A research on energy saving measures by the type of water service provider

By

LEE, Hojin

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

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Committee in charge:

Professor Cho, Yong-Sung, Supervisor ____________________

Professor Lee, Junesoo ____________________

Professor Kim, Yeong Jae ____________________

Approval as of May, 2024

ABSTRACT

Research on Energy saving measures by type of water service provider

By

Lee, hojin

In order to prevent climate change caused by recent abnormal temperature phenomena, goals are being set to reduce greenhouse gases worldwide. Each country is also implementing various policies to reduce carbon. In the domestic water supply sector, a lot of effort is being made to reduce energy in line with this national policy stance. However, energy saving is not well achieved compared to other industrial sectors. This is because it is a water purification plant that produces 'water', which is an essential industrial material, so a stable water supply is the top priority. In addition, there are 161 local governments (water service providers) and K-water, a wide-area water supply service provider. Another reason is that water service providers has different conditions and energy consumption patterns. The purpose of this project is to first classify many business operators into 4~5 groups, and to present optimized energy saving measures for each group. 161 local governments were grouped by analyzing the correlation through data such as total cost and power source unit using water supply statistics (Ministry of Environment). The government and K-water have proposed various energy-saving policies, but each local government believes that a policy specific to the region is necessary because it was difficult to apply all of the uniform policies (manual). The purpose is to reexamine various measures such as the application of high-efficiency facilities, optimal operation of facilities, high-efficiency operation, and renewable energy development, which have been continuously promoted by energy saving, and to provide a tool for each local government (waterworks) to choose from while presenting optimal operation plans based on energy diagnosis at each workplace by applying EMS. Of course, the policies presented are just

one example. It does not present the correct answer, and it is important to propose a policy proposal method for energy saving by individual local governments and to discover more efficient and practical energy saving policies through energy diagnosis by business operators in the future.

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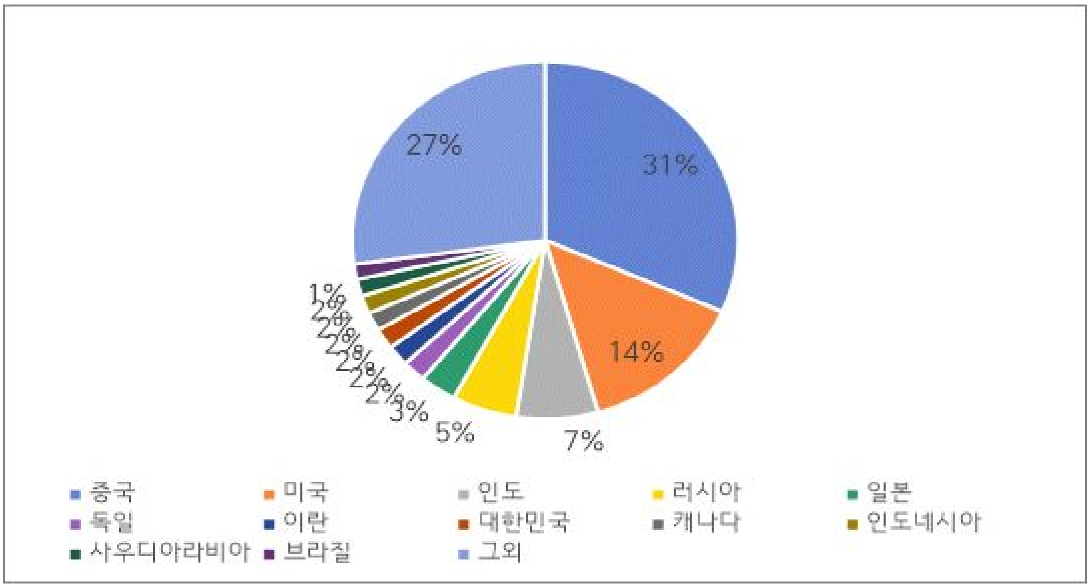
1.1 Global Carbon Neutrality

After the Paris Agreement (2016) and the UN Climate Summit (2019), 121 countries joined the Climate Target Alliance, designating 2050 carbon neutrality as a global goal. In addition, due to the COVID-19 incident, awareness of the seriousness of climate change has expanded, and major countries' carbon neutrality declarations are accelerating. As shown in Figure 1, as of 2021, Korea's carbon dioxide emissions were about 614 million tons, ranking 8th among 29 Organization for Economic Cooperation and Development (OECD) countries.

[Figure 1-1] Global greenhouse gas emissions, including the top 12 countries in greenhouse gas emissions



Nations	China	the United States	India	Russia	Japan	Germany
greenhouse gas emissions	10,398	4,632	2,251	1,795	1,014	652
	31.5%	14.0%	6.8%	5.4%	3.1%	2.0%
Iran	Republic of Korea	Canada	Indonesia	Saudi Arabia	Brazil	Other countries
621	614	546	537	513	450	8,946
1.9%	1.9%	1.7%	1.6%	1.6%	1.4%	27.1%

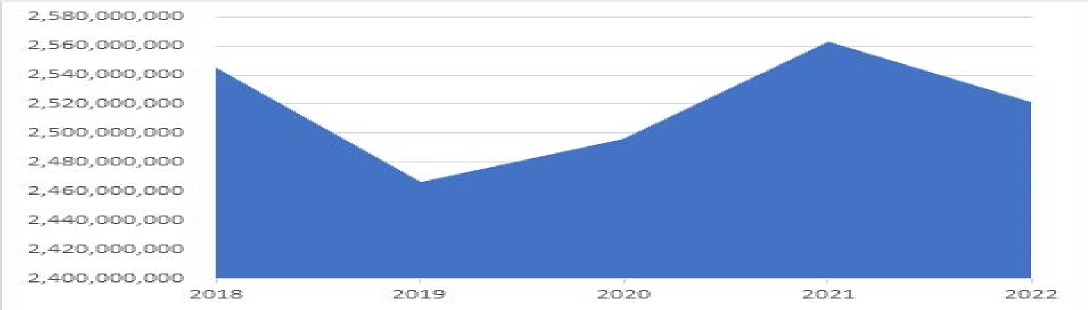
Adoption of the Paris Agreement in 2015, Korea has established a new 2030 reduction target, and in October 2021, it officially declared 2050 carbon neutrality to the international community and raised the 2030 National Greenhouse Gas Reduction Goal (NDC) by reducing it by 40% compared to the peak emission point of 2018. Although the period to reach 2050 carbon neutrality is running out, it is unlikely that Korea, which is mainly focused on industries that emit a lot of greenhouse gases such as automobiles, shipbuilding, petrochemicals, and semiconductors, will be able to make a drastic reduction without a structural transition overall. Action plans for these carbon-neutral goals should be established in various domestic and industrial fields.

Through a cabinet meeting in July 2022, the government set energy demand efficiency as the direction of the government's energy policy. The goal was to promote demand efficiency innovation in three major areas: industry, building, and transportation. In this project, energy saving in the industrial field, especially the water supply sector, was considered. The water supply sector is an essential industrial field for producing water in Korea, and electricity supply is essential. It is intended to propose a plan to reduce carbon emissions by reducing the amount of electricity used in Korean waterworks. As of 2021, electricity used by domestic waterworks sites was 2,562,897 GWH, accounting for about 0.6% of electricity used in Korea. Although it does not account for a large proportion, it is not a very small value to reduce carbon emissions. Among the national greenhouse gas reduction goals (NDCs) set by the government in 2030, the industrial sector goal is to reduce by about 14.5% compared to the base year 2018. Plans are being made to lower the amount from 260.5 million tons CO2eq to 222.6 million tons CO2eq.

1.2. Current status of domestic water supply and need to manage electricity usage

The domestic water supply consists of 161 local water supply operators and K-water. As of 21, domestic power consumption and charges are 2,562,897 GWH, which is on the rise every year.

[Figure 1-2] Power consumption status of water supply over the last 5 years



Of course, the biggest reason is the increase in electricity cost due to the recent rise in crude oil prices around the world, such as the war in Ukraine, but more importantly, there is no management plan for electricity usage and each workplace has not felt the need to save money.

Stakeholders related to waterworks sites were investigated as to why it was difficult to reduce power costs. Stakeholders include the government (central and local governments), business operators, K-water, and citizens, and most of them recognized that water was essential, forcing them to use a lot of electricity. From the operator's point of view, 161 operators nationwide with various characteristics said that the uniform power consumption reduction policy proposed by the government was difficult to apply to individual sites due to various conditions.

[Table 1-1] Many stakeholders' opinions on energy saving

Stakeholders	Opinion	Role
Government	Difficulty in achieving carbon neutrality targets Due to the large number of individual water supply companies (161), uniform management is difficult	Strong commitment to cost-cutting government policy
water supplier	High electricity bills for tap water production costs Advanced facilities such as the introduction of advanced water treatment water purification plant Lack of operator expertise	Establishment of various manuals professional training needs/implementation
k-water	So far, many energy-saving policies need to be realized	As a company specializing in water management, it plays a leading role such as consulting
the public	I hope the cost of producing tap water will be lowered and the price of water will be lowered	Changes in perception of water (such as water-saving)

* Refer to the data of '22 self-survey (23 local governments) and establishment of electricity cost reduction measures (Ministry of Public Administration and Security, '18)

2. Research questions and methods

This study aims to classify 161 waterworks sites nationwide with various domestic characteristics by type and suggest various ways to save energy according to the type by reflecting the opinions of various stakeholders.

1) Type classification of individual water service providers

161 water supply companies nationwide with various characteristics are classified into 4 or 5 groups. Water supply statistics (Ministry of Environment) are used to classify them by type through water treatment method, general cost, power consumption per unit production amount, and water supply population data.

2) Consider ways to save various energy proposed in Korea.

3) It is selectively presented so that energy saving measures can be applied for each classified type.

4) It aims to strengthen the professionalism of operators through manualization of energy-saving measures and professional training.

The results of this study according to the above procedure are thought to be used as data that can implement energy saving in the practical aspect of the workplace.

3. Classification of waterworks site types

3.1 Classification method

There are various cases of classifying waterworks sites by type. The reason for classifying many business operators is that their characteristics vary. In fact, the Ministry of Environment and the Ministry of Public Administration and Security, which conduct evaluation of waterworks operators, are classified and evaluated by the types of waterworks operators.

[Table 3-1] Evaluation method of government waterworks (type classification)

Sortation	Evaluation	Type classification	Criteria for Type Classification
Ministry of Environment	Evaluation of Waterworks Operations Management Status	7 Groups	Water Supply Population, Metropolitan Water Supply Standards
Ministry of Public Administration and Security	Management evaluation of directly managed companies	7 Groups	Population, financial independence, population growth rate, etc

Based on these cases, this study reclassifies the types into measures specialized in energy saving measures. Factors that classify the types of water supply companies vary. In order to classify each business site into similar characteristics, it is necessary to find important factors related to energy saving. The information disclosed in the water consumption statistics published annually by the Ministry of Environment includes 1) general cost 2) electricity consumption per unit production 3) water treatment method 4) energy independence rate 5) water production volume 6) water supply population 7) water purification plant format, which is an important factor in classifying types. The table below shows the factors necessary to classify the types, and the reasons are as follows.

[Table 3-2] Key indicators in water supply statistics and reasons for selection

key indicators	Indicator Description	Reasons for selection
Total cost	Cost (circle) required to produce a ton of water	Proportionate to power usage (high correlation)
Power supply unit	Power required to produce one ton of water (kWh)	Proportionate to power usage (high correlation)
water supply population	the relevant population in the waterworks establishment	Determining the size of the waterworks office and determining the size of the budget
Energy independence rate	% of total electricity usage to cover renewable energy	Efforts to Improve Renewable Energy

The selected main indicators show the following characteristics.

○ Total cost (KRW/m^3)

The total cost is the cost (in won) required to produce one ton of tap water. High overall cost means a high cost and a high energy consumption.

○ Power supply unit (kWh/ton)

The power unit is the amount of power consumed to produce one ton of water. High power unit means a lot of energy is consumed, and low means efficient. It is a very direct indicator in evaluating energy saving for individual water service providers.

○ water treatment method

The water treatment method refers to a method of a water purification plant that produces purified water. Recently, a membrane (RO) type water purification plant that consumes high energy, such as advanced water treatment, has been introduced to supply clean water, and a lot of energy is consumed. Therefore, you need to know the water treatment method of individual waterworks providers to present energy saving measures accordingly.

○ Energy independence rate (%)

The energy independence rate refers to the ratio of renewable energy to the amount of power used in the workplace. The higher the energy independence rate, the lower the amount of power consumed, the more carbon-neutral the goal can be achieved. Renewable energy referred to here includes solar power, solar power, hydrothermal power, and wind power.

Correlation was analyzed to examine the adequacy of the additionally reviewed indicators. For the correlation, the CORREL function of the Excel program was used. The degree of correlation between the two ranges is expressed as values of ?1 and +1 as a numerical value, and a + value means that the two variables have a correlation.

Correlation coefficient correlation

| 0.9 to 1 | Very strong correlation

| 0.7~0.9 | Strong correlation

| 0.4~0.7 | Correlated

| 0.2~0.4 | Weak correlation

| 0.2 to 0 | No correlation

The correlation between the selected indicators and energy consumption of each workplace was analyzed, and it can be seen that there is a positive correlation. Of course, there may be an error in the data to classify and group 161 water supply companies only into these four indicators. However, for the purpose of energy saving, classification using the correlation coefficient between the power consumption index and other indicators is of great significance, and classification of types in a more precise manner will need to be studied in the future.

[Table 3-3] Correlation between indicators and energy consumption

Sortation	Correlation (compared to power usage)	Remark
Total cost	79.3%	a strong correlation
Power supply unit	82.7%	a strong correlation
water supply population	54.3%	Correlated
energy independence rate	23.5%	a weak correlation

161 water supply companies nationwide were classified through the selected factors. Four indicators were used to score out of 40. It was calculated out of 10 points for each indicator, and 10 points were imposed if it was above the national average for each indicator, and 5 points were given if it was below the national average. There may be errors because it is a simple dichotomous method of giving scores, but in this study, 161 water companies nationwide are classified from about 4 to 5, so there is no big problem in classifying the types of dichotomous score calculations.

[Table 3-4] Classification methods

Indicators	Classification method	Scoring
Total cost	Above and below the national average	10 or 5 points
Power supply unit	Above and below the national average	10 or 5 points
water supply population	Above and below the national average	10 or 5 points

energy independence rate	Above and below the national average	10 or 5 points

Since the lower the cost, the lower the cost, the general cost, and the power unit, 10 points were calculated if it was below the national average, and 5 points were calculated if it was above the national average. The higher the water supply population, the larger the water supply business, so it is 10 points for above average and 5 points for below average. The higher the energy independence rate, the higher the effort to improve energy saving, so it was calculated as 10 points for above the national average and 5 points for below. The score calculation results of 161 business operators nationwide are as follows.

3.2 Type Classification Assessment

[Table 3-5] Evaluation results

Sortation	Total cost		Power supply unit		water supply population		Energy independence rate		total score
	KRW/m^3	score	kWh/m^3	score	Population (thousand)	score	%	score	
Seoul	731	10	0.23	5	9,911	10	9.5	10	35
Busan	1,016	10	0.14	10	3,422	10	2	5	35
Daegu	818	10	0.31	5	2,445	10	4	10	35
Incheon	804	10	0.2	10	2,981	10	1.3	5	35
Gwangju	730.8	10	0.03	10	1,470	10	0	5	35
Daejeon	597.9	10	0.1	10	1,479	10	12.7	10	40
Ulsan	1,001	10	0.43	5	1,139	10	1.2	5	30
Sejong	976.9	10	0	10	353	10	0	5	35
Suwon City	682	10	0.21	10	1,221	10	3.3	5	35
Seongnam City	658.4	10	0.31	5	955	10	0	5	30
Uijeongbu City	871.6	10	0.06	10	463	10	0	5	35
Anyang City	692.2	10	0.1	10	556	10	2.2	5	35
Bucheon City	653.5	10	0.15	10	842	10	9.1	10	40
gwangmyung City	700.5	10	0.09	10	302	5	0	5	30

Pyeongtaek City	990	10	0.5	5	560	10	0	5	30
Dongducheon City	966.7	10	0.24	5	95	5	0	5	25
Ansan City	665.5	10	0.14	10	705	10	46.6	10	40
goyang City	675.7	10	0	10	1,087	10	0	5	35
Gwacheon City	1,304	10	0.11	10	62	5	4	10	35
guri City	825.4	10	0.3	5	198	5	0	5	25
Namyangju City	857.6	10	0.29	5	700	10	4.8	10	35
Osan City	818.4	10	0	10	238	5	0	5	30
Siheung	634.7	10	0.15	10	532	10	0	5	35
Gunpo	844.7	10	0.07	10	280	5	0	5	30
Uiwang	1,010	10	0.09	10	164	5	3.2	5	30
Hanam City	542	10	0.06	10	291	5	11	10	35
Yongin City	755.5	10	0.3	5	1,084	10	0	5	30
Paju City	839.3	10	0.12	10	471	10	0	5	35
Icheon City	1,282	10	0.06	10	223	5	0	5	30
Anseong City	1,390	10	0.08	10	184	5	0	5	30
Gimpo City	884	10	0.3	5	474	10	0	5	30
Hwaseong-si	877	10	0	10	893	10	0	5	35
Gwangju City	765.9	10	0.1	10	364	10	0	5	35
Yangju City	1,147	10	0	10	232	5	0	5	30
Pocheon City	1,794	5	0.45	5	144	5	0	5	20
the city of Yeoju	1,750	10	1.89	5	104	5	0	5	25
Yeoncheon County	1,782	5	0.68	5	43	5	0	5	20
Gapyeong County	2,601	5	0.24	5	52	5	0	5	20
Yangpyeong County	1,765	10	0.43	5	97	5	26.3	10	30
Chuncheon City	1,100	10	0.12	10	281	5	0	5	30
Wonju City	1,127	10	0.29	5	341	10	0	5	30

Gangneung City	1,073	10	0.08	10	204	5	10.9	10	35
Dong hae City	1,334	10	0.27	5	91	5	73.6	10	30
Taebaek City	2,963	5	0.25	5	42	5	0	5	20
Sokcho City	1,014	10	0.05	10	83	5	0	5	30
Samcheok City	2,579	5	0.52	5	60	5	0.9	5	20
Hongcheon County	3,060	5	0.13	10	54	5	3.9	10	30
Hoengseong County	3,030	5	0	10	39	5	0	5	25
Yeongwol County	4,523	5	0.52	5	30	5	0	5	20
Pyeongchang County	5,833	5	0.62	5	34	5	0	5	20
Jeongseon County	3,255	5	0.19	10	30	5	8.9	10	30
Cheorwon County	2,230	5	0.05	10	42	5	0	5	25
Hwacheon County	8,030	5	0.17	10	17	5	0	5	25
Yanggu County	1,300	10	0.11	10	18	5	0	5	30
Inje County	3,031	5	0.32	5	27	5	0	5	20
Goseong County	3,414	5	0.14	10	25	5	10.7	10	30
Yangyang County	2,303	5	0.04	10	26,201	5	0	5	25
Cheongju City	782	10	0.21	10	833	10	5.6	10	40
Chungju City	1,114	10	0.28	5	202	5	4.4	10	30
Jecheon City	1,671	10	0.14	10	127	5	0	5	30
Boeun County	1,820	5	0.02	10	17	5	0	5	25
Okcheon County	2,871	5	0.52	5	45	5	0	5	20
Yeongdong County	3,433	5	0.23	5	38	5	0	5	20
Jeungpyeong County	1,368	10	0	10	37	5	0	5	30
Jincheon County	971.3	10	0.13	10	82	5	103.1	10	35
Goesan County	2,738	5	0.05	10	28	5	0	5	25

Eumseong County	1,085	10	0	10	91	5	0	5	30
Danyang County	2,826	5	0.56	5	22	5	0	5	20
Cheonan City	953.2	10	0.49	5	656	10	0	5	30
the city of Gongju	1,941	5	0.06	10	93	5	9.8	10	30
Boryeong City	2,319	5	0.04	10	92	5	0	5	25
Asan City	1,021	10	0	10	324	10	0	5	35
Seosan City	1,558	10	0	10	176	5	0	5	30
Nonsan City	1,920	5	0	10	104	5	0	5	25
Gyeryong City	1,120	10	0	10	41	5	0	5	30
Dangjin City	1,287	10	0.01	10	149	5	0	5	30
Geumsan County	2,260	5	0	10	43	5	0	5	25
Buyeo County	2,528	5	0	10	57	5	0	5	25
Seocheon County	2,229	5	0	10	46	5	0	5	25
Cheongyang County	1,880	5	0.08	10	14	5	0	5	25
Hongseong County	2,101	5	0	10	94	5	0	5	25
Yesan County	1,530	10	0.5	5	63	5	0	5	25
Taean County	3,477	5	0	10	61	5	0	5	25
Jeonju City	898.5	10	0	10	665	10	0	5	35
Gunsan City	1,166	10	0	10	271	5	0	5	30
Iksan City	941	10	0.14	10	285	5	0	5	30
the city of Jeongeup	1,769	5	0	10	109	5	0	5	25
Namwon City	2,000	5	0.35	5	76	5	0	5	20
Gimje City	2,002	5	0	10	84	5	0	5	25
Wanju County	2,432	5	1.5	5	81	5	0	5	20
Jinan County	3,400	5	0.67	5	21	5	0	5	20
Muju County	2,221	5	0.15	10	20	5	0	5	25

Jangsu County	2,005	5	0	10	20	5	0	5	25
Imsil County	2,114	5	0.64	5	25	5	0	5	20
Sunchang County	1,352	10	0.2	10	23	5	0	5	30
Gochang County	2,020	5	0	10	55	5	0	5	25
Buan County	1,836	5	1.03	5	52	5	0	5	20
Mokpo City	906.2	10	0.03	10	226	5	0	5	30
Yeosu City	1,339	10	0.07	10	272	5	0	5	30
Suncheon City	998.7	10	0.05	10	277	5	0	5	30
Naju City	1,840	5	0	10	100	5	0	5	25
Gwangyang City	1,038	10	0.19	10	135	5	39.3	10	35
Damyang County	1,959	5	0.37	5	39	5	0	5	20
Gokseong County	1,025	10	0.36	5	24	5	0	5	25
Gurye County	1,641	10	0.53	5	20	5	0	5	25
Goheung County	1,477	10	0.34	5	50	5	0	5	25
Boseong County	1,125	10	0.28	5	25	5	37.4	10	30
Hwasun County	2,798	5	0.23	5	57	5	0	5	20
Jangheung County	1,800	5	0	10	35	5	0	5	25
Gangjin County	1,093	10	0.07	10	24	5	0	5	30
Haenam County	1,153	10	0.35	5	56	5	0	5	25
Yeongam County	2,114	5	0.08	10	53	5	0	5	25
Muan County	1,269	10	0	10	87	5	0	5	30
Hampyeong County	1,867	5	0.42	5	31	5	0	5	20
yeong gwang County	2,289	5	0.16	10	51	5	0	5	25
Jangseong County	1,226	10	0.03	10	42	5	0	5	30
Wando County	3,271	5	0.48	5	50	5	0	5	20

Jindo County	1,800	5	0.7	5	32	5	0	5	20
Sinan County	2,123	5	1.29	5	35	5	0	5	20
the city of Pohang	1,067	10	0.2	10	487	10	0	5	35
Gyeongju-si	1,644	10	0.29	5	247	5	0	5	25
Gimcheon City	797.9	10	0.3	5	126	5	0	5	25
Andong City	1,653	10	0.05	10	149	5	0	5	30
Gumi City	679.8	10	0.08	10	420	10	0	5	35
the city of Yeongju	1,951	5	0.33	5	93	5	0.5	5	20
Yeongcheon City	2,640	5	0.03	10	100	5	99.9	10	30
Sangju City	2,63	5	0.32	5	74	5	0	5	20
Mungyeong City	1,487	10	0.17	10	67	5	0	5	30
Gyeongsan City	1,223	10	0.18	10	272	5	6.4	10	35
gum wi city	2,714	5	0.3	5	20	5	0	5	20
Uiseong County	5,527	5	0.63	5	48	5	0	5	20
Cheongsong County	1,690	10	0.5	5	19	5	0	5	25
Yeong yang County	2,334	5	0.15	10	15	5	0	5	25
Yeongdeok County	2,632	5	0.22	10	35	5	0	5	25
Cheongdo County	1,001	10	0	10	35	5	0	5	30
Goryeong County	1,044	10	0.35	5	32	5	0	5	25
Seongju County	3,593	5	0.07	10	35	5	0	5	25
Chilgok County	1,417	10	0	10	112	5	0	5	30
Yecheon County	2,996	5	0.32	5	50	5	0	5	20
Bonghwa County	2,793	5	0.26	5	21	5	0	5	20
Uljin County	3,913	5	0.34	5	39	5	0	5	20
Ulleung County	2,638	5	0.29	5	8	5	0	5	20
Changwon	1,147	10	0.27	5	1,036	10	1	5	30

City									
Jinju City	877.3	10	0.04	10	352	10	1.1	5	35
Tongyeong City	1,193	10	0.22	10	130	5	0	5	30
the city of Sacheon	1,267	10	0.1	10	110	5	0	5	30
Gimhae City	1,197	10	0.1	10	550	10	0.6	5	35
Miryang City	2,087	5	0.07	10	92	5	0	5	25
the city of Geoje	1,116	10	0.18	10	246	5	0	5	30
the city of Yangsan	1,164	10	0.2	10	352	10	0	5	35
Uiryeong County	2,881	5	0	10	20	5	0	5	25
Haman County	2,030	5	0.53	5	65	5	2	5	20
Changnyeong County	2,168	5	0.12	10	63	5	20.8	10	30
Goseong County	2,195	5	0	10	42	5	0	5	25
Namhae County	1,964	5	0.18	10	33	5	0	5	25
Hadong County	1,294	10	0.04	10	27	5	0	5	30
Sancheong County	2,400	5	0.78	5	16	5	6.9	10	25
Hamyang County	2,466	5	0.35	5	25	5	7.8	10	25
Geochang County	1,976	5	0.08	10	49	5	0	5	25
Hapcheon County	3,070	5	0.24	5	25	5	0	5	20
Jeju Island	1,066	10	0.27	5	526	10	11.7	10	35

3.3 Type classification results

The results of classifying the types based on the evaluation results are as follows. 161 water service providers (local governments) were divided into 4 groups, with 33 in Group 1, 51 in Group 2, 45 in Group 3, and 32 in Group 4.

[Table 3-6] Results of water supply business classification

Sortation	Local government (water service provider)	Remarks
Group 1 (33)	Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Sejong, Suwon, Uijeongbu, Anyang, Bucheon, Ansan, Goyang, Namyangju, Siheung, Hanam, Paju, Hwaseong, Gwangju, Gangneung, Cheongju, Asan, Jeonju, Gwangyang, Pohang, Gumi, Gyeongsan, Jinju, Gimhae, Yangsan, Jeju, Jeju	35 to 40 points
Group 2 (51)	Ulsan, Seongnam, Gwangmyeong, Pyeongtaek, Osan, Gunpo, Uiwang, Yongin, Icheon, Anseong, Gimpo, Yangju, Yangpyeong, Chuncheon Wonju, Donghae, Sokcho, Hongcheon, Jeongseon, Yanggu, Goseong, Chungju, Jecheon, Jeungpyeong, Eumseong, Cheonan, Gongju, Seosan, Gyeryong, Dangjin, Gunsan, Iksan, Sunchang, Mokpo, Yeosu, Suncheon, Bosung, Gangjin, An, Andong, Yeongcheon, Mungyeong, Cheongdo, Chilgok, Changwon, Tongyeong, Sacheon, Geoje, Changnyeong, Changnyeong, Hadong	30 to 35 points
Group 3 (45)	Dongducheon, Guri, Yeoju, Hoengseong, Cheorwon, Hwacheon, Yangyang, Boeun, Goesan, Boryeong, Nonsan, Geumsan, Buyeo, Seocheon, Cheongyang, Hongseong, Yesan, Taean, Jeongeup, Gimje, Muju, Jangsu, Jangchang, Naju, Gokseong, Gurye, Jangheung, Haenam, Yeongam, Yeonggwang, Gyeongju, Gimcheon, Cheongsong, Yeongyang, Yeongdeok, Goryeong, Seongju, Miryang, Uiryeong, Goseong, Namhae, Sancheong, Hamyang, Geochang	25 to 30 points
Group 4 (32)	Pocheon, Yeoncheon, Gapyeong, Taebaek, Samcheok, Yeongwol, Pyeongchang, Inje, Okcheon, Yeongdong, Danyang, Namwon, Wanju, Jinan, Imsil, Buan, Damyang, Hwasun, Hampyeong, Wando, Jindo, Sinan, Yeongju, Sangju, Gunwi, Uiseong, Yecheon, Bonghwa, Uljin, Ulleung, Haman, Hapcheon	a score of 25 or less

From the selected results, it can be seen that they are classified into similar types of water supply businesses. Metropolitan cities/ big cities/small cities, that is, similar local governments in terms of scale, were classified, and it can be seen that they are grouped among small local governments.

The characteristics of the group are summarized as follows.

○ Group 1: A large-scale business site with a low power supply unit and a low overall cost (centred by special metropolitan cities and municipal governments)

○ Group 2 is a medium-sized business with slightly lower power supply and overall costs than average (centred by municipalities)

○ Group 3 is a medium-sized workplace with slightly higher power source unit and overall cost than average (centred by municipal and county-level local governments)

○ Group 4 is a small business with higher than average power source unit and total cost (centred by county-level local governments)

4. As is analysis : the existing Energy-saving measures of each type of waterworks sites

The energy saving policies reviewed and proposed by the government (Ministry of Environment, etc.) and K-water and the energy saving measures applied at home and abroad are as follows.

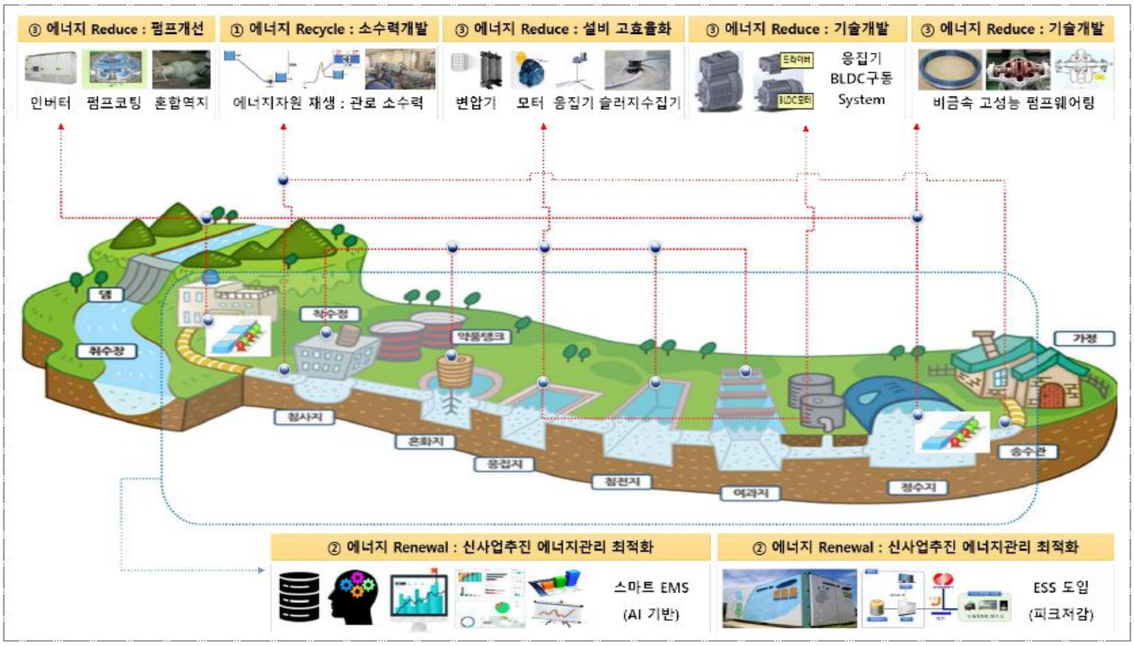
First, there are ways to replace low-efficiency devices with high-efficiency devices in terms of facilities, application of new technologies that consume low power through technological development, and energy management systems that can manage overall energy in the workplace.

The Ministry of Public Administration and Security distributed the [Local Waterworks Power Cost Reduction Manual] in 2017, and the Ministry of Environment also announced various energy saving policies. In particular, K-water has promoted various energy saving policies since 2013, centering on the metropolitan waterworks site. Nevertheless, the amount of electricity consumed to produce one ton of water over the past 10 years is 0.184 kWh, which is gradually increasing.

[Figure 4-1] Current status of electricity source units at metropolitan waterworks sites over the past 10 years

In this study, various energy saving measures are summarized and presented. The figure below is an energy saving plan reviewed and applied by K-water, and the main contents are as follows.

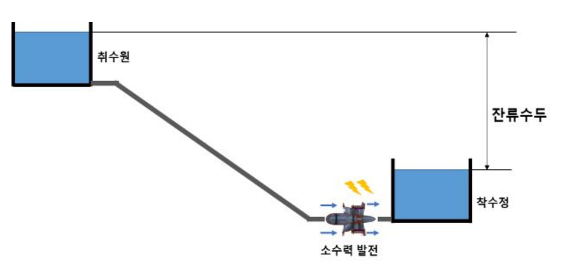
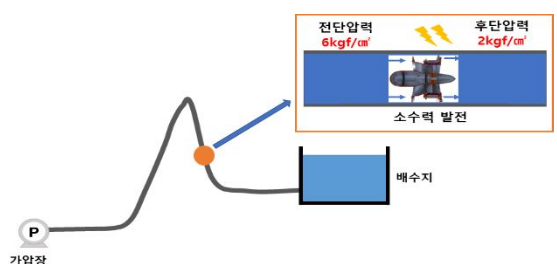
[Figure 4-2] Energy saving measures at waterworks sites (example)



4.1. Development of Waterworks Small Hydroelectric Power

It can be applied to places where economic feasibility and installation site are secured among places where unused pressure energy can be used for pipes at the waterworks site. Small hydroelectric power generation through reuse of unused energy is very ideal in terms of recycling energy. This is because if it generates power using local energy and the generated power is used at the workplace, it may not consume that much power.

[Figure 4-3] A plan for the development of small hydroelectric power

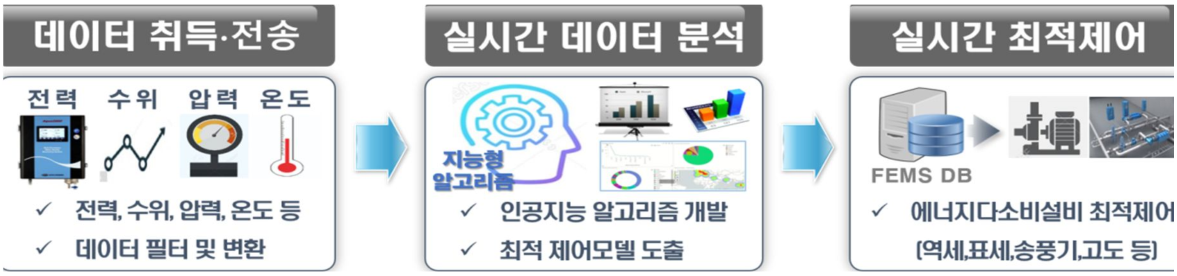
Business inflow side	Pressure relief valve on the pipe
	

K-water has developed and operated small hydroelectric power (2.0 MW) in eight metropolitan water facilities, and is reducing carbon emissions by about 4,000 tCO_2 through annual 8.4 GWh power generation. If we investigate and expand small hydroelectric power installation sites across the country, there will be more carbon emissions effects.

4.2. AI based EMS(Energy management system)

It is a plan to establish an optimal energy management system for monitoring, analyzing, and controlling the amount of power in real-time with a big data-based AI algorithm. Power is always consumed in the workplace. There are various measures, such as monitoring the power consumed in real time to turn off unnecessary power and stopping the pump if the efficiency is low. In addition, for pumps that consume a lot of power at waterworks sites, it is possible to establish an efficient operation plan.

[Figure 4-4] Principles of AI-based EMS construction



A domestic application case is an EMS case installed by K-water in a Geumsan water purification plant in 2014. There are cases of saving about 3% of energy and about 30 million won per year through real-time energy management and automatic pump control.

[Figure 4-5] EMS Construction Case

[Table 4-1] Energy saving performance of K-water Geumsan Water Purification Plant

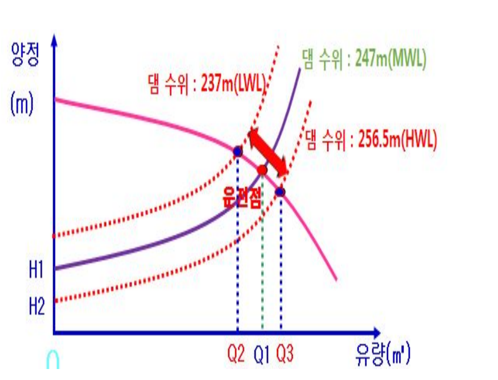
Power supply unit	Unit	medium to long term	2013	2014		remarks
		Goals	Performance	Goals	Performance	
Total	(kWh/㎥)	0.1978	0.2187	0.2059	0.2123	Save 3%
a water purification plant	(kWh/㎥)	0.2455	0.2601	0.2471	0.2496	Save 4%
a pump station	(kWh/㎥)	0.1544	0.1848	0.1755	0.1795	Save 3%

4.3. Operation of the pump in the pressurization plant(water intake plant)

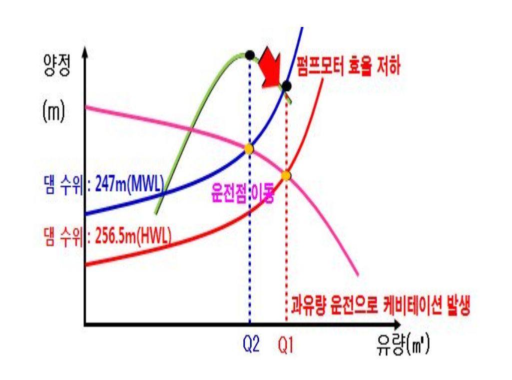
The place that consumes the most electricity (energy) at the waterworks site is the pressurization plant (water intake plant). This is because a large-capacity pump is installed to supply water to the water purification plant. The table below is an example of the optimal frequency operation of the pump through EMS as the current status of the pressurization pump at the water intake plant of the Geumsan Water Purification Plant operated by K-water.

[Figure 4-6] Schematic diagram of Geumsan Water Purification Plant and Pressurization Plant System

[Figure 4-7] Changes in pump operation curves



Pump operation curve change



Problems with Pump Operation Point Variation

VVVF (inverter) is a device that controls the speed of a three-phase agricultural induction motor, consisting of a converter unit that converts three-phase commercial power, which is alternating current, into direct current, and an inverter unit that converts and outputs the direct current into alternating current of variable voltage and frequency. These inverters are used to operate the in-line pressurization plant pump at waterworks, and their efficient operation plan is determined by various conditions. It is possible to suggest an optimal frequency operation plan according to the pump suction pressure in the in-line pressurization plant. In addition, it is intended to find an optimal efficient operation plan within the range of stable water supply in the waterworks plant, and to suggest an optimal energy use plan for the waterworks plant.

The design capacity of the pump for the manual pressurization field is 14(7)m3/min of inflow flow rate and 65m of required amount. However, the pump suction pressure in the pressurization field varies according to the change in the water level of Yongdam Dam, which is the water intake source of the manual pressurization field, and the water intake point of the water intake tower, and as a result of analyzing the water level data for the past year, it is 3-5kgf/cm2, and 45-80% of the required amount of pump at the time of design (65m). This is the main reason why the pump's optimal efficiency operation point changes every time.

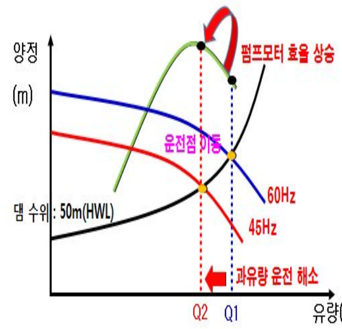
[Table. 4-2] Operation status of the pressure pump in the manual pressure tank

Operating period	Pump pressure (kgf/cm^2)	frequency (Hz)	runoff flow rate (m^3)	the amount of electricity (kWh)	Power supply unit (kWh/m3)
2012.06 ~2013.12	3~5	60	1350	245	0.1832

An economical power source unit operation plan was presented by collecting data (flow rate, power consumption, discharge pressure) at the shift operation (frequency fluctuation) point by dam level and supply flow rate. By presenting the economic pump operation frequency to the EMS (energy management system), it is to facilitate optimal operation for all workers. This is to find an optimal economic operation point according to the suction pressure of the pump by changing the frequency of the inverter of the frequency pressurizer pump, and it is effective in preventing the water supply accident in advance of the water supply accident by preventing the cavitation phenomenon caused by the operation of the excess flow rate by moving the pump operation point.

[Figure 4-8] Operation of the optimal operation plan for the pressure pump of the manual pressurizer

Development of a program for deriving optimal driving plans



Optimal pump motor operation (60Hz → 45Hz)

Through the optimal operation of the water pressure pump, the power source unit of the water pressure field showed an improvement of about 3% (0.1848 → 0.1795 kWh/m3, 3.8 million won/year).

[Table. 4-3] An Energy Saving Case for the Optimal Operation of a Manual Pressure Plant

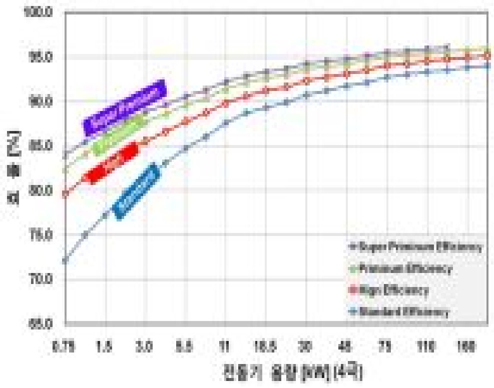
the amount of supply (m³/day)	Pressure (kg/cm²)	Originally (no frequency change)			Change (optimal frequency operation)			energy saving (kWh/년)	Savings (KRW 1,000/year)
		Frequency (Hz)	Operating time	the amount of electricity (kW)	Frequency (Hz)	Operating time	the amount of electricity (kW)		
16,132	5	60	21	247	45	28	178	35,962	3,839
	4	60	22	245	50	26	201		
	3	60	23	240	55	24	220		

4.4. Facilities of high efficiency intake plant

Since 2009, "energy reduction plan" has been established and promoted in accordance with national policy, but the introduction rate of high-efficiency facilities for low-pressure motors, transformers, and lighting facilities is low. It is possible to reduce the energy consumed by introducing high-efficiency facilities for low-pressure motors, transformers, and lighting facilities. It is to replace old power and water treatment facilities with high-efficiency facilities and technology development products. As of 2021, the introduction rate of high-efficiency facilities of major facilities in water purification plants, such as motors and transformers, is 41% for motors and 53% for transformers, and energy can be saved by replacing them with high-efficiency facilities for facilities that have a useful life.

[Figure 4-9] High efficiency motor and pump efficiency curve

<High efficiency motor>



<High efficiency motor efficiency curve>

In the case of the OO water purification plant, the existing motor (90.5% efficiency) was replaced with a 95% efficiency motor, saving about 7 million won in annual power costs.

[Table. 4-4] A Case of Saving the Construction of High-Efficiency Motor Vehicles

Sortation	Existing	improvement
Motor efficiency	90.5%	95.0%
electricity cost	160 million won	153 million won
Power supply unit	0.1754kwh/㎥	0.1677kwh/㎥(4.6% 개선)
Savings	-	about 7 million won/년
investment costs		200 million won

4.5. Reduction of power costs through optimal operation

4.5.1. Optimal operation of drainage by time zone

The domestic electricity rate structure varies. In particular, the electricity rate system has different unit prices by season and by time. 1) By season, it is divided into summer/winter/spring and autumn, and 2) the unit price is different due to light/medium/maximum load during the day. For example, the table below is an industrial power (A) rate system with a contract power of less than 300 kW, and it can be seen that the unit price varies by season and by time.

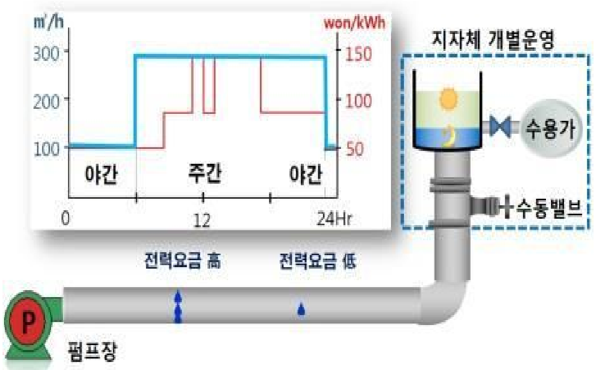
Here, the maximum load is 11:00 to 12:00, 13:00 to 18:00, and the other hours are intermediate load times.

[Figure 4-10] Industrial Power (A) Rate Table (KEPCO)

Classfication		Basic price (won/kw)	price (won/kWh)			
			time	summer(6~8)	spring,fall	winter(11~2)
A	1	6,490	경부하	87.2	87.2	94.6
			중간부하	113.0	92.0	111.5
			최대부하	146.5	111.2	140.9
	2	7,470	경부하	82.3	82.3	89.7
			중간부하	108.1	87.1	106.6
			최대부하	141.6	106.3	136.0
B	1	6,000	경부하	84.0	84.0	91.2
			중간부하	111.6	90.6	109.2
			최대부하	145.4	109.4	137.9
	2	6,900	경부하	79.5	79.5	86.7
			중간부하	107.1	86.1	104.7
			최대부하	140.9	104.9	133.4

Energy can be reduced if electricity is saved as much as possible during the maximum load time when the unit price of electricity is high. The pump is operated as much as possible during the light load time (22:00 to 08:00) when the unit price is low, water is produced and sent to the consumer, and the operation is stopped during the maximum load time. Energy can be saved by intensively increasing the water level at night by using the residence time of the water distribution (purified resin) and stopping the operation during the maximum load time.

[Figure 4-11] Comparison of operation of water distribution (regular water distribution)

<table>
<tr><th>Existing (intensive weekly supply)</th><th>Improvement (utilization of drainage residence time)</th></tr>
<tr><td>Simple facility operation method according to customer usage</td><td>Operation method in consideration of day and night electricity rates, water distribution residence time, etc</td></tr>
<tr><td>
</td><td>
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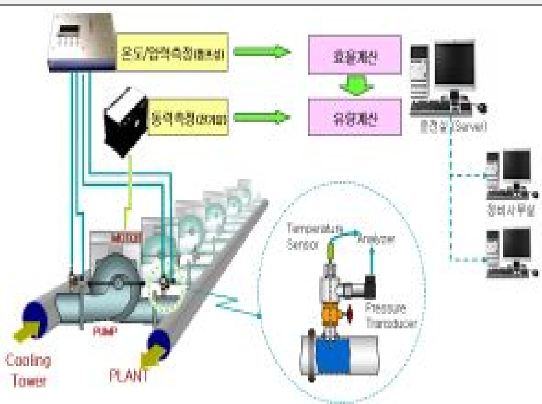
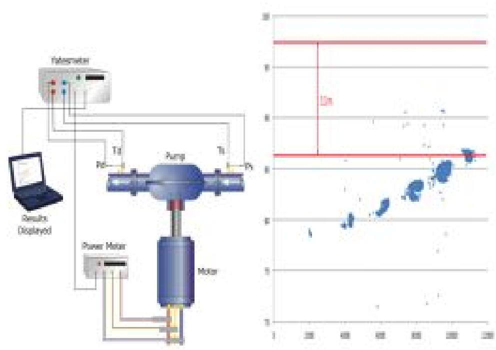
4.5.2. High efficiency operation of the pump

The efficiency of the pump changes from time to time depending on the period of use and the purpose of use. In particular, since the pump operates 24 hours a day at the waterworks site, the efficiency of the pump is very important in terms of energy saving. Therefore, in the case of a pump whose useful life has elapsed or its performance has rapidly deteriorated, the efficiency of the pump is measured through performance diagnosis.

[Figure 4-12] Pump performance diagnosis flow chart

<table>
<tr><th>Diagnosis of water intake and water pressurization pump</th><th>Comparison of rating and operational positivity</th></tr>
<tr><td>
</td><td></td></tr>
</table>

Energy may be saved by selecting the operation priority of the pump and operating the pump with high efficiency first. The pump with the lowest power source unit (kWh/m3) for each pump expiration is operated first. Through the EMS (Energy Management System), the supply flow rate (m3), power usage (kWh), and power source unit (kWh/m3) by pump exhalation are searched, and the operation ranking is adjusted for individual or pump combinations so that the pump with the lowest power source unit (kWh/m3) operates first. Frequently operated pumps will be less efficient, and if the pump is replaced by periodically measuring the efficiency of the pump through EMS, energy can be saved through the high-efficiency operation management of the waterworks.

4.6. Development of new and renewable energy such as solar power

It is necessary to consider the application of various renewable energy such as solar power generation and hydrothermal energy development on the site of the waterworks. This is to develop eco-friendly energy centered on existing thermal power by innovating the national energy system and introducing renewable energy. In order to be carbon neutral in water purification plants, it is possible to consider developing hydrothermal energy using solar and water temperature differences in water purification plants, producing green corn using renewable energy, and promoting an integrated building BIPV project.

5. To be analysis : the prospective energy saving measures of each type of waterworks site

The various energy saving measures proposed so far are applicable to waterworks sites, and there are many workplaces that are already applied. However, applying all of these consumes a lot of budget and effort, and it will be difficult to apply all of them in reality. As mentioned earlier, operators of waterworks sites want more realistic energy-saving operations. Therefore, in this content, some of the most efficient and appropriate energy saving measures for each classified type are suggested.

For reference, this cannot be the correct answer. However, rather than presenting a manual uniformly, if an optional method is applied in this way, it will be more efficient from the perspective of the operator of the waterworks site, so it is intended to present a methodological aspect. Previously, 161 local governments (water supply companies) nationwide were classified into four groups, and energy saving measures for each classified group would be matched.

First of all, the characteristics of the group are analyzed and the characteristics of energy saving measures are as follows.

[Table. 5-1] Characteristics of Group (Type)

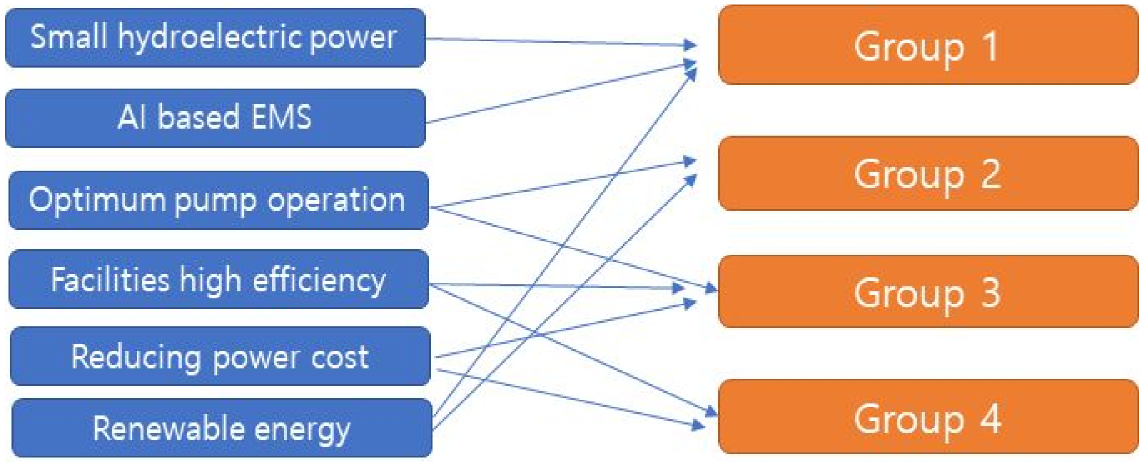
Sortation	Characteristics of the group	Plan for Energy Conservation
Greup 1	a workplace with a low power supply unit and a low overall cost	Advanced energy conservation measures need to be applied, and renewable energy needs to be actively discovered
Greup 2	Workplaces with slightly lower than average power supply unit and overall cost	EMS-based savings through energy status analysis
Greup 3	Workplaces where the unit of power source and overall cost are slightly higher than average	Aggressive application of energy saving cases within budget
Greup 4	Workplaces where the unit of power source and overall cost are slightly higher than average	Basic energy saving measures need to be applied first to workplaces with low budget

[Table. 5-2] Characteristics of energy-saving measures reviewed

Sortation	energy-saving measures	Characteristics			
		input budget	Operational difficulty	Installation period	Effect
1	Waterworks Small Hydroelectric Power Development	A lot	It's easy	It's long	a small amount
2	Building AI-Based EMS	a small amount	the middle	It's short	A lot
3	optimum pump operation	a small amount	It's hard	It's short	A lot
4	Facilities High Efficiency	the middle	It's easy	the middle	the middle
5	Reduce power costs through optimal operation	a small amount	It's easy	It's short	A lot
6	renewable energy development	A lot	the middle	the middle	the middle

First of all, the characteristics of the group are analyzed and the characteristics of energy saving measures are as follows.

[Figure 5-1] Energy saving measures applicable for each group (example)



5.1. Group 1 Energy Saving Measures

The energy status of Group 1 waterworks is as follows.

[Table. 5-3] Group 1 Energy usage, etc

Sortation	Energy consumption(MWh)	Power supply unit(kWh/m3)	Renewable energy generation(MWh)
Group 1 (as of '22)	19,072MWh	0.13	558
Target (5% reduction)	18,119MWh	0.12	586

Group 1 is well managed for energy consumption management, such as power source units. Technologies applicable to these workplaces are the development of small water supply systems and the expansion of renewable energy development. Since many energy saving efforts have already been applied, such as the high efficiency of facilities and the introduction of high efficiency technology development products, a lot of effort is required to reduce more energy by introducing AI-based EMS. The reason for introducing EMS is that AI-based real-time energy management efforts are required to continuously maintain current energy savings. Group 1 waterworks sites may be able to set a goal of reducing energy consumption by 5%, that is, increasing renewable energy generation by 5%.

5.2.2 Group characteristics and energy-saving measures

The energy status of Group 2 waterworks is as follows.

[Table. 5-4] Group 2 Energy consumption, etc

Sortation	Energy consumption(MWh)	Power supply unit(KWh/m3)	Renewable energy generation(MWh)
Group 2 (as of '22)	1,896MWh	0.37	32
Target (5% reduction)	1,706MWh	0.34	35

Group 2 maintains relatively well in managing energy consumption, such as power source units. The technology applicable to these workplaces is to streamline the operation plan based on EMS. The optimal operation of the pump and the high-efficiency operation of the pressurization field (water intake station) pump would be the best alternatives. In addition, replacement of some low-efficiency facilities with high-efficiency facilities should be promoted in a timely manner. Group 2 waterworks sites could set a goal of reducing energy consumption by 10%, that is, increasing renewable energy generation by 5%.

5.3.3 Group characteristics and energy saving measures

The energy status of Group 3 waterworks is as follows.

[Table. 5-5] Group 3 Energy consumption, etc

Sortation	Energy consumption(MWh)	Power supply unit(KWh/m3)	Renewable energy generation(MWh)
Group 3 (as of '22)	1,547MWh	0.42	25
Target (5% reduction)	1,315MWh	0.36	27

Group 3 is a workplace that requires energy consumption management, such as a power source unit. The technology applicable to these workplaces requires high efficiency of facilities in addition to streamlining EMS-based operation plans. In particular, priority energy diagnosis is required for the workplace, and low-efficiency pumps and other electrical facilities need to be replaced immediately. Group 3 waterworks sites may be set with the goal of reducing energy consumption by 15%, that is, increasing renewable energy generation by 5%.

5.4. 4 Group characteristics and energy saving measures

The energy status of Group 4 waterworks is as follows.

[Table. 5-6] Group 4 Energy usage, etc. status

Sortation	Energy consumption(MWh)	Power supply unit(kWh/m3)	Renewable energy generation(MWh)
Group 4 (as of '22)	2,135MWh	0.51	20
Target (5% reduction)	1,708MWh	0.41	21

Group 4 is a workplace that immediately requires energy consumption management, such as power source units. Energy management is not well-managed, and energy savings are required through timely budget input. Group 4 waterworks sites may be set to reduce energy consumption by 20%, that is, increase renewable energy generation by 5%.

6. Conclusion and future research

6.1 Type classification of waterworks sites

Waterworks workplaces of 161 local governments nationwide were classified into four groups. According to the water supply statistics, levels were classified above and below the national average using the general cost, power source unit (kWh/m3), water supply population, and energy independence rate, and were scored. The correlation between the classification index and the reduction of power consumption, which is the goal of this project, was analyzed, and it was confirmed that there was a sufficient positive (+) correlation. Classifying local government water supply businesses with the above four indicators may not be true, but this is only an example as a methodical tool. The government, such as the Ministry of Environment, also classifies them into groups through this type of classification method in grasping the actual conditions/current status of various water service providers, and in consideration of this, energy saving was suggested as a methodology for policy suggestion. It is expected that this method will be of great help in presenting water supply policies nationally. Rather than applying uniform and theoretical simple technologies, it is expected that operators of each workplace will be able to accept policies more realistic if a method that can be introduced so that the parts of each technology can be applied by group (type).

6.2 Introduction and application of various energy-saving policies

Various energy-saving policies such as the domestic government and K-water were proposed. In this project, this policy was introduced once again and actual application examples were presented. If major facilities such as pumps and transformers are in low efficiency, they should be replaced with high-efficiency facilities, and through EMS, it can be used as a tool to diagnose the energy consumption status of each business site in real time and to improve it. The optimal operation plan for the pump that consumes the most energy at the waterworks site was reviewed by dividing it into an optimal operation plan for each time period in connection with the electricity rate unit price (Hangjeon). In addition, the optimal frequency operation method using a VVVF inverter in the pressurization field was also presented as an example. In addition, it introduced a plan to apply small hydroelectric power generation and renewable energy using energy head on the pipe. In addition, this plan was matched and applied to the four types of groups mentioned above. Local governments in groups 1 and 2, which are relatively well managed for energy, actively manage through EMS to maintain the current power supply unit, and propose new policies, such as the development of renewable energy and the high-efficiency operation of large-capacity motors, with the aim of saving about 5 to 10%.

6.3 Future Tasks

The method presented in this study is only an example. Classifying 161 local governments nationwide into four groups may be partially correct, but untargeted local governments may belong to them. It is a method of classifying four groups, and it should be possible to elaborately classify the groups by developing indicators that can reflect the characteristics of local governments. Of course, in this study, it was confirmed that there was a positive (+) correlation through correlation analysis of the EXCEL function, but statistically, a step to verify this will be needed.

In addition, there will be a variety of methods in addition to the proposed energy-saving policy (carbon reduction). Topics that were not reviewed in this study should be continued to future tasks.

In addition, when the effectiveness of the presented case is verified, for example, applied in local government A, the economic analysis should be reviewed by accurately measuring the effectiveness (saving amount) compared to the investment cost.

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