After ISO 50001: A Study on the Performance and Improvement of the Energy Management System in the Water Sector

By

SHIN, Hongseob

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

2021

After ISO 50001: A Study on the Performance and Improvement of the Energy Management System in the Water Sector

By

SHIN, Hongseob

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

2021

Professor Lee, Junesoo

After ISO 50001: A Study on the Performance and Improvement of the Energy Management System in the Water Sector

By

SHIN, Hongseob

CAPSTONE PROJECT

Submitted to

KDI School of Public Policy and Management

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF PUBLIC MANAGEMENT

Committee in charge:

Professor Lee, Junesoo, Supervisor ______________________ Junesoo Lee

Professor Kim, Jin hun ______________________

Professor Joo, Yumin ______________________

Approval as of August, 2021

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Today, global efforts to cope with the climate crisis make headlines. In particular, the industrial circles are making efforts to develop renewable energy sources and actively introduce energy saving technologies to reduce greenhouse gases. Among many countries, Korea's water supply business consumes a lot of energy due to its mountainous topographical features and the use of long pipelines in the multi-regional water supply system. For this reason, K-water, which operates domestic water supply businesses, has recognized the importance of energy management early on and has implemented an energy management system in accordance with the energy management system [ISO 50001]. However, there is also skepticism that energy saving results from the introduction of ISO 50001 have never been demonstrated in detail, and that ISO is only a form of documentation or manual. Therefore, this paper attempts to verify the quantitative performance of how energy efficiency has improved since the energy management system (ISO50001) was introduced and examine the contents that need to be supplemented in order for the system to operate efficiently in reality.

Previous studies have set the requirements of ISO50001 as independent variables and verified the financial performance of energy conservation and greenhouse gas reduction as dependent variables. However, in this paper, one of the International M&V Standards and SEP M&V Protocol is used to demonstrate the energy saving and financial performance of the system. The SEP M&V protocol calculates the adjusted energy baseline of the reporting period based on the multiple linear regression method and calculates the avoided energy saving of the gap with the actual energy usage. In addition, the six ISO requirements of K-water for obtaining the ISO 50001 certification are checked, and the areas that need improvement are studied. Benchmarking the U.S. case of granting companies an energy management performance rating through state-set standards, the improvement of K-water energy performance assessment indicators is proposed. In addition to this, this paper examines the operation of domestic energy management leading enterprises and what organizational operations are needed for K-water's energy management.

The period between 2000 and 2014 is set as the baseline period, and the dependent variable is energy consumption. The independent variables are tap water production, the advanced treatment rate, and precipitation. Each of the independent variables is confirmed to be independent through the Pearson correlation coefficient and the VIF, and R-square is 0.9823, indicating a suitability of more than 98%. Among the dependent variables, water turbidity is rejected with p values exceeding 20%, and the water level at the intake station is rejected beyond the engineering validity criteria. The linear regression equation is $Y=1.113287X1+0.3546334X2-0.0729407X3-3.127904$, and the result of verification according to this model points to 226GWh of energy savings with 3.2% of energy performance rate from 2015 to 2019. The annual savings are around 4.5 billion won, and the annual greenhouse gas reduction is found to be 2.1 billion won. Apart from this, the review of the suitability of K-water's energy performance assessment indicators currently in use concluded that it is an unsuitable evaluation method for most water purification plants and water intake plants. Consequently, to supplement the existing evaluation method, this paper presents an energy management readiness assessment table to K-water and domestic waterworks operators by benchmarking the score cards of the U.S. energy management performance rating system in proposing suitable energy performance assessment indicators for water projects. Through this, more scientific energy impact on factor management is expected.

Furthermore, the review of the requirements in ISO 50001 suggests two ISO integrative certifications to address the issue of redundancy due to the high overlap with ISO 140001 and proposed an organizational institution that reflects the characteristics of K-water, a renewable energy producer and large energy consumer. As a result of studying the case of domestic energy leading companies, P and I, the unification of energy decision making is emphasized, and the establishment of an energy committee is needed. It is necessary to create a management goal in which greenhouse gas emissions and energy consumption indicators are linked through the energy committee, and to pool companies' capabilities in coordinating opinions from energy production and consumer departments and responding to climate change. Overall, this will enable K-water to play a pivotal role in responding to the domestic climate crisis along with the Ministry of Environment.

I. Introduction

Today, global efforts to overcome the climate crisis have become a hot topic day after day. In order to overcome climate crisis caused by greenhouse gases and environmental challenges, such as air pollution, both developed and developing countries have set a goal of voluntarily reducing greenhouse gas emissions and keeping the global average temperature rise below 2℃ before the Industrial Revolution. Although there are many ways to reduce greenhouse gas emissions, the International Energy Agency (IEA) states that improving energy efficiency is a policy tool that contributes the most to reducing greenhouse gas emissions. It is one of the most feasible measures to reduce greenhouse gas emissions in terms of avoiding social conflicts resulting from the construction of large-scale renewable power generating facilities (International Energy Agency [IEA], 2018).

Even in the water supply sector, which consumes large amounts of energy, the need to reduce and manage energy used to purify water to cope with energy depletion and climate crisis is increasing. The general water supply process conveys water from a stream to a water purification plant, undergoes a purification process through the process of mixing, cohesion, sedimentation, filtration, and disinfection, and then distributes it to final consumers. Pumps, blowers, and sludge dehydrators used in this process consume a lot of energy. The operating cost of the water purification facility consists of labor costs, electricity rates, coagulants, and maintenance costs, of which 37.7% is the labor cost, followed by the electricity rate at 37.4% (K-water, 2015). Considering that the electricity fee used for water treatment is charged based on the industrial electricity fee, which is a relatively low fee, it can be assumed that a large amount of energy is being consumed in the water treatment process.

K-water, which exclusively operates a multi-regional water supply system in Korea, first introduced the ISO 50001 energy management system to the Geum-san water purification plant in 2014 and attempted to systematically manage energy. Since then, it has been managing the nationwide waterworks site energy in accordance with the Plan Do Check Act (PDCA), an energy management system approach. **However, K-water has so far avoided the three-way certification except when it**

was first certified, and it has not been expanded in the domestic industry at all. Considering that there are 117 companies that have introduced and certified energy management systems in Korea, 943 companies have been designated for greenhouse gas management. Still, the penetration rate is low, and until recently, companies have approached energy management simply by replacing high-efficiency energy facilities and controlling production (Kook, 2019). This approach may lead to short-term performance but may not sustain energy management. In light of this reality, the purpose of this study is to assess the effectiveness of energy efficiency in managing energy systems in the field of water supply and to investigate what needs to be supplemented to make energy management systems work more effectively in reality.

Some authors have conducted studies to evaluate the financial performance of energy savings and GHG reduction by taking the requirements of ISO 50001 as a variable. In addition, baek states that ISO 50001 can be used as a means for domestic companies to reduce greenhouse gas emissions and respond to the "greenhouse gas target management system." However, there has been little research on the verification of energy savings based on real long-term data, and this paper aims to fill the gap by investigating and statistically demonstrating the amount of energy use savings before and after the introduction of the energy management system.

There are three particular points to focus on throughout this paper. **First of all, the SEP (linear regression model) predicts energy usage by finding independent variables such as, water production, water level of river, and precipitation. This gives much room to have more accurate data of energy savings. Second, the current energy performance evaluation system and energy performance index are analyzed. Improvement measures are also presented. To this end, this paper investigates how the current energy performance assessment is being conducted and also verifies the current indicators that are applied to each water treatment plant in Korea. Lastly, through detailed case studies of energy management systems in Korea and abroad, this paper recommends several ways to improve the energy management system in the water supply field.**

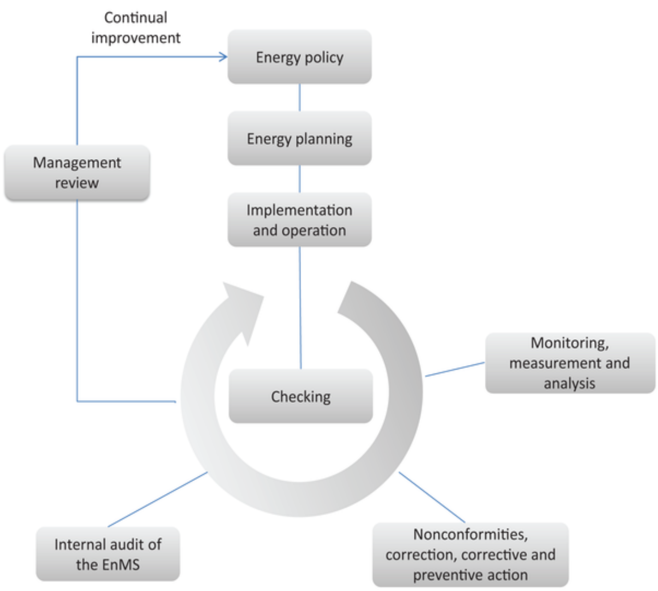
Chapter 1 consists of two parts: the status of the introduction of energy management systems in the water supply sector and the performance and implications of energy management systems. Chapter 2 reviews the overview and prior research of energy management systems. Chapter 3 outlines issues of the energy management system in the water supply sector. In chapter 4 and 5, the quantitative performance of the energy management system is assessed, and policy suggestions are followed for the energy management system to work more effectively.

II. Literature Review

2.1 The concept of the Energy Management System (EnMS)

The ISO 50001 Energy Management System (EnMS) is an international standard for energy management established by the International Organization for Standardization in 2011. ISO (2018) argues that energy management systems are a set of energy policies, objectives, and interrelated factors to establish processes to achieve goals. This system is based on the Plan-Do-Check-Act (P-D-C-A) continual improvement framework as shown in Figure 1.

Figure 1. Energy management system model for the international standard



Note. Adapted from *Energy management systems — Requirements with guidance for use,* by ISO, 2011 (https://www.iso.org/obp/ui#iso:std:iso:50001:ed-1:v1:en).

Within the PDCA framework, the *plan* determines energy policies with CEO, establishes energy targets, and action plans for improving energy performance. The *do* includes the education of the members of the organization, the communication for compliance with the requirements of the executing department, and the design and purchase of the facilities. The *check* executes and operates corrective and preventive measures through monitoring, measurement, and analyses of important energy sources. Lastly, based on this, the *Act* complements the improvement and implementation plan for the continuous operation of EnMS.

The main purpose of introduction of the EnMS is to reduce costs and greenhouse gas emissions by improving energy efficiency and also to establish processes to ensure that these activities continue to take place. This process shares P-D-C-A standard framework with ISO's other types of management systems such as ISO 9001 quality management system (QMS), ISO 14001 environmental management system (EMS) (Jung, 2020). In particular, the EnMS (ISO50001) overlaps with the Environmental Management System (ISO14001). The specialization of the EnMS is that it is focused on energy efficiency improvement and management. As such, the EnMS is similar in appearance to quality management systems and environmental management systems, but has several characteristics that differ from the objectives, performance management and stakeholders (see Table 1).

Table 1. Comparison of the EnMS with other International Standards

Section	**ISO 50001**	**ISO 9001**	**ISO 14001**
Objectives	To increase energy efficiency (Cost reduction)	Customer satisfaction	To consider the main environmental aspects
Key Processes	- Energy review - Energy base line - Detailed Action Plan	- Definition of Quality Objective - Planning QMS	- Identify environmental legislation - Detailed Action Plan
Performance	Energy Performance Index	Improvement in defect rate	Associated regulatory

management			compliance rate

Note. Adapted from *A study on establishment and certification of ISO 50001 application process for urban railway sector for sustainable energy management,* by B. Jung, 2020. Seoul: Hanyang University.

2.2 Literature review

A. Recent Research Trends in ISO 50001 (EnMS)

Since 2011, research trends on the energy management system have mainly dealt with national GHG reduction measures through the introduction of an energy management system. In 2010, the Framework Act on Low Carbon, Green Growth was enacted in Korea, and based on this law, the government has set the national goals for greenhouse gas reduction and implemented measures for enterprises, such as the GHG Emission Trading Scheme.

A year later, the International Standard for ISO 50001 was implemented. As a result, many methodological studies have been conducted to achieve the goal of reducing greenhouse gas emissions by means of energy management systems. Baek (2012) analyzed the requirements of ISO 50001 and the government reporting the form of GHG emission permit scheme. Baek argues that the introduction of an energy management system would make it easier to respond to GHG Emission Trading Scheme and selected priorities for further attempts to reduce GHG emissions through a case study by In-ha University. Park (2013) made an energy review and monitoring model by examining items that can be applied in common with ISO 50001 and the GHG Emission Trading Scheme.

Since 2014, research has mainly been conducted based on the assumption that the energy management system will help companies cope with the climate crisis and have a positive impact on performance management. For instance, Hong (2014) organized a survey to measure the performance of companies applied to the EnMS through a Delphi technic of academic and industrial experts. Subsequently, Kook (2017) further refined these questions and conducted a survey on actual companies. In this study, the financial performance of energy reduction and greenhouse gas reduction is measured for companies applying the EnMS.

Table 2. Summary of EnMS studies

Trend	Research title	Methodology	Key contents
A Study to Achieve GHG Reduction Goals by Using the EnMS	- Suggested Action Plan for the Greenhouse Gas & Energy Target Management System based on the Energy Review of ISO 50001 (Beak, 2012) "Case of the Inha University " - A Study on the Applicability and Usefulness of GHG·Energy Target Management System under the requirements of ISO50001 (Park, 2013)	Case study	Reviewing methods for responding to the greenhouse gas target management system based on the ISO 50001 requirements
	- A Study on Preliminary Application of Energy Management System to Seoul City (Kim, 2011)	Case study	Diagnosing the Seoul Metropolitan Government's climate change response system and determining the applicability of the EnMS
A Study on the Performance Evaluation of the Introduction the of EnMS	- A study on item development and validity analysis of energy management assessment (Hong, 2015)	Survey-Delphi technique	Developing assessment criteria questions to evaluate energy management levels
	- A Study on the Impact of ISO 50001 Certification Factors on Climate Response and Financail Performance (Kook, 2017)	Survey-Correlation analysis	Evaluating the financial performance of energy and greenhouse gas savings using the requirements of the EnMS as an independent variable

Note. Reproduced by the author

B. Research on energy performance evaluation

Korea Energy Corporation (KEA) created M&V guidelines for calculating energy savings for facility replacement in 2015 for energy saving company (ESCO) projects. The guidelines provide principles and installation guidance for improving energy efficiency and allow ESCO and ESCO's customers to settle on savings.

Table 3. Overview of KEA M&V Guidelines

M&V		Method	Description
Option I		Direct Comparison	To determine energy savings when EPIA is turned on / off
Option II	A	Adjusted Calculation	To measure core relevant variables
	B		To measure all relevant variables
	C		To verify energy performance by comparing the results between before and after activities
Option III		Calibrated Simulation	To apply in the case that baseline energy data does not exist or is unavailable

Note. Adapted from *M&V guidelines for calculating energy savings for device replacement,* by KEA, 2015 (http://www.kemco.or.kr/web/kem_home_new/info/data/open/kem_view.asp?q=19231).

Worldwide research on energy performance assessment has become more active with SEP, IPMVP, and FEMP being used by major advanced countries (see Table 4). Chiu (2012) analyzed the improvement effect of the energy performance index for enterprises introducing ISO50001 in Guangdong Province, China. The annual average energy improvement of 18.5% was demonstrated by calculations according to energy intensity (energy intensity=$\frac{\text{Consumption(kW)}}{\text{Output(U.S.dollar)}}$).

Table 4. Review of the International M&V standards

M&V	Contents	Characteristics
SEP M&V Protocol	M&V Guidelines by business	Requires ISO 50001 certification. Specific modeling options, tools, and evaluation criteria.
IPMVP	General Purpose M&V Guidelines	Include a clear description of the M&V option. Both SEP and FEMP borrow M&V options from this guide.
FEMP M&V Guideline	General Purpose M&V Guidelines	Provide specific details of uncertainty.

Note. Adapted from *Development of guidelines for energy management performance evaluation,* by KEA, 2013*,* Ulsan: Korea Energy Agency.

C. Context of study

All in all, there is a lack of research to prove the results of greenhouse gas reduction or energy efficiency improvement in the workplace where an energy management system is applied. In fact, there has been a constant problem in industrial sites where it is impossible to determine whether the energy management system functions properly in water projects as there has been no quantitative verification of how effective the system is in energy saving. In addition, most of the certification requirements for energy management systems focus on documentation requirements, such as preparing for procedures to pass certification reviews. In reality, however, energy management requires more detailed standards, such as setting achievable energy targets and upgrading indicators to assess energy performance.

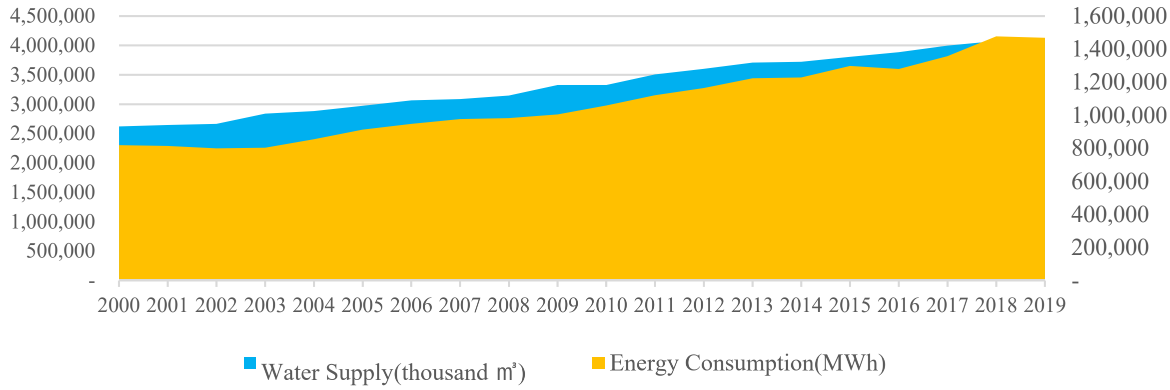
From this perspective, this study attempts to quantitatively verify how energy efficiency has improved before and after the introduction of the energy management system using the international performance evaluation standard, the "SEP M&V Protocol." In addition to this, I also investigate the requirement standards that the EnMS must supplement in order to work more successfully in organizations.

III. Energy Management System for Regional Waterworks in Korea

3.1 The need to improve energy efficiency

Since 2000, the annual increase in the domestic water supply energy consumption has been 3.2%, and water supply has increased by 2.4% annually. The overall pattern is that energy consumption increases as water supply increases, except that the growth rate of energy consumption is more than 33% higher than that of water supply. This leads to a sharp rise in energy costs to water supply sales. Statistics have shown that the sales of waterworks rise by 3.5 percent annually while energy costs increase by 6.3 percent annually.

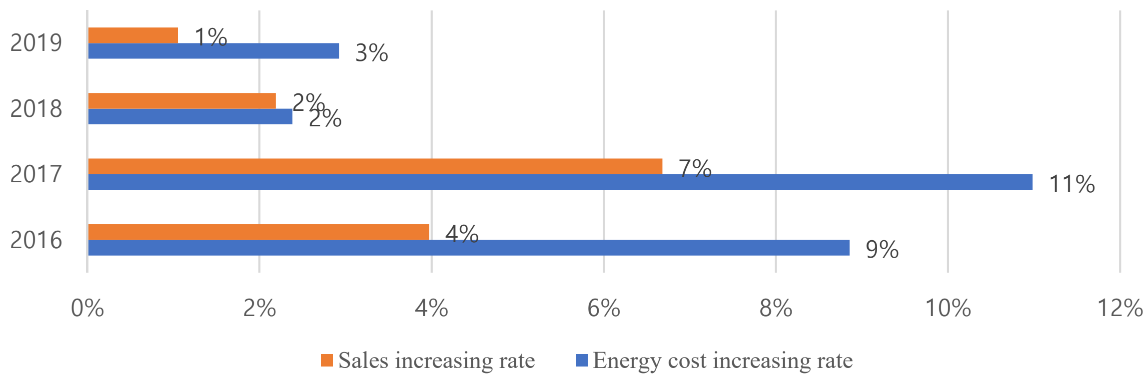
Figure 2. Relationship between energy consumption and water supply



Note. Reproduced from *Annual Report of Water Supply Management,* by K-water, 2019 (https://www.data.go.kr/data/15036934/fileData.do.) Daejeon: K-water.

Energy costs are expected to rise further in the future, given that Korea's power rates fall short of the average of electricity rates in OECD countries. The issue concerning efforts to reduce greenhouse gas emissions related to energy use is also growing. In Korea, there is a lot of energy consumed particularly in the industry sector, and thus the social demand for reducing greenhouse gases in the industry is expected to increase. This suggests that it is more important than anything else to introduce an energy management system in the water supply sector and continuously increase energy efficiency in order to enhance the competitiveness of the waterworks business and reduce greenhouse gases.

Figure 3. Comparison of increase in water supply sales and energy costs



Note. Reproduced from *Cost information in Regional Waterworks*, by K-water, 2019 (https://www.kwater.or.kr/cust/sub04/sub01/char/char06Page.do?s_mid=1982) Daejeon: K-water.

3.2 Analysis of K-water's EnMS

A. Planning and Policy

K-water declared quality/environment/green management regulations as a top management responsibility policy. The regulation defines green management as "management that saves resources and energy in management activities and efficiently utilizes them, minimizes the occurrence of greenhouse gas emissions and environmental pollution, and fulfills social and ethical responsibilities." (K-water, 2007). In addition, the operation and management regulations for water facilities adopt sustainable, low-energy, and eco-friendly operation and management as the core principle of the operation and management of water supply. Moreover, the basic plan for pipe network management and the comprehensive improvement plan for water supply facilities, which are subplans of this regulation, are set to develop the efficiency of transport energy and the overall energy reduction of water supply facilities.

B. Organizations

There are two departments that manage energy in K-water: Water Management Department . and Green Energy Department. The energy management department in the water supply sector is the Water Management Department that belongs to the Water Division. The Water Management Department has set goals for the energy management of water purification plants across the country every year and encouraged energy saving through the evaluation of water purification plants. Evidently, if it is well linked to an internal evaluation system and achieves its energy goals, it can receive corresponding incentives.

On the other hand, the Green Energy Department of the Green Infrastructure Division is in charge of policies to cope with greenhouse gases. The Green Energy Department's task is to oversee the construction and operation of CDM, REC, and renewable energy power plants using renewable energy. Greenhouse gas reduction is also classified as part of its renewable energy policy and carried out by this department. However, this poses a challenge as greenhouse gas management tasks that need to be comprehensively considered for CDM, REC, and energy consumption management are not being carried out organically due to the division of the departments that internally perform new and renewable energy work and the departments that manage energy consumption.

Separately, the Energy Diagnose Department takes charge of providing energy efficiency improvement opportunities to water purification plants that consume energy through surveys of energy use, major facilities, energy saving methods, and recommendations of applicable technologies.

C. Energy Planning and Implementation Budget

As a public institution, K-water complies with the government's Framework Act on Low Carbon, Green Growth and operates its business in accordance with the domestic guidelines. Internally, it has a strong energy management system, such as preparing guidelines for the energy saving in water facilities, suggesting proper efficiency for each energy-consuming facility, and recovering energy savings from manufacturers during the operation period if inefficient facilities are installed. If a high-efficiency pump is purchased and installed, the efficiency is measured using the energy efficiency measurement method agreed by K-water and the manufacturer within the warranty period. If the guaranteed efficiency is not met, the manufacturer is forced to identify the cause and take action. The annual budget invested in energy-saving facilities under this guideline has been set up and executed at an annual average of 25 billion won since the energy management system was introduced in 2014, and the budget for energy efficiency improvement will be continuously drawn up after 2020. The main tasks after 2020 will be to develop artificial intelligence (AI) energy management technology and apply new market-developed saving technologies in the areas of pumps, motors, and lighting.

D. Operational Infrastructure and Energy Performance Monitoring

The infrastructure for operation includes power monitoring and greenhouse gas management systems. Through the power monitoring system, all energy data used by 180 water purification plants across the country are collected in real time. Data from each regional headquarters are also collected by the real-time water information management system at the head office. This data can be accessed and used by any authorized K-water employee. Meanwhile, the greenhouse gas management system is operated by a greenhouse gas data platform that automatically links the purchase data to the greenhouse gas management system when purchasing electricity, oil, and LPG gas. Because the water purification plant purchases all of the energy from outside, employees can compare and manage greenhouse gases generated at the water plants by time and by business without having to enter data into the system separately. Through these data management platforms, all energy-related data generated in water purification plant are stored and used as verification data as well as design basis data for energy-related projects. In addition, this data is the basis for setting energy source targets for each business site to be assessed and is stored for more than 20 years in the long term.

Table 5. Analysis of EnMS' requirements and K-water's system

Requirements of EnMS			Management System (In K-water)	Redundancy with ISO14001
1. Management Responsibility	1.1 Top management 1.2 Management representative	① Establishing energy policies ② Organizing an energy management team	- Regulations for Quality Environment Green Management - Clean water management department vs. New & renewable energy department	◎
2. Energy policy	-	① Continuous improvement in energy performance ② Ensuring the availability of necessary resources ③ Complying with applicable legal requirements	- Principles for the Operation and Management of Waterworks - Implementing greenhouse gas emission capacity obligations	
3. Energy planning	3.1 Legal and other requirement	① Identifying legal requirements related to energy use ② Considering legal requirements that apply	- Framework Act on Low Carbon, Green Growth - GHG Energy Management Guidelines (MOE) - Guidelines for Rationalizing Energy Use of Public Institutions - Guidelines for Energy Saving in Waterworks Facilities - Carbon management system (greenhouse gas inventory) - Operational Integrated Information System (Waterworks) - Establishing a site-specific energy management plan	◎
	3.2 Energy review	① Documenting methodology and evaluation criteria for preparation ② Identifying and analyzing past energy consumption ③ Selection of important energy use ④ Modification of equipment, systems, and process variables that affect the use of important energy ⑤ Prioritizing and recording performance improvement		
	3.3 Energy baseline	① Establishment of using the initial energy review information ② Consideration of data in the appropriate time period	- Preserving energy consumption data for more than 20 years	
	3.4 Energy performance indicators	① Designating performance indicators suitable for measuring and monitoring energy performance ② Definition of energy performance indicators	- Energy intensity (kWh/㎥)	◎
	3.5 Energy objectives, target, and energy management action plan	① Documenting targets for processes and facilities ② Action plan establishment (including responsibility, means of achievement, schedule, and verification methods for performance improvement)	- Long-Term Planning of Energy management	◎
4. Implementation and operation	4.1 Competence, training, and awareness	① Training for employees ② Identifying the necessity of education and training	- Energy Saving Training	◎
	4.2 Communication	① Internal communication procedures	- Consultation on setting goal (Energy intensity)	

		② Establishing a process for improvement proposals and opinions on EnMS		
	4.3 Documentation	Standardization level of energy management document management		
	4.4 Operation control	① List management of important energy use facilities ② Standards for process operation	- Regulations for Operation and Management of Waterworks Facilities	
	4.5 Design	① Considering opportunities for energy performance improvement when updating facilities and processes	- Post-installation efficiency measurement and follow-up management for major energy facilities (If the guaranteed efficiency is not found within the defect guarantee period, the cause is identified and measures are taken (manufacturer)) - Energy diagnosis, Measuring the efficiency of the pump motor and diagnosing the energy of the multi-energy business site	
	4.6 Procurement of energy service, products equipment and energy	① Energy performance evaluation when purchasing facilities ② Verification system for energy efficiency after purchase ③ Purchasing regulations for Effective Energy Performance	- Criteria for measuring efficiency in design basis and specification - High-efficiency energy equipment and materials used in regulations on the promotion of the supply of high-efficiency local materials	
5. Checking	5.1 Monitoring, measurement and analysis	① Periodic monitoring of energy performance indicators ② Monitoring energy usage	- Monitoring the performance of greenhouse gas reduction targets - Monitoring the energy consumption of waterworks	◎
	5.2 Evaluation of legal and other requirements	① Implementing and evaluating compliance with statutes (measuring instruments)	- Periodic calibration of the instrument	
	5.3 Internal audit of the EnMS	Internal audit on the suitability maintenance of the decisions of the EnMS plan		
	5.4 Nonconformities, correction, corrective action and preventive action	Corrective action for nonconformities Implementation of improvement measures for energy management		
6. Management review	6.1 Input to management review	Review energy policy, review energy performance indicators, correct target achievement level	- Evaluation of energy performances in internal assessment - Incentive impact of departments and individuals on failure	◎
	6.2 Output from management review	Decision making and measures, such as changes in energy performance, changes in policy, changes in performance indicators, allocation of resources, etc.	- Top-down goal setting	

Note. Reproduced from *Guidelines for Energy Saving in Water Supply Facilities*, by K-water, 2014 (https://www.kwater.or.kr/gov3/sub03/infoView.do?apprid=201501007709&s_mid=55) Daejeon: K-water

3.3 Implications of Energy Management System Application

K-water is one of the most energy-consuming public institutions in Korea, along with Korea Railroad and Korea Expressway Corporation. In addition, since energy costs account for a very high proportion of costs, it has recognized the importance of energy management and operated regulations, energy evaluation methods, and energy data management systematically since early on. However, although the EnMS was introduced earlier than other agencies, continuous third-party verification has not continued. It argues that 100% meets the requirements of the energy management system, but it is only a seemingly satisfied requirement and cannot be proof that the energy management system is working perfectly.

A. The redundancy with other standards (ISO14001)

K-water has both ISO9001 and ISO14001 as well as the EnMS. ISO9001, ISO14001, and ISO50001 are all based on the same regulations (quality/environment/green management regulations). **Furthermore, ISO14001 operations have redundant functions throughout ISO50001's policy, planning, adjustment, and operation.** ISO14001 conducts environmental performance evaluations (EPE) to measure the level of environmental management and to identify the degree of improvement. K-water's EPE is classified into six major groups and measures management performance indicators, such as environmental accounting and compliance with green purchase codes as well as the performance of operational indicators (COD emissions, noise and vibration emissions, power output, and energy consumption). The assessment uses the same index as the energy consumption measured in ISO50001. In addition, it attempts to communicate with various stakeholders, including customers, executives and employees, local communities, and the government, for sustainable management through the publication of sustainable management reports. This report is prepared in compliance with the GRI Guidelines (G3) and shares the results of the improvement of water quality in dams and reservoirs, the use and purchase of environment-friendly products, the response to climate change, CDM projects, and energy saving projects (Jang, 2008).

B. The Inadequate measurement of energy performance

The obvious difference between ISO50001 and ISO14001 is that ISO14001 measures universal environmental monitoring, such as life, water pollution, and air pollution prevention in addition to environmental aspects while ISO50001 focuses only on energy, sets goals that can be achieved based on the actual amount of energy usage, and finds opportunities for energy savings by production processes. However, it is difficult to grasp such opportunity with the energy unit index currently used by K-water as an indicator of performance measurement. **Although energy intensity has the advantage of intuitively expressing the effects of performance, they are only meaningful when the correlation between water supply and energy use is high.**

C. Issues of internal and external evaluation methods

The evaluation system of energy performance for energy management is largely divided into external and internal evaluations. A typical external assessment is a public organization's performance evaluation. In order to efficiently operate tap water production processes and enhance the competitiveness of domestic water supply businesses, energy intensity is evaluated as one of the leading indicators of "water supply efficiency." **However, to continue to improve the energy intensity, tremendous costs are required each year to reduce energy**.

In conjunction with external assessments, internal assessments also apply the same assessment techniques, with energy savings allocated to each office in a top-down goal setting from the head office each year, and the evaluation results reflect the features of the workplace and individuals. The fact that external and internal assessments are correctly aligned with clear goals can be expected to have good results. **However, offices that are given the goal of improving the energy unit compared to last year and forced to save energy to achieve the goal are operating in a short-term perspective to meet the annual targets rather than long-term energy-saving activities.** In addition, complaints from field managers are being expressed in the form of allocating reduction targets collectively, regardless of facility investment, without consideration of the current situation at each business site. Apart from this assessment, **additional targets for the GHG target management are also assigned to each office,**

which is an indication of overlapping assessment of the same content as energy saving, adding to the burden on field energy managers.

IV. Energy Performance Evaluation

4.1 Verification of Energy Performance Evaluation Method

A. Energy Intensity Method

Waterworks use "energy intensity" as performance indicators. The energy intensity method has the advantage of being able to represent energy efficiency as a result of the increased production of products compared to the total energy consumption method. Table 6 shows that the total energy consumption in 2013 and 2014 was reduced by 10kWh. However, the energy performance assessment rather deteriorated by 12.6 percent in 2013 because 100 kWh of energy was used to produce 200 tons of products, and 90 kWh was used to produce 160 tons of products in 2014 (Rho, 2016).

Table 6. Review of International M&V standards

Category	Total Production	Total Energy Consumption	Energy Intensity
Y2019	200ton	100kWh	0.500 kWh/ton
Y2020	160ton	90kWh	0.563 kWh/ton
Energy Performance		10kWh	-0.063 kWh/ton
Energy Performance Rate		10.0%	- 12.6%

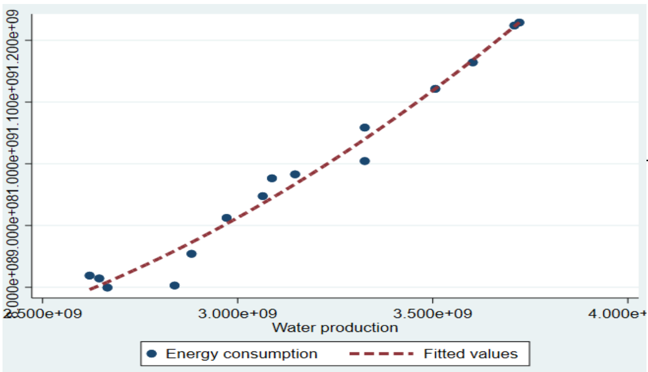
Note. Adapted from *A study on the energy performance assessment methodology and reliability improvement for industry,* by Rho, 2016, Dongguk University.

In the case of the energy intensity method, it needs an assumption that energy consumption is very closely related to production. When water production is an independent variable and has a significant impact on energy consumption in the water purification plant, this would mean that the energy intensity indicator is highly valuable as an efficiency index. Therefore, a correlation analysis was conducted between the energy consumption and water production of the water purification plants to verify the energy intensity method in the water sector. If the correlation between these two variables is high, the energy intensity could be used as an indicator of energy performance in the water sector. Conversely, if the correlation is low, this indicator cannot be used as an index to determine energy performance.

B. Correlation Analysis between Energy Consumption and Water Production

First of all, the correlation analysis between energy consumption and water production in waterworks nationwide showed 98% (0.9839). As can be seen from the scatterplot in Figure 3, the two variables are highly correlated. **This indicates that it is reasonable to use energy intensity indicators as an indicator of energy efficiency in case of waterworks nationwide data.**

Figure 4. Correlation between energy consumption and water production



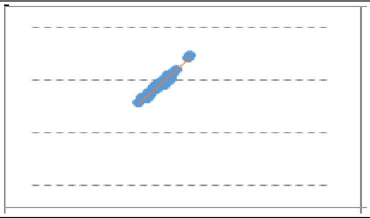
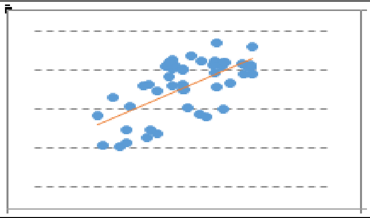
	H	C
H	1.0000	
C	0.9839	1.0000

Second, the correlation between energy consumption and water production was analyzed for each process sites needed for tap water to be supplied to customers. The process divides a water transport process that moves water from dams or streams to water purification plants, a water treatment process, and a supply process that supplies tap water to customers.

(1) Water transfer process

For the water transfer process, the data of the Paldang 2 intake station and Daecheong intake station was analyzed. The Paldang intake station shows a high correlation of 96.30% between energy consumption and water production. On the other hand, Daecheong intake station has a relatively low correlation of 51.47%. Daecheong intake station does not change energy consumption depending on the amount of water it transfers, but also changes energy consumption for other reasons (precipitation, water level). Consequently, energy intensity can be used for Paldang water intake stations, but more sophisticated energy evaluation indicators are needed for Daecheong intake stations, rather than simple energy intensity indicators.

Figure 5. Correlation between energy consumption and water production (The case of intake station)

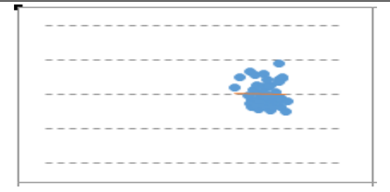
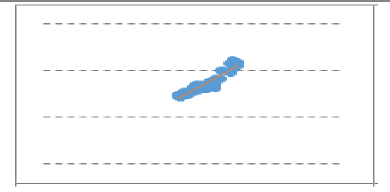
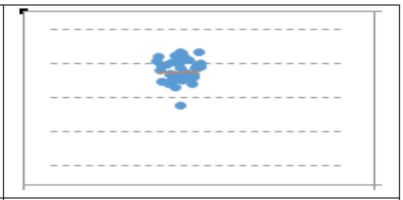
Paldang 2 intake station	Daecheong intake station
	
R^2 = 96.30%	R^2 = 51.47%

(2) Water purification plant

In the case of a water purification plant, the difference is more pronounced depending on whether there is a pump that transfers water to another place or whether the water purification plant is located at a higher level and can naturally deliver water down to customers. The Banwol Water Treatment Plant and Cheongju Water Treatment Plant, which are nature flows, do not have pumps, so there is no correlation between water production and energy consumption. Rather, the sudden water purification process changes the amount of energy usage by the event as well as increases and decreases depending on the amount of energy usage in the office, such as air conditioners and heaters, in the summer or winter. For these water purification plants, the energy intensity cannot be used as a performance indicator, but an annual change or total energy consumption in energy use can be used instead as an indicator for proper energy management. In the case of Goyang water purification plant, a pump is found, showing a correlation between water production and energy consumption. **Since there are not many cases where water pumps are present in a water purification plant, it is not appropriate to use the energy intensity as a performance indicator in the water purification process except for special cases.**

Figure 6. Correlation between energy consumption and water production (The case of water purification plants)

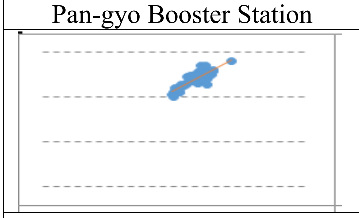
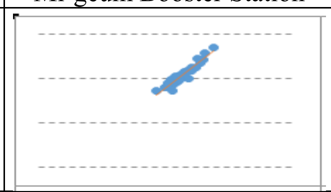
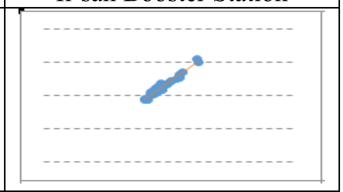
Banwol Water Treatment Plant	Goyang water purification plant	Cheongju Water Treatment Plant

		
R^2 = 0.09%	R^2 = 86.83%	R^2 = 0.25%

(3) Booster Station

In the case of booster station, unlike water intake or water purification plants, most of the facilities have only pumps. Only water must be pumped from a low to high place since consisting of simple facilities, water production, and energy consumption remain highly correlated. **Therefore, it is appropriate to use the energy intensity as an energy performance indicator for the booster station.**

Figure 7. Correlation between energy consumption and water production (The case of booster Station)

Pan-gyo Booster Station	Mi-geum Booster Station	Il-san Booster Station
		
R^2 = 71.06%	R^2 = 90.73%	R^2 = 96.08%

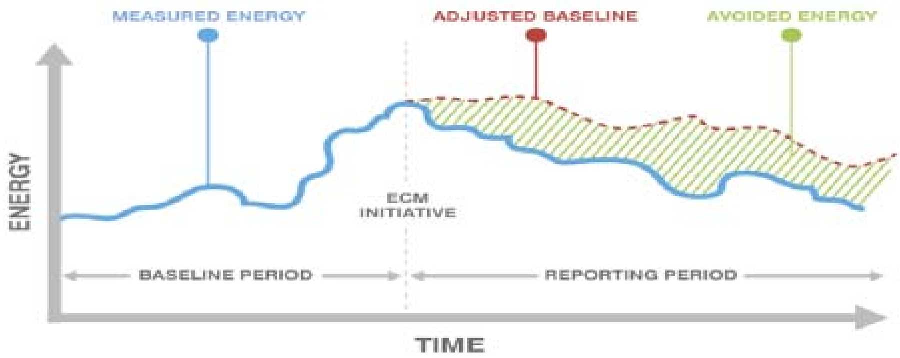
Note. Reproduced by the author

4.2 Energy Performance Evaluation Using Statistical Technique

To evaluate the performance of the introduction of the EnMS in the water sector, the energy performance assessed using the Superior Energy Performance (SEP) M&V protocol. This protocol is an M&V standard developed by Lawrence Berkeley National Laboratory (LBNL), and the U.S. Department of Energy evaluates energy performance in its domestic operations through this method. The most important procedure for conducting performance assessments by SEP is to first set a baseline period and then establish the most optimized linear regression model by identifying potential factors affecting energy consumption. Once the linear regression model of the baseline period is defined, an adjusted baseline is created using data from the subsequent reporting period. The difference between the adjusted baseline and the actual energy consumption is the real energy savings and avoided energy (KEA, 2013).

Figure 8. Concept of Energy Performance Evaluation by Statistical Technique

Energy performance (Avoid energy) = Adjusted baseline – Actual energy consumption



Note. Adapted from *Development of Guidelines for Energy Management Performance Evaluation,* by KEA, 2013, Ulsan: Korea Energy Agency.

A. Data collection

In order to establish statistically valid linear regression models and accurately analyze energy performance, the right selection of baseline periods and the collection of high-quality data during the reporting period are the basic prerequisites. Because the energy source in the waterworks uses only electrical energy, the electricity energy figures specified in the rate notice were selected. In addition, water production, water turbidity, advanced water purification rate, water level, and precipitation of the water intake source were selected as independent variables that are expected to affect energy consumption.

For each independent variable, there are significant characteristics to note. First, tap water production is the final product of the water purification plant, which is judged to have the greatest impact on energy consumption. This has already been demonstrated by an earlier correlation analysis. Second, water turbidity is the most important characteristic of input materials. It is assumed that good turbidity may cause less operation of water purification facilities, and high turbidity may consume a lot of water purification facilities. Third, advanced water treatment is an additional facility that has recently been introduced to remove trace amounts of pollutants or flavor-smelling substances. Although this data was to be removed as it could be judged as an extension of the production line, it was not possible to calculate and eliminate the amount of energy used separately; therefore, it was chosen it as a factor that affects energy consumption. Fourth, in the water sector, water transportation process (water intake and booster stations) is the most energy consumer. When a booster station carries water from a purification plant to a reservoir, there is no water head change. But in the case of water intake plants, the water level of the stream or the dam always changes. Therefore, the intake water level was selected as a factor affecting energy consumption. The last factor is precipitation. Precipitation was chosen as the cause factor assuming that annual precipitation affects water consumption.

The baseline used annual data from 2000 to 2014, and the reporting period was intended to obtain a baseline adjusted using five years of data from 2015 to 2019. The variables in water supply and energy consumption were too large-scale, resulting in a fundamental asymmetry between independent variables when describing the extent of the change in the dependent variables. Consequently, for water supplies and energy consumption, the units were adjusted using log scale.

B. Multiple regression modeling

For the coefficients in the linear regression model to be estimated, it is necessary to assume that there must be no complete linear relationship between the independent variables, including the constant (Yang, 2013). This assumption is violated when continuous explanatory variables have strong linear relationships with each other. This is called a multicollinearity. If independent variables are the same as each other, it is pointless to compare the effects of each independent variable on the dependent variable; therefore, it is crucial to confirm that each variable is independent. The Pearson's correlation coefficient of independent variables (tap water production, water turbidity, the advanced treatment rate, intake water level, and precipitation) that are expected to affect the power consumption were reviewed.

Table 7. Correlation coefficient of independent variables

	ln_q_c	tub	adv	level	ln_pre~p
ln_q_c	1.0000				
tub	-0.4847	1.0000			
adv	0.8148	-0.4244	1.0000		
level	0.4491	-0.0854	0.2736	1.0000	
ln_precip	-0.0281	0.6798	-0.1576	0.0549	1.0000

Multicollinearity's threshold was 0.7 (70%), and the correlation coefficient between water production and the rate of advanced water treatment was 0.8148, which is beyond the threshold. Nevertheless, the reason for this result is that water supply and the advanced water treatment rate increase every year due to customers' interest in water quality, thus the correlation coefficient seems to be very meaningful. In practice, however, it is hard to see that there is a variable correlation as both variables are admitted. In addition, a Variance Information Factor (VIF) measurement, along with the correlation coefficient test, re-checks the multicollinearity once again. The VIF of independent variables are shown for energy consumption (dependent variable), and if the VIF is usually greater than 10, a multicollinearity issue should be suspected. The following table shows that the VIF values of all five independent variables are below 10.

Table 8. VIF value of independent variables

Variable	VIF	1/VIF
ln_q_c	5.34	0.187294
adv	3.41	0.293579
tub	3.38	0.295683
ln_precip	2.66	0.375883
level	1.36	0.737572
Mean VIF	3.23	

The multiple regression model analyzes the relationship between independent variables and dependent variables. The multiple regression model means that a change in the Y value of the dependent variable is explained by the independent variables X1 and X2~X4. In this paper, dependent variable Y was set as energy consumption, and a regression analysis was performed with X1 as tap water production, X2 as turbidity, X3 as the rate of advanced water treatment, X4 as the intake water level, and X5 as precipitation.

Table 9. Multiple regression analysis results

Source	SS	df	MS			
				Number of obs	=	15
				F(5, 9)	=	99.15
Model	.320602995	5	.064120599	Prob > F	=	0.0000
Residual	.005820133	9	.000646681	R-squared	=	0.9822
				Adj R-squared	=	0.9723
Total	.326423128	14	.023315938	Root MSE	=	.02543

ln_power	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_q_c	.9770785	.1316575	7.42	0.000	.6792485	1.274909
tub	-.0033964	.0033162	-1.02	0.332	-.0108983	.0041054
adv	.4693142	.2439589	1.92	0.087	-.0825592	1.021187
level	.0171088	.0109812	1.56	0.154	-.0077325	.0419501
ln_precip	-.0184976	.06995	-0.26	0.797	-.1767355	.1397404
_cons	-.8742241	2.557931	-0.34	0.740	-6.660666	4.912217

In regression tables, R-square and P>|t| values should be carefully examined. The R-square value is a measure of whether a change in a dependent variable can be described as a change in an independent variable. Simply put, the higher the number, the more appropriate the model is. In Table 8, results show that the adjusted R-square is 0.9823, suggesting that the independent variables explain energy consumption more than 98.2%. In addition, the P value is a value that identifies a significant level. The turbidity variable was rejected because in SEP standards, only the dependent variables with a P value of less than 20% should be met. Accordingly, the assumption that high turbidity would result in more operation time and energy consumption of water treatment facilities was rejected. Also, the coefficient corresponding to the water level at the intake station was positive (+), indicating that the higher the water level at the intake station, the higher the energy consumption. This should be dismissed as beyond the engineering feasibility criterion. Therefore, the turbidity and water level variables were removed. As a result, in the final model, water production, the advanced water treatment rate, and the precipitation were identified as independent variables as they had a statistically significant impact on energy consumption.

Table 10. Final multiple regression analysis results

Source	SS	df	MS			
				Number of obs	=	15
				F(3, 11)	=	151.48
Model	.3187084	3	.106236133	Prob > F	=	0.0000
Residual	.007714729	11	.000701339	R-squared	=	0.9764
				Adj R-squared	=	0.9699
Total	.326423128	14	.023315938	Root MSE	=	.02648

ln_power	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_q_c	1.113287	.1027463	10.84	0.000	.8871444	1.339431
adv	.3546334	.2429308	1.46	0.172	-.1800536	.8893205
ln_precip	-.0729407	.044474	-1.64	0.129	-.1708273	.024946
_cons	-3.129704	2.205778	-1.42	0.184	-7.984589	1.725182

4.3 Performance of the EnMS (with SEP standard)

The regression equation in the Superior Energy Performance (SEP) M&V protocol is shown in Table 10.

Table 11. The regression equation

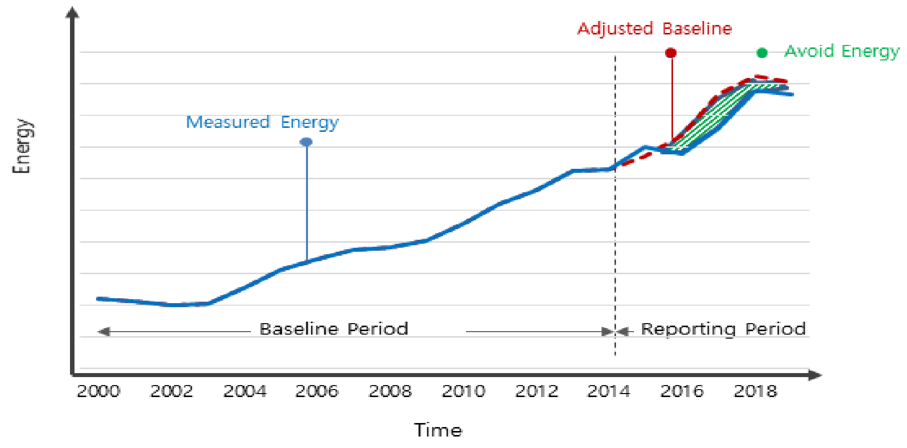
F-test	R2	Linear Regression equation
0.0000	0.9764	Y=1.113287X1+0.3546334X2-0.0729407X3-3.127904

The baseline period from 2000 to 2014 was set and the adjusted baseline's energy consumption by the impact factor of the reporting period was obtained using the multiple regression model. In the water sector, the EnMS was introduced in 2015, and 226,629,569kWh of electricity energy was saved for five years until 2019 with the 3.2% improvement rate. This is a low improvement rate compared to previous studies, but the actual energy saved was a huge effect worth 22.6 billion won (4.5 billion won per year). It also reduced greenhouse gases by 2.1 billion tons a year.

Table 12. Estimation of Energy Savings by the Introduction of the EnMS

Category	Energy Consumption (kWh)
Adjusted Baseline	7,107,519,803
Reporting Period	6,880,890,234
Energy Performance	226,629,569
Energy Performance Rate	3.2%

Figure 9. Adjusted Energy Baseline in the water field



V. Complementation of ISO50001 Requirement Standards

As previously demonstrated, an entity's application of an energy management system can reduce the enterprise's energy consumption and benefit from cost as well. Nevertheless, many domestic companies, including K-water, have failed to continue their certification of the EnMS. There are several reasons why K-water avoids the third-party certification. One of them is the fact that the ISO 14001 certification process and the ISO 50001 certification process have high redundancy. This results in a cost burden on businessmen to maintain two certifications with similar characteristics. Accordingly, in the majority of cases, ISO 14001 is maintained, a larger and more comprehensive area of the environment and energy. If the three-party certification is not continued, there will be a lack of objective verification of whether the process of the energy management system functions properly, which eventually may lead to the poor operation of the energy management system.

5.1 Integrated certification and supplementation of specific internal criteria

The EnMS (ISO50001) is a professional international standard focused solely on the energy sector. However, the requirements for the third-party certification of the EnMS are substantially redundant with ISO14001. In *1. Management Responsibility*, K-water has the same internal regulatory basis for environmental management and energy management, and in *3.4 Energy performance indicators, 3.5. Energy objects, target and management action plans, and 5.1 Monitoring, measurement* *and analysis*, it has to go through a redundant certification process. Therefore, it is proposed that the ISO50001 certification be integrated when it is certified to ISO14001, without having to undergo multiple redundant certifications. Evidently, the full certification of the EnMS requires an additional certification for non-redundant requirements. Yet, such additional certification can make up for the lack of an integrated certification by modifying the internal evaluation system and fostering certification examiners. Although the third-party certification is an excellent method of certification in terms of objective evaluation, it can be more effective than the former if experts inside K-water are appointed and utilized as certification auditors.

In addition, the program can improve the energy performance checks currently lacking in K-water. One of the important parts for achieving the goal of the energy management system is by far the Check-Act part. It is crucial to take corrective actions and appropriate measures in a timely manner through the checks of energy actions implemented through energy management activities. However, the current K-water energy internal assessment system simply assesses energy saving goals (energy intensity). This calls for the need to verify that proposed goals are feasible, and appropriate measures should be taken to achieve them: the way in which energy use is stopped to realize that the current short-term goals are not appropriated. The assessment of these goals and actions would require additional qualitative checks in addition to energy saving objectives. In that sense, this paper presents an energy evaluation table applicable to the domestic water sector by referring to the energy management performance rating system implemented in the U.S. and the ISO50001 checklist in the U.S. water supply sector.

With the U.S. energy management performance rating system, in order for a target company to be rated, it must satisfy the assessment according to the 'Industrial Facility Best Practice Scorecard.' Following this, a qualitative assessment was made to achieve energy goals through the evaluation of five areas: data management (DM), management of significant use (SU), energy supply management (ES), energy performance measurement options (EP), and system sustainability (SS). By benchmarking this scorecard, the energy management readiness assessment table that can be used in K-water is shown in Table 12 including the domestic water supply sector defined.

First, an assessment of the energy data management is needed. Data on energy consumption is not only necessary to identify opportunities for energy efficiency improvement, but also essential to prove energy performance improvements. In particular, since many high-efficiency devices have not yet been applied, this information must be released to energy managers to prevent market failures regarding incomplete information. Ultimately, if the data prove and share examples of improved energy performance, the dissemination of high-efficiency devices is further promoted.

Second, the management of big energy consumption facilities is necessary. This provides a significant understanding in the energy usage of all facilities in the workplace, but more importantly, it is more useful to understand the critical part of energy that consumes a large amount of energy. In the water sector, the energy consumption of pumps in particular is an important management point, accounting for 85% of the total energy consumption. Consequently, it is crucial for pumps to be installed with separate power meters so that each system can determine when, where, and how much energy has been used. This process makes it possible to determine the efficiency change of critical energy use facilities and the timing of their status and replacement. In the case of critical energy use facilities, timely replacement and management are considered essential as operating costs far exceed replacement costs.

Table 13. Energy management readiness assessment table

As- is	To-be
Energy Intensity (15 points)	① ***Assess Current Energy Baseline Status* (5 *points*)** - Identify activities and operations that consume the most energy or are inefficient - Perform an energy audit ② **Monitor and Measure the Results of the Energy Improvement Management Program (4 points)** - Review what the facility currently monitors and measures to track energy use - Determine what else the facility needs to monitor and measure its priority energy improvement operations - Manage data misses ③ **Energy optimization (3 points)** - Utilize energy at low-cost time zone - Review of the appropriate rate system ④ **Maintain the Energy Improvement Program (3 points)** - Perform sharing and benchmarking of excellent energy management sites - Expand involvement of management and staff - Information dissemination on successful cases

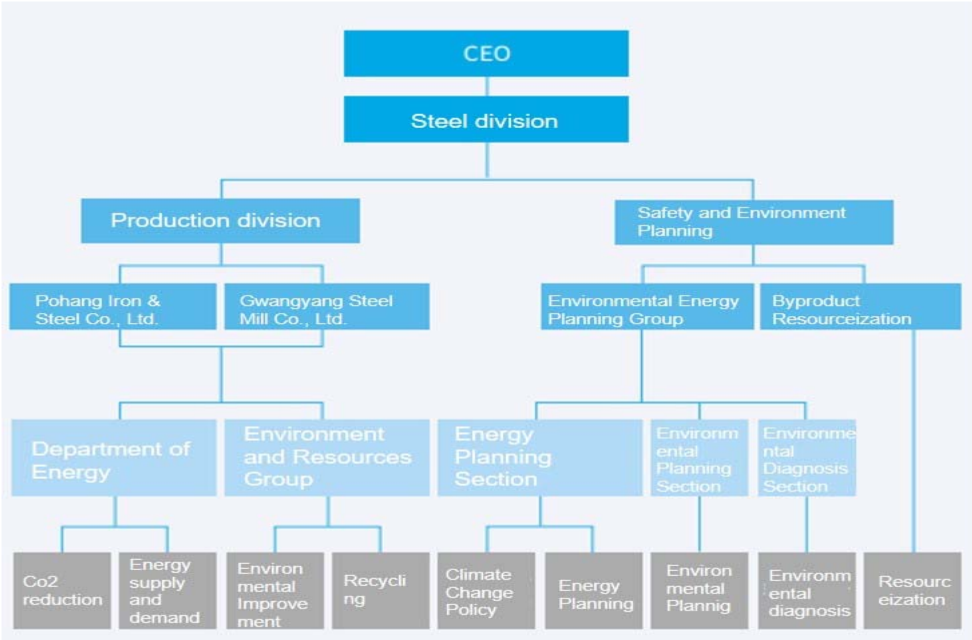
5.2 Role and Responsibility of Energy Management Team

K-water has a hydroelectric and tidal power plant and businesses as a power plant operator in Korea through renewable energy sources. On the other hand, it is also an energy consumer who consumes large amounts of energy in the water business. To achieve both major goals of developing renewable energy and improving energy efficiency in the era of climate crisis, role and responsibility (R&R) coordination by K-water's internal energy-related departments is essential.

A. Case Study

This paper introduces two companies that manage energy in the best way and are most leading energy companies. The first P company is a steel-producing company that uses a lot of energy in Korea. Due to its high energy consumption, the company is well aware of the importance of climate change and energy policies and has implemented a process scheduling that makes the most of late-night power with low purchasing prices to reduce energy costs. In 2012, the company was the first in Asia to be certified as an ISO 50001 international standard in the field of steel. It operates a 'Safety and Environment Planning' Department directly under the CEO and makes decisions on climate change policies, energy planning, and environmental planning through the 'Environmental Energy Planning Group.' Indicators of the company's CO_2 emissions and energy use are reported to the board of directors through the head of the production division, the head of the steel division, and the CEO. The board of directors and the management committee deal with critical financial issues related to climate change on the agenda.

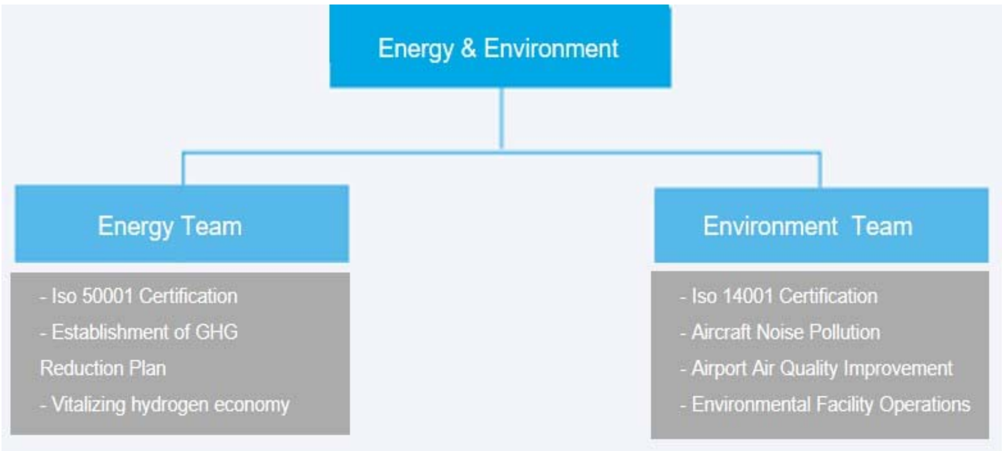
Figure 10. A Case of Energy Organization and R&R in P Company



Note. Adapted from *Posco Corporate Citizenship Report 2019,* by POSCO, 2019 (http://corporatecitizenship.posco.com) Seoul: POSCO.

Next, company I is the third in the world and the first in Korea to be certified an energy management system (ISO 50001) in the building sector in 2012. The re-certification was completed in 2020, and currently, strategic environmental management is being promoted to minimize any environmental impact during management activities. The company also manages environmental performance indicators to improve energy efficiency and strengthen the management of environmental resources. These indicators consist of integrated indicators of energy and environment, such as energy use, renewable energy facilities, waste generation, and disposal. The organization has an energy and environment department in the facility headquarters. ISO50001 and ISO14001 are managed in a single department, and decisions regarding energy and environment are made in another independent department.

Figure 11. A Case of Energy Organization and R&R in I Company



Note. Adapted from *Sustainability Management Key Issues,* by Incheon Airport, 2019 (https://www.airport.kr) Inchon: Inchon Airport.

B. R&R Coordination

To take advantage of K-water's assets and implement integrated energy management, this paper presents R&R improvement measures for internal energy departments. In the case of the head office, it is proposed to establish an energy committee so that each work can be organically coordinated while maintaining the working system that is performed by each sector and division.

As before, the Water Management Department has monitored energy performance while the Energy Diagnose Department has captured the opportunity factors for energy efficiency improvement through energy diagnoses. However, it is necessary to integrate the tasks related to the greenhouse gas target setting and emission trading system into the environmental management role of the management innovation office under the vice president and to expand the tasks not only to manage greenhouse gas emissions but also to oversee national policies related to climate change.

The roles of the CEO-controlled Energy Committee are as follows. First, it remains crucial to establish energy management goals linked to the management of greenhouse gas emissions. Energy management goals covering energy consumption and greenhouse gas emissions should be further established, not just separately considering the management of greenhouse gas emissions and energy consumption as it is now. Second, the committee shall select Key Performance Index (KPIs) and determine specific investment plans to achieve its objectives. The third role centers on opportunities to coordinate the opinions of the departments developing energy and the departments consuming it, and to unite enterprise-wide capabilities. Finally, the commission may also address mid- to long-term directions and financial risks related to K-water's climate change assignment. On a domestic scale, tasks related to climate crisis are carried out by the Ministry of Environment. In the future, the government and civic groups would continue to demand roles related to climate change from K-water, an affiliated agency of the Ministry of Environment and the nation's number one renewable energy company. Subsequently, if an energy headquarter is made in K-water, it will be necessary to establish the role of the energy headquarter by bringing together the roles of national policy assistance, climate change and environmental management (Management Innovation Department), and government consultation on renewable energy plans, and energy management (Water Management Department).

VI. Conclusion

6.1 Research summary and implications

This study objectively verified the amount of energy saving and financial performance before and after applying the EnMS (ISO50001) in domestic waterworks according to the international performance evaluation standards. It also analyzed K-water's management system in accordance with the requirements of the EnMS and investigated what needs to be supplemented in order for the EnMS to function more effectively in the enterprise. Energy savings and financial performance were calculated by the SEP M&V protocol, which is a widely used energy evaluation criterion, and case studies of other companies were conducted to complement the requirements. The results of the study are summarized as follows.

First, K-water's management system is aligned with the six requirements of ISO 50001 (management responsibility, energy policy, energy planning, implementation and operation, management, and review). In detail, (1) K-water has quality/environment/green management regulations as a policy for energy management. Integrated regulations on the environment and green energy operate in line with the international trend that emphasizes the importance of sustainable management. (2) Since K-water produces renewable energy and also consumes energy, a dual assessment is made to evaluate the same assessment in different ways depending on how energy is produced and consumed. (3) The evaluation of energy performance only measures energy intensity as a way to assess energy performance. However, the application of this uniform evaluation method is rather an obstacle than proper evaluation.

Next, financial performance before and after the introduction of the EnMS was measured, as well as the verification of energy performance indicators. Energy intensity, a current indicator of energy performance evaluation, is deemed unsuitable. According to a survey of the suitability of eight representative water intake, water purification plants, and pressurization plants owned by K-water, the energy intensity index was found inapplicable in some of the water intake stations and the majority of the water purification plants. Therefore, I propose to use both energy intensity and energy performance improvement rates of the SEP M&V protocol as an energy performance indicator. As Table 13 explains, the energy intensity and energy performance improvement rates have their respective pros and cons. In particular, energy intensity is a very simple yet intuitive indicator; therefore, its advantage is that it can be managed in real time. On the other hand, the improvement rates of SEP have the advantage of being able to find and manage factors that affect energy consumption and to measure the baseline energy consumption. Through the analysis of the energy balance, it was evaluated as a more advanced performance indicator of the energy intensity index. Therefore, using energy intensity as an indicator of performance evaluation for water intake and pressurization plants and the SEP protocol as a performance indicator for water purification plants can cover the shortcomings of using only one energy indicator. In the case of water purification plants, there are many facilities for energy management, and in some cases, various energy consumption factors can occur. The SEP protocol will be of great help to energy managers in finding and managing energy consumption characteristics and energy impact factors of their water purification plants. In addition, in the case of water intake stations, flexible responses are needed to ensure that the SEP protocol can be used as an evaluation indicator under the judgment of the people in charge if various factors of influence are considered.

Table 14. Pros and Cons of Energy Intensity and Energy improvement rate of SEP

Category	Energy Intensity	Energy improvement rate of SEP
Pros	- Simple (real-time energy management) - Efficient - Intuitive	- Analysis of factors affecting energy consumption - Realistic energy efficiency measure - Results acceptable based on statistics
Cons	- Inapplicable Measurement Target - No consideration of the current status of each business establishment (temporary increase in supply, etc.)	- Complexity - Requirements of an evaluator's statistical ability - Requires a lot of data

The calculation of energy savings and the financial performance before and after the introduction of the EnMS used internationally-validated SEP M&V protocol methods. For data collection, energy consumption was set as a dependent variable and water supply, advanced water treatment rate, and precipitation were determined as independent variables by checking their multicollinearity and P-values. The data baseline period was 14 years from 2000 to 2014, and a multi-linear regression analysis was used to calculate adjusted baseline. According to the calculated results, the domestic water supply business saved 226 GWh of electricity over the five years and achieved financial results of 22.6 billion won (4.5 billion won per year) when converted into Korean won. If this is converted into greenhouse gas emissions, greenhouse gas emissions reduced by 2.1 billion tons per year.

Finally, in order for the EnMS to function better in K-water, the following improvements should be made; for entities (including K-water) that are certified with ISO 14001, an integrated certification is required to exclude duplicate certifications. If overlapping costs and time are reduced through an integrated certification, it is expected that the energy management system will be expanded to include companies that need energy management among those that maintain the existing ISO 14001 certification. In addition, special requirements in the energy sector that does not belong to the integrated certification requirements can be addressed by introducing internal expert assessments. As well as the quantitative assessment of the current simple energy assessment, non-measuring assessments that can verify that the EnMS system is properly maintained by each business site can be carried out in parallel.

Furthermore, an internal R&R coordination on the energy management of K-water is proposed. For companies where both energy production and consumption must be managed, such as K-water, separate production and consumption management departments are maintained to suit their respective business characteristics, but an integrated decision-making framework, such as the Energy Commission, is needed to ensure organic decisions. The Energy Council can set goals in conjunction with energy consumption and greenhouse gas emissions and determine specific investment plans to achieve these objectives.

Recently, the paradigm of the energy sector has changed considerably. For example, global companies' voluntary campaign (Renewable Energy 100) to use 100% of electrical energy needed for business activities is drawing attention. Such initiative breaks the old notion of a supplier-oriented energy policy and calls for strengthening the role of consumers (Lee, 2019). Previously, K-water relied on the Ministry of Commerce, Industry, and Energy and supplier-oriented policies and followed the price determined. However, for the future, it can consider the sustainability of the environment and establish new business goals that meet the value of pursuing eco-friendly tap water production through renewable energy. In particular, while domestic companies try to achieve the goal of RE100 through external purchases rather than the self-production method of renewable energy, K-water remains as the only company in Korea that has the potential to replace 100% of energy consumed by itself based on the amount of renewable energy resources and technologies.

6.2 Significance and Limitations of Research

This study was carried out to express opposition to enterprises that doubt the performance of the energy management system or to the skepticism that the EnMS (ISO 50001) will face the limits of manual and documentation, and to find what the EnMS should improve to make a better operating system as a manual. Based on the research results described, I hope this paper will help companies that wish to apply ISO 50001 (especially those in the water sector) to establish an efficient energy management system. This study argues that the energy management system differs from other ISO systems in that it produces visible economic results immediately upon the introduction and emphasizes that energy intensity, which is mainly used as a performance index in Korea, can be ineffective in some waterworks. Therefore, additional quantitative performance indicators should be considered.

The limitation of this study is that it investigated only the adequacy of energy performance indicators. It is therefore necessary to further study how much energy savings should be set to achieve. Currently, the goal is set in alignment with external evaluation targets without specific grounds for setting targets for energy performance. However, not only is the goal itself difficult to achieve in a site that has to accomplish the goal set for no reason each year, but it is only an expedient goal that does not take into account the circumstances of each site. If the target is not set correctly, the result will not be satisfied either. In addition, despite the fact that this paper expressed an improved opinion on the R&R coordination of internal organizations, there have not been many studies by companies that are also electricity sellers and consumers. In that sense, additional case studies are needed regarding the R&R coordination of internal organizations.

Finally, the analysis of K-water's energy consumption using the SEP M&V method found a factor affecting energy consumption. This analysis expected that if SEP is used for each site (especially for water purification plants where the energy intensity evaluation cannot be applied), independent variables on energy consumption for each water purification plant can be found and more scientifically controlled. This method will not only evaluate the performance of energy, but also provide a good opportunity to get new ideas to reduce energy consumption.

References

Beak, W. (2012). *Suggested action plan for the greenhouse gas and energy target management system based on the energy review of ISO 50001* [Master's thesis, Inha University]. KERIS. http://www.riss.kr/search/detail/DetailView.do?p_mat_type=be54d9b8bc7cdb09&control_no=c3b65b825d69ba10ffe0bdc3ef48d419

Chiu, T.-Y., Lo, S-L., & Tsai, Y-Y. (2012). Establishing an integration-energy-practice model for improving energy performance indicators in ISO 50001 energy management systems. *Energies, 12*(5), 5324-5339.

Hong, S. (2014). *A study on item development and validity analysis of energy management assessment* [Master's thesis, Yonsei University]. KERIS. http://www.riss.kr/search/detail/DetailView.do?p_mat_type=be54d9b8bc7cdb09&control_no=39f8fabbca67b0b2ffe0bdc3ef48d419

Incheon Airport. (2019). *Sustainability management key issues.* Inchon Airport. https://www.airport.kr

International Standardization Organization. (2011). *Energy management systems — Requirements with guidance for use.* ISO. https://www.iso.org/obp/ui#iso:std:iso:50001:ed-1:v1:en

International Standardization Organization. (2015). *ISO 14001:2015, environmental management systems—requirements with guidance for use*. ISO/IEC: Geneva, Switzerland.

International Energy Agency. (2018). *World energy outlook 2018*. International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2018

International Standardization Organization. (2018). ISO *50001:2018(en) Energy management systems - Requirements with guidance for use.* The International Organization for Standardization. https://www.iso.org/obp/ui/#iso:std:iso:50001:ed-2:v1:en

International Standardization Organization. (2018). *ISO 50001:2018. energy management systems—requirements with guidance for use*. ISO/IEC: Geneva, Switzerland.

Jang, J. I. (2008). A study on adoption of EMS for the government-owned enterprises: A case of KOWACO. *Korean Journal of Business Administration, 21*(3), 1159-1187.

Jung, B. (2020). *A study on establishment and certification of ISO 50001 application process for urban railway sector for sustainable energy management* [Master's thesis, Hanyang University]. KERIS. http://www.riss.kr/search/detail/DetailView.do?p_mat_type=be54d9b8bc7cdb09&control_no=2697f5fd735dfdb3ffe0bdc3ef48d419

Kim, W. (2012). *A study on preliminary application of energy management system to Seoul City* (Report No. 2011-PR). The Seoul Institute.

Kook, H. (2019). *A study on the impact of ISO 50001 certification factors on climate response and financial performance* [Doctoral dissertation, Soong-sil University]. KERIS. http://www.riss.kr/search/detail/DetailView.do?p_mat_type=be54d9b8bc7cdb09&control_no=99c3d1b223bb069bffe0bdc3ef48d419

Korea Energy Agency. (2013). *Development of guidelines for energy management performance evaluation.* Korea Energy Agency.

Korea Energy Agency. (2015). *M&V guidelines for calculating energy savings for device replacement.* Korea Energy Agency. http://www.kemco.or.kr/web/kem_home_new/info/data/open/kem_view.asp?q=19231

K-water. (2015). *Total water supply cost*. K-water. https://www.kwater.or.kr/cust/sub04/sub01/char/char06Page.do?s_mid=1454

K-water. (2019). *Cost information in Regional Waterworks*. K-water https://www.kwater.or.kr/cust/sub04/sub01/char/char06Page.do?s_mid=1982

K-water. (2019). *Annual report of water supply management.* K-water. https://www.data.go.kr/data/15036934/fileData.do

Lee, Y., Cho, M. S., Chae, H. J., Kim, J. C., & Lee, S. C. (2019). The status of RE100 and its implications in Korea. *Journal of Energy and Climate Change, 14*(1). 43-52.

Park, S. (2013). *A study on the applicability and usefulness of GHG·energy target management system under the requirements of ISO50001: Focusing on the cases of designated entities*. Department of Climate Change Policy. Graduate School Kyung-sung University.

Rho, K. W. (2016). A study on the energy performance assessment methodology and reliability improvement for industry. Department of New and Renewable Energy Engineering. Dongguk University.

POSCO. (2019). *Posco corporate citizenship report 2019.* POSCO http://corporatecitizenship.posco.com

Yang, O. (2013). *Stata utilization for business administration*. South Korea: Jiphil Media.