campus design, operation, maintenance, and resident behaviors through the open competition for each building or project, and provides loans of advance payment. Thereafter, the loan is repaid over 10 years as the energy saving costs through the project.

Table 5. Green Building Standards

Classification	Details
Harvard's Green Building Standards	• Devised the Green Building Standards in 2007 • Comprehensive Green Building Standards based on smart design process from renovation and building system improvement, etc., revised in 2009. • Integrated design plan, total life cycle cost, energy modeling / GHG, submetering, performance target setting, 30~34% energy efficiency, LEED gold certification, operation management guidelines

Source: http://www.keei.re.kr/keei/download/focus/ef1403/ef1403_50.pdf

4) Energy efficiency based on partnership and network

The Higher Education Funding Council for England (HEFCE) operates the Revolving Green Fund in 3 types of RGF 1, 2, and 3, respectively. RGF 1 provides support for the businesses of a relatively small financial scale by forming partnerships with external companies. RGF 3 corresponds to the project of the largest financial scale with a loan repayment period of 10 years. Furthermore, it runs the Green League, where students form a voluntary network of "People & Planet" and ranks and fuels competition for the environmental and ethical activities of universities in the UK.

Table 6. Green Campus Partnership Project Details of the University of Pennsylvania.

Classification	Details
Energy	• Developed goals to reduce energy consumption by 17% in 2007 and reduce carbon emissions by 23% by 2014
Architectural design and construction	• Goal to acquire the LEED silver certification for new and renovated buildings • Expansion of green space, and improvement of indoor and outdoor environment's quality • Elevate awareness of sustainable design
Mutual connections with students	• Encourage interest in the environment and sustainability via a student orientation called Penn Greend
Academics	• Added parts for climate changes and sustainability inside the curriculum • Held lectures, conferences, discussion groups, tours, and exhibitions related to sustainability
Fund	• Green Fund Grant • Climate Action Plan Research Grants

Source: http://www.keei.re.kr/keei/download/focus/ef1403/ef1403_50.pdf

4.2. Cases of libraries related to the energy efficiency

The Central Library of the City of Asan became the first library in the country to acquire the "Zero Energy Building Main Certification (ZEB 5)" by the Korea Energy Agency. The Central Library of the City of Asan is an educational and research facility of 1 basement floor and 5 floors above the ground and has a total floor area of 9,037 m2, and it was also built as a pilot project for the Ministry of Land, Infrastructure and Transport's Zero Energy Building to prepare standards for the national energy policy. The Zero Energy Building Main Certification granted for a building actually completed is the second in the country for the Central Library of the City of Asan, and the first for and as a library. In addition to the Zero Energy Building Main Certification (ZEB 5), the Central Library of the City of Asan has acquired a certification for a passive building main certification (2.0L/㎡·a), building energy efficiency rating of 1++ main certification, and the green building general rating main certification, thereby acquiring all certifications in the field related to the eco-friendly architecture in Korea. Furthermore, at the 21st Energy Winner of the Year Award co-hosted by the Consumer Citizens' Association and the Ministry of Trade, Industry and Energy, it was the only public institution to win the Energy Conservation Award and the Korea Energy Agency President's Award.

Meanwhile, the Zero Energy Building Certification System was first implemented in January 2017 by the Ministry of Land, Infrastructure and Transport to make significant contributions to the national greenhouse gas reduction and the energy consumption reduction, and promote them as an innovative growth engine for the building sector in response to the fourth industrial revolution.

As for the characteristic of the Central Library of the City of Asan, the fact that a total budget of KRW 340 million were saved by receiving support for the new and renewable facilities (solar power) for KRW 90 million from Korea Energy Agency and the Building Energy Management System (BEMS) worth KRW 250 million from the Korean Institute of Civil Engineering and Building Technology as a part of the R&D project for the Ministry of Land, Infrastructure and Transport is evaluated to have been meaningfully completed.

Table 7. The Central Library of the City of Asan

Classification	Details
Purpose of introduction of the relevant technology	• Eco-friendly and nature-friendly public libraries
Operational status of the relevant technology	• Passive construction technologies such as window area ratio considering defense, optimization of the outer area, the highest rating high airtightness, high insulation triple windows, improvement of the construction method of internal and external insulation materials, and the application of thermal bridge barrier materials. • Active technologies such as external electric awning, heat exchange recovery device, BEMS (building energy management system), high efficiency lighting, automatic control system, remote meter reading system, and renewable energy application of geothermal and solar systems, and as such, national energy saving public building standards were prepared by applying all construction methods.
Provision of services via the relevant technology Plan for managing the relevant technology	• By utilizing the "Building Energy Management System (BEMS)" facility, the Ministry of Land, Infrastructure and Transport will conduct energy performance monitoring in the future to provide an optimized energy management plan, etc.,, thereby continuously maintaining excellent energy performance.
Advantages and improvements via the introduction of technology	• The energy self reliance rate is 27.77%, which resulted in the budget savings. • Contributed to the reduction of national greenhouse gas emissions.

Issues following the introduction and operation of technology	• Project costs increased, which is a disadvantage of zero energy buildings.

Source: https://news.mt.co.kr/mtview.php?no=2019031809285456249, http://www.goodnews365.net/news/articleView.html?idxno=37563

4.3. Cases of building green library

"Green library" is a leading concept of a library whose main goals are energy saving, green, and eco-friendliness. An eco-friendly green library means a structure which designed, built, re-constructed, operated, and reused from an ecological and resource efficient point of view (Recycle, 2000), and in this context, the greening of library also includes the resources used for the library, library operation and service process (Ahn, Kwak, & Noh, 2013). The cases of green library may be presented as in **Table 8**.

Table 8. Discussions of Green Library

Classification	Details	
Central Library of the City of Uiwang	Use of land and transportation	• Installation of bicycle storage
	Energy resources and environmental load	• Use of solar power: - Solar hot water supply system was applied - Solar electronic sensitive automatic urine washer - Solar outdoor light was installed - Electronic sensitive hot air dryer • Waste wood recycled • 9 eco-friendly certified products applied • Containers capable of separating 4 or more types were installed • ABC fire extinguisher (ammonium phosphate) • Formed artificial turf to suppress dust generation
	Ecological environment	• Partial greening of the roof
	Indoor environment	• Air purification work was conducted • Materials with low contents of hazardous substances were used • A plan to reduce glare was devised • Design was made considering the senior citizens and the disabled
Central Library of the Province of Gyeonggi-do	Use of land and transportation	• Community facilities were installed within the complex • Bicycle storage was installed • Class 1 rating was acquired for high speed information and communication
	Energy resources and environmental load	• New environmental technology and industrialization method were applied • Environmentally friendly materials were applied
	Ecological environment	• Artificial environment greening technique was applied (roof greening, wall greening) • Terrestrial biotope was formed (ecological park)
	Indoor environment	• Design cared for the senior citizens and the disabled

Taejangmaru Library	• Taejangmaru Library is one located in Yeongtong-gu, Suwon-shi, Gyeonggi-do. • The building was designed with materials certified by the Korea Air Cleaning Association, and was constructed based on energy saving, eco-friendly architecture such as rain gutter systems and BIPV (solar solar collectors). • Following validation by experts in each field, such as use of land and transportation, energy resources and environmental load, and eco-environment, indoor environment, etc., eco-friendly library certification was secured from Korea Land and Housing Corporation.

Source: http://www.kharn.kr/news/article.html?no=10011

5. Energy efficiency plan for and at the libraries

For the energy sector, following the influence of the fourth industrial revolution technologies, the energy using equipments are expected to evolve towards the direction of the real time monitoring, remote and autonomous control, and the optimization of energy consumption as they are connected and systematized through the IoT. To participate in such energy efficiency policies, the library sector is also realizing and promoting energy efficiency through the green library and the zero energy building certification, etc.

1) Need for policy changes to promote energy efficiency

As a policy implication, the energy efficiency related policies could increase their efficiency by utilizing the high quality information generated on a real time basis. During the initial phase, the importance of policies inducing behavior changes of the users of energy is largest. After the autonomous control for optimization becomes possible, the importance of the system's distribution policy is expected to emerge. Therefore, for the library sector, it is necessary to discuss the establishment of an eco-friendly library and the related energy efficiency guidelines and plans in the context of the comprehensive development plan, and it is also necessary for the individual libraries to discuss energy efficiency and eco-friendliness in the context of the mid- and long-term library plan.

2) Zero energy and the new construction and reconstruction of high efficiency buildings

The requirement of the zero energy building means the act of requiring the acquisition of the zero energy building certification system (ZEB certification), which the government introduced for the first time in the world in 2017. The ZEB certification system applies the concept of "energy self-reliance rate," which provides that the relevant building produces more than a certain percentage of its total energy consumption with new and renewable energy, etc., and grants the certification by varying ratings according to the extent of achievement.

According to the zero energy building roadmap devised in 2016, the Ministry of Land, Infrastructure and Transport plans to apply the ZEB certification requirement for the small and medium sized public buildings (500-3,000 m2) in 2020. Libraries must also expand their zero energy buildings in line with the national policies. While it may be said that the Central Library of the City of Asan is the first case, it may be said that the interest and support of not only the library sector but also the library and information science researchers are needed to ensure that such cases may continue to emerge in the future.

Table 9. Roadmap for the Requirement of Zero Energy Construction

Classification	2020	2025	2030
Existing	• Public buildings • Total floor area : 500-3,000㎡	• Private and public buildings • Total floor area : 500-5,000㎡ • Multi family housing properties (30 or more households)	• Private and public buildings • Total floor area : 500㎡ or more
Revised	• Public buildings • Total floor area : 1,000㎡	• Public (500㎡ or more) • Private (1,000㎡ or more) • Multi family housing properties (30 or more households)	• Private and public buildings • Total floor area : 500㎡ or more

Source: http://www.kharn.kr/news/article.html?no=10011

3) Development of an environment for high efficiency smart library

Consequently, energy efficiency may be considered together with the development of technology for the era of the fourth industrial revolution. Given that the energy using equipments are connected and systemized through the IoT, real time monitoring and remote control, and furthermore, the autonomous control and optimization of energy consumption are expected to evolve towards the smartization of libraries and real time monitoring in the IoT environment of smart libraries, as well as autonomous control and optimization of energy consumption. As for the cases of the utilization of smart sensor, 25 public libraries located in the City of Seoul are implementing the projects to provide a pleasant indoor environment by installing the IoT based indoor environmental sensors and analyzing the air quality data of the library (Noh & Son, 2016). As the sensor technologies and the Cloud server technologies, etc., are integrated, it is possible to measure 6 indoor environmental factors of fine dust, temperature, humidity, CO2, noise, and VOCs (Volatile Organic Compounds).

To build a high efficiency smart library environment, it is necessary to expand the supply of high efficiency equipments, which is one of the main measures to improve the domestic energy efficiency, and as relevant systems, the 3 largest energy efficiency management systems, energy consumption efficiency ratings, and the standby power reduction programs may be referenced.

4) Exploration of the directions for energy efficiency at the library level

Beyond everything, it is necessary to discuss the directions for the energy efficiency at the library level. The directions of energy efficiency following the fourth industrial revolution and the zero energy building certification system promoted since 2017 may be understood in the context of green library, which has been discussed for and by the library field since the 1980s. Along with the current direction of implementation of the green library, it is necessary to promote energy efficiency in consideration of the changes in the energy sector according to the fourth industrial revolution, such as the IoT based real time energy data collection and utilization, energy management general control room, and smart equipments.

As for the current directions of implementation for green library, six largest issues are discussed including the construction of eco-friendly library, water resource conservation of the library, energy efficiency and air environment preservation, materials and resources, indoor environmental friendliness, and the interior design. To expand and introduce such a green library certification system, first, in the construction of an eco-friendly library, zero energy buildings ought to be expanded based on the ZEB certification system. Second, in the case of interior design, materials and resources, eco-friendly construction methods and new technology application, eco-friendly, recycled and local materials must be used. Third, in the case of the indoor environmental friendliness, a thermostat and management utilizing the fourth new technologies ought to be used.

Table 10. Direction of Implementation for the Green Library

Energy & Atmosphere Performance
• Energy efficiency may be evaluated by the quantity of energy consumed and whether alternative energy is used. Since the energy consumption of buildings is intimately related to the greenhouse gas emissions from the use of fossil fuels, energy saving of buildings is suppresses the greenhouse gas emissions. Furthermore, the use of alternative energy may reduce the use of fossil fuels while reducing the greenhouse gas emissions which may be caused thereby. The conservation of the atmospheric environment refers to reducing the carbon dioxide emissions, and is an item for energy savings according to the heating methods such as cogeneration, district heating, and individual heating. The greening directions which libraries can work on with respect to eco-friendly strategies of increasing energy efficiency and air environment conservation are as follows. • **(Active Utilization of Solar Energy)** Dr. Mary McLeod Bethune Regional Library of the LA Library installed a 44-kilowatt photovoltaic solar-powered unit in its building. This system is equipped with approximately 480 solar panels and provides over 57,500 kilowatts of power per hour per year. The Sum Valley Annex also provides 20% of the building's power with solar energy. • **(Energy Saving via Utilization of High Insulation Technologies)** In the case of the Sum Valley Annex, double glazed windows are installed across the entire library building, thereby increasing the building's energy efficiency by 60% or mover. In addition to high efficiency daylighting, a lighting sensor and a high mass wall system with excellent insulation were installed. • (The installation of a low temperature maintained roof, well light blocked windows, and high efficiency air conditioners also increase the energy efficiency) Whether to use a heat absorption method or a heat shield method ought to be appropriately determined and used depending on the situation of the library or the season. For instance, the Dr. Mary McLeod Bethune Regional Library of the LA Library reduces the heat absorption via utilization of white concrete and white coated roofs.

Source: http://www.keei.re.kr/keei/download/focus/ef1403/ef1403_50.pdf

5) Efficiency via mutual connection between libraries and regions

In the case of “Green Challenge” of the Graduate School of the University of Cambridge, mutual connections with students are implemented. For instance, a student orientation called “Penn Greend” encourages interest in the environment and sustainability. Therefore, the library may also hold lectures, conferences, discussion groups, tours, and exhibitions related to climate changes and sustainability within the program, and from the outside, by strengthening the mutual connections with the library and the region, energy efficiency, greening, and eco-friendliness ought to be promoted. As an official from the City of Asan states, "The fact that the Central Library of the City of Asan acquired the zero energy building certification for the first time as a library in the country is the result of Asan's public building policy, which has been continuously implementing the construction of eco-friendly public buildings," the City's interest and support are essential.

6) Installation of energy center and the provision of consulting support

A control tower is prepared to verify the energy flowchart for the entire building at a glance. At LS R&D Campus and Seoul Campus, the quantity of power coming from KEPCO and the power produced by the new and renewable energy system are verified on a real time basis, and the quantity of power currently used at the buildings is also managed. As such, in most of the cases, the BEMS is installed to monitor the energy consumption of buildings and control the active system. Through the energy consumption management system, each room's energy consumption, indoor temperature and humidity, CO2 concentration, solar power generation, and the ESS consumption are monitored at least 15 minutes apart. Furthermore, if the BEMS is used, the On/Off and set temperature can be controlled for the EHP indoor unit for each room. Such control function can apply the control methods of pre-cooling (Choi, Kwak, & Goo, 2014) and the night-purge (Shin et al., 2015), and it was announced that approximately 10% of energy consumption may be reduced by pre-cooling (Lee et al., 2018). Therefore, by preparing an energy center inside the library, it is expected that the 4 elements of buildings of the energy production, energy charge and discharge, energy saving, and energy management may all be controlled from here.

7) Enhancement of perception and education of the employees and local residents

It seems necessary to provide various educational programs which enable the employees and local residents to realize the importance of eco-friendly buildings. As with the Graduate School of the University of Cambridge, the parts of climate changes and sustainability may be added to the education or within the program process, and lectures, conferences, discussion groups, tours, and exhibitions related to sustainability may also be promoted. In the case of the librarians' education, the establishment of liberal arts courses related to environment and sustainability, which are also among the Seoul National University's building energy savings activities, and the establishment of a green curriculum by operating a green leadership curriculum, seminars to strengthen the capacity for managing greenhouse gas emission facilities, and the education for sustainability for the employees, etc., including the education for those in charge of the operation and management of green life could be conducted.

6. Conclusion and Recommendations

Improving the energy efficiency and expanding the use of renewable energy are considered to be among the most crucial countermeasures for climate changes and the global demand for energy. Above everything, it is evaluated that the energy efficiency advancement for the public sector has led the national energy savings and contributes significantly to the expansion of the energy savings awareness. In connection with the energy saving and energy efficiency at the libraries, such keywords as green library and green library, etc., have been discussed for long. Currently, in connection with the green library or energy efficiency, in the library sector, it is being dealt with at the level of the individual libraries or in the context of the zero energy building pilot project of the Ministry of Land, Infrastructure and Transport. In terms of the establishment and operation of libraries overall, it is likely that an effective implementation would be impracticable without the support and guidelines from the parent institution or the government in that the mid- to long-term development or specific implementation plans for energy efficiency are not in place yet. The detailed plans and guidelines for promoting the energy efficiency at and by the libraries would need to discuss 1) the need for policy changes to promote the energy efficiency, 2) new construction of the zero energy and high efficiency buildings, 3) development of a high efficiency smart library environment, 4) seeking of directions for energy efficiency in the context of the library, 5) mutual connections between the libraries and regions, 6) preparation of an energy center, and 7) the improvement of the perception and education of the employees and local residents, etc. Furthermore, while it is important to apply the high efficiency devices and facilities for energy conservation, =it is also necessary to pay attention to the efficient energy management and utilization of energy information by utilizing the Internet of Things, Big Data, and the Cloud servers, etc.

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