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Improvement Effect of Green Remodeling and Building Value Assessment Criteria for Aging Public Buildings

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Abstract: The Green Remodeling Project under South Korea's Green New Deal policy is a government-led project intended to strengthen the performance sector directly correlated with energy performance among various elements of improvement applicable to building remodeling by replacing insulation materials, introducing new and renewable energy, introducing high-efficiency equipment, etc., with public buildings taking the lead in green remodeling in order to induce energy efficiency enhancement in private buildings. However, there is an ongoing policy that involves the application of a fragmentary value judgment criterion, i.e., whether to apply technical elements confined to the enhancement of the energy performance of target buildings and the prediction of improvement effects according thereto, thus resulting in the phenomenon of another important value criterion for green remodeling, i.e., the enhancement of the occupant (user) comfort performance of target buildings as one of its purposes, being neglected instead. In order to accurately grasp the current status of these problems and to promote 'expansion of the value judgment criteria for green remodeling' as an alternative, this study collected energy usage data of buildings actually used by public institutions and then conducted a total analysis. After that, the characteristics of energy usage were analyzed for each of the groups of buildings classified by year of completion, thereby carrying out an analysis of the correlation between the non-architectural elements affecting the actual energy usage and the actual energy usage data. The correlation between the improvement performance of each technical element and the actual improvement effect was also analyzed, thereby ascertaining the relationship between the direction of major policy strategies and the actual energy usage. As a result of the relationship analysis, it was confirmed that the actual energy usage is more affected by the operating conditions of the relevant building than the application of individual strategic elements such as the performance of the envelope insulation and the performance of the high-efficiency system. In addition, it was also confirmed that the usage of public buildings does not increase in proportion to their aging. The primary goal of reducing energy usage in target buildings can be achieved if public sector (government)-led green remodeling is pushed ahead with in accordance with biased value judgment criteria, just as in the case of a campaign to refrain from operating cooling facilities in aging public buildings. However, it was possible to grasp through the progress of this study that the remodeling may also result in the deterioration of environmental comfort and stability, such as the numerical value of the indoor thermal environment. The results of this study have the significance of providing basic data for pushing ahead with a green remodeling policy in which the value judgment criteria for aging existing public buildings are more expanded, and it is necessary to continue research in such a direction that the quantitative purpose of green remodeling, which is to reduce energy usage in aging public buildings, and its qualitative purpose, which is to enhance their environmental performance for occupants' comfort, can be mutually balanced and secured at the same time.

Keywords: public building; aging of buildings; green remodeling; value assessment criteria; energy performance; comfort performance

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1. Introduction

1.1. Background and Purpose

In order to address the challenges of overcoming the economic recession, which was further exacerbated by the COVID-19 pandemic, the current South Korean government set two policy directions: the Digital New Deal and the Green New Deal in 2020. Ten key projects were designated as implementation strategies for the above-mentioned two policy directions. Data Dam, AI Government, and Smart Healthcare were designated as three projects to be implemented according to the Digital New Deal policy direction, whereas Green Remodeling, Green Energy, and Eco-friendly Mobility of the Future were specified as three projects to be implemented according to the Green New Deal policy direction. In addition, Green and Smart Schools, Digital Twin, Digitalization of SOC, and Smart and Green Industrial Complexes were set up as four projects to be implemented for the convergence of the Digital New Deal and the Green New Deal [1].

Among the projects, Green Remodeling is intended to strengthen the energy-related performance of buildings among the architectural elements by replacing insulation materials, introducing new and renewable energy, introducing high-efficiency equipment, etc., with public buildings taking the lead in green remodeling in order to induce energy efficiency enhancement in private buildings. Its goal is to ensure through this that public buildings with a gross floor area of 500 m^2 or more are completed as zero-energy buildings by 2023. However, the evaluation of the results (achievements) related to the promotion of green remodeling is biased toward the energy saving figures for heating and cooling.

The main reason for such biased evaluation is that the problem of the aging of a building is addressed only by focusing on energy overconsumption due to the thermal insulation and the facility system deteriorating as a result of their aging, etc. However, paradoxically, the energy consumption of an aging building cannot exceed the capacity range of the cooling and heating system already installed in it. The scenario of energy consumption increasing due to an aging system is a scenario in which the cooling and heating functions of the system deteriorate as it ages, with its uptime increasing in order to meet the temperature conditions due to the deterioration of its functions, thus resulting in the increasing energy usage. However, since one day is limited to 24 h, the margin of additional system uptime is limited.

Accordingly, it has been judged necessary to check whether the actual energy usage is high in aging buildings. More specifically, it is necessary to improve the fragmentary judgment criterion itself, i.e., making a judgment based on whether to apply technical elements confined to energy performance enhancement through thermal insulation improvement and facility system replacement and the prediction of improvement effects according thereto in the so-called green remodeling promotion strategy.

From our point of view regarding green remodeling intended to improve aging buildings, it is necessary to expand the value assessment criteria in a variety of ways, including not only the amount of energy usage but also the effects of thermal environment improvement for the users living in aging buildings as compared with the energy usage levels and the degree of contribution to urban regeneration by the remodeling of aging buildings [2].

A method that can evaluate the effect of maintaining the thermal environment relative to the energy usage level works by conducting dynamic energy simulations to check the "Discomfort Hours" or "Not Met Hours" reports during one year, thereby determining the level of the thermal environment that is likely to deviate from the comfort range. Even for buildings with the same level of energy usage, it is possible to conclude by making value assessments that buildings with lower discomfort hours have higher efficiency in achieving the purpose of the energy used. However, in order to perform such analyses, it is necessary to quantitatively measure and know all the energy performance correlation information values of the existing target buildings. In particular, it is difficult but necessary to accurately simulate various energy-related conditions, such as the operational state as well as the shape of each building, with the digital twin technique.

In spite of this difficulty, in order to proceed with this study seeking to explore factors influencing the value of existing buildings for the establishment of value assessment criteria for the improvement effects of green remodeling of aging public buildings, it was ascertained whether green remodeling influenced the real amount of energy usage by analyzing data related to energy usage in existing public buildings in Korea and conducting an exploratory analysis of data on the characteristics of energy usage. In addition, basic research for the establishment of value assessment criteria for green remodeling was conducted together with some other research through data analyses, simulations, and field investigations.

1.2. Study Method

For the expansion of the value judgment criteria for green remodeling, this study conducted a correlation analysis of non-architectural elements affecting the actual energy usage and the actual usage data.

Measurements were performed on the actual environment of real buildings to which the improvement technology element of green remodeling as shown in an actual remodeling consulting case was applied in order to ascertain how much additional values other than the energy aspect, including the improvement of the living environment, were enhanced, and simulations were conducted to determine which method should be applied to enhance the actual values.

A total analysis of public institution data was conducted to determine whether public institution buildings could actually be defined as high energy consumption buildings as a result of aging, and the energy usage data on the building groups by year of completion were compared to verify whether aging buildings actually use a lot of energy.

The thermal insulation levels, facility systems, etc., of aging public buildings were investigated, and the collected actual energy consumption data were analyzed to ascertain whether the buildings were overconsuming energy. In addition, correlation analyses were performed to ascertain the relationship between the actual energy usage in the buildings and the major strategies of green remodeling, such as improving their insulation performance, applying new and renewable energy, and replacing the LED lighting. Figure 1 shows the overall process of this study.

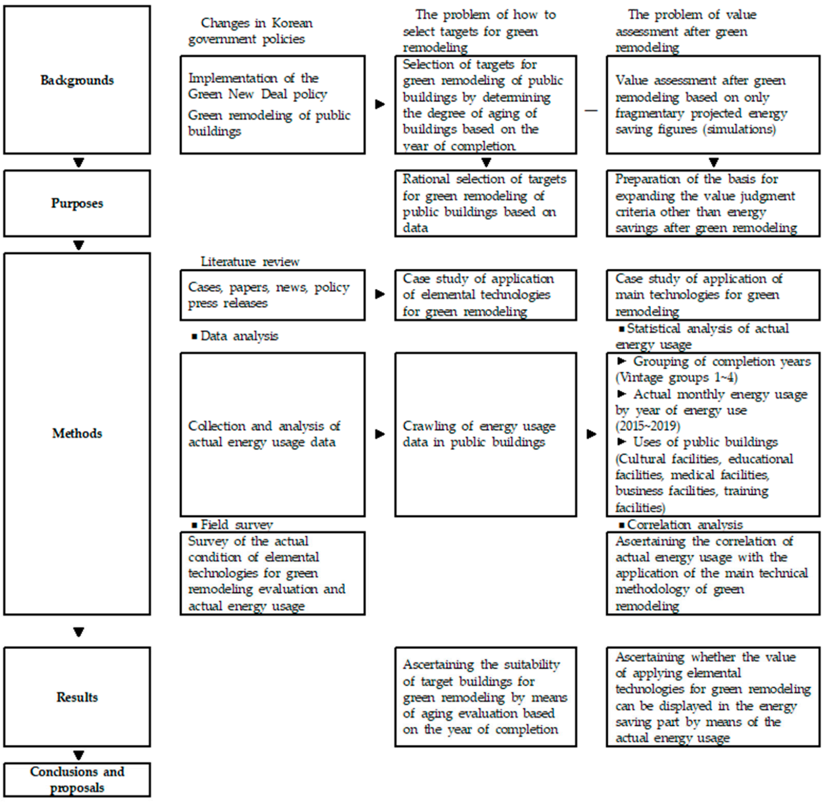


Figure 1. Research flowchart.

2. Analysis of the Relationship between the Actual Amount of Energy Usage and the Major Strategic Elements of Green Remodeling

2.1. Necessity of Analyzing Non-Architectural Elements Affecting the Actual Energy Usage

As for the elements correlated with the actual energy usage in a building, not only the building envelope insulation performance and the system efficiency as defined in the major strategies of green remodeling but also the building use characteristics greatly affect the actual energy usage in the building.

To take an example as proof of the above premise, in the case of a residential building as shown in Figure 2, after analysis it was shown that there is a very strong correlation of 0.82 between the price of the building and the electricity usage charge.

This is a fragmentary example, but methodologically in a study on quantification methods based on big data analysis of explanatory variable factors that contain the uncertainty of the actual energy usage in buildings, it can be confirmed that the amount of energy usage in a building has a very high correlation with the price of the building.

In analyzing the relationship between the actual energy usage in a building and the major strategic elements of green remodeling, analysis of non-architectural elements affecting the actual energy usage can be an important judgment criterion [3], and methodologically in the process of this study, it was judged that the correlation and the actual energy usage and such non-architectural elements also proves the utility and necessity of using the analysis technique.

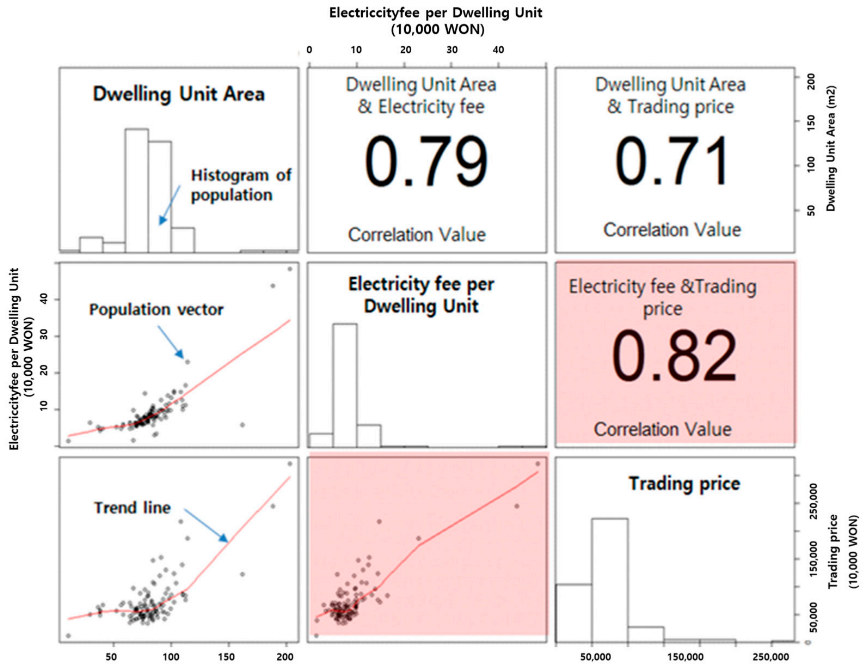


Figure 2. 2010~2015 range scale of Correlation analysis between market price and Annual electric energy fee.

2.2. Policy Trends through Press Releases Related to Green Remodeling of Public Buildings

In July 2020, the Ministry of Environment and the Ministry of Trade, Industry and Energy implemented the Green New Deal policy to restore the green ecosystem, spread new and renewable energy, and lay the foundation for the green industry, together with efforts to establish carbon neutrality as the point of orientation. The Green New Deal is largely divided into three areas: green transformation of the urban/space/living infrastructure, diffusion of low carbon/decentralized energy, and establishment of a green industry innovation ecosystem. Among them, the government announced a plan to push ahead with green remodeling of public buildings in a zero energy project for public facilities close to people's lives [4].

5.4 million buildings, about 75% of the total 7.2 million buildings in Korea, are aging buildings and at least 15 years old, and 135,000 buildings in particular are facilities used by vulnerable groups such as children and the elderly. Thus, activation of green remodeling projects has been required. Accordingly, many local governments are participating in the improvement of living environments for vulnerable groups, such as by undertaking the design of about 790 green remodeling cases regarding aging public buildings for vulnerable groups under the current 2020 Green Remodeling Project for Public Buildings (total project cost of KRW 340 billion) among the projects covered by the 3rd supplementary budget [5].

2.3. Applied Technologies Trends in Green Remodeling of Aging Buildings in Europe and the United States

As for the technical elements of green remodeling used in urban regeneration cases in Europe and the United States, exterior wall insulation, boiler installation, and piping construction were carried out for remodeling in each residential complex, whereas exterior wall insulation, ventilation equipment, and new and renewable energy (solar, photovoltaic, geothermal, etc.) facilities were applied for remodeling in each small-scale complex, among overseas urban regeneration cases such as exterior wall insulation, window insulation, rooftop greening, boiler installation, etc. As for the percentage of each technical element of green remodeling, the parts related to wall insulation accounted for 20%, the largest proportion, and the parts related to ventilation equipment represented a large proportion of 13%. Wall insulation was applied in all the cases observed, and ventilation equipment was applied in more than half of the cases. It is summarized in Table 1 and Figure 3.

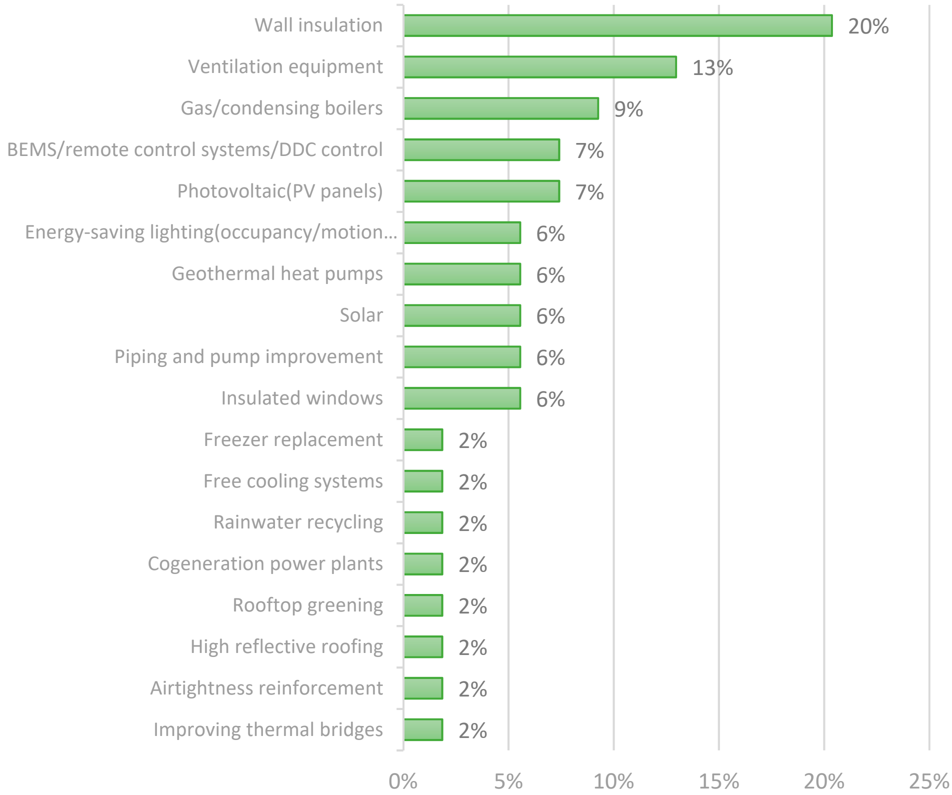


Figure 3. Visualization of the percentages of the applied technologies for green remodeling in urban regeneration projects in Europe and the United States.

Table 1. Applied technologies for green remodeling in urban regeneration projects in Europe and the United States [6–12].

	Wall Insulation	Insulated Window	Improving Thermal Bridges	Airtightness Reinforcement	High Reflective Roofing	Rooftop Greening	Cogeneration Power Plants	High-Efficiency Feed Water Pump	Gas/Condensing Boilers	Solar	Photovoltaic	Ventilation Equipment	Geothermal Heat Pumps	Rainwater Recycling	BEMS	Free Cooling Systems	Energy-Saving Lighting	Freezer Replacement
Belss/Luedecke	•	•					•	•										
Karlsruhe	•							•	•	•								
Hackney Homes Project	•	•							•									
Metchley·Derwent·Coniston House	•								•									
Ready4Retrofit Project	•								•		•	•						
Second Life School Project	•		•								•	•	•					
Post War Residential Building	•									•	•	•	•	•				
Dieselweg 3-19	•							•		•		•	•		•			
Alliance Center	•			•							•	•			•		•	
200 Market Building, Portland, USA	•				•	•			•			•			•	•	•	
Empire State Building	•	•										•			•		•	•

2.4. Applied Technologies Trends in Green Remodeling of Aging Buildings in South Korea

This study investigated the main technical elements of green remodeling for aging buildings in urban regeneration areas in Korea and the technical elements of improvement corresponding to green remodeling among the support projects implemented by the state in favor of aging buildings for urban regeneration. The investigated main technical elements of green remodeling for aging buildings were cool roofs, rooftop waterproofing, window replacement and exterior wall insulation on the energy side, and reinforcement of carbon fiber sheets and steel braces on the structure side. The national support projects implemented in favor of aging buildings for urban regeneration include the Place Renewal Project, the Village Happiness Project, the Seoul-type New Deal Alley Housing Appearance Project, and the Gyeonggi-do Urban Regeneration Priming Water Project.

Window replacement and exterior wall insulation are essential technologies for green remodeling. Depending on the project, such technologies as cooling and heating equipment replacement, rooftop repair, and seismic reinforcement are also used. In the case of cool roofs, the Ministry of Environment and local governments are actively pushing for them not only to reduce indoor temperatures but also to mitigate heat islands. It is summarized in Table 2 and Figure 4.

Table 2. Cases of the applied technologies for green remodeling of aging buildings in urban regeneration areas in South Korea [13,14].

Energy-Independent Village	Insulated Window	Exterior Wall Insulation	Floor Insulation	Roof Insulation	Insulated Door	Wind Proof Construction	LED Lighting	Photovoltaic	Solar	ESS Installation	Rooftop Greening	High-Efficiency Heating and Cooling	Geothermal	Wood Pellet Stove	Cool Roof	Boiler Distributor	Dimming Sensor	High-Efficiency Feed Water Pump	Total Heat Exchanger
Seongdaegol, Seoul	•	•				•	•	•	•	•									
Sipjaseong, Seoul	•	•					•	•	•		•	•	•	•					
Hobakgol, Seoul	•	•					•	•							•				
EungamSangol, Seoul	•	•					•	•				•			•				
Nangoknanhyang, Seoul	•	•				•	•	•								•			
Seokgwan-dong, Seoul							•	•									•	•	
Guweol3-dong, Incheon								•											
AbandonedMine, Gyeongangbuk-do								•	•										
Suncheonman, Suncheon	•	•	•	•				•	•				•						•
Junggeum, Imsil-gun, Jeollabuk-do	•	•			•	•	•	•											

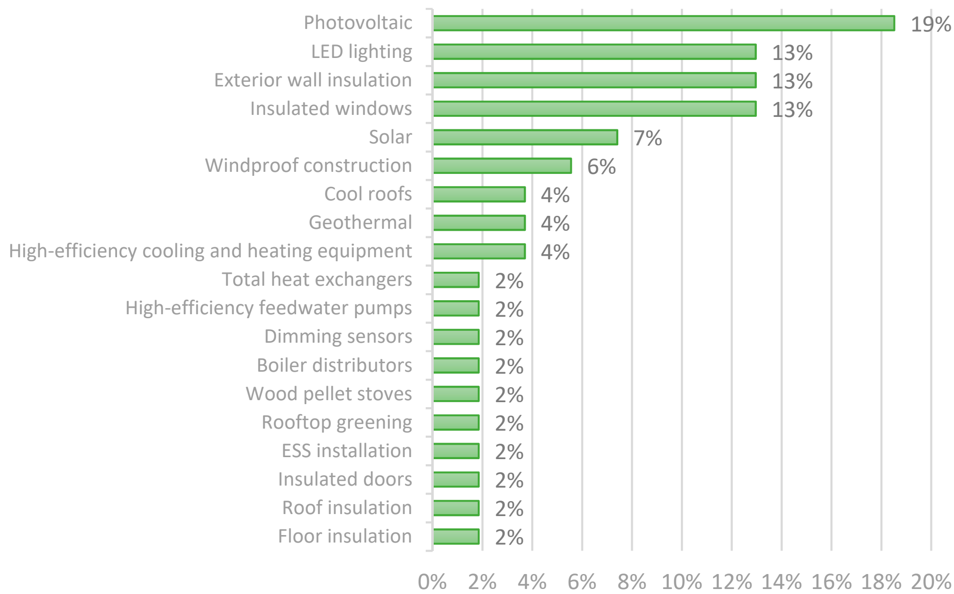


Figure 4. Percentages of the applied technologies for green remodeling of aging buildings in urban regeneration projects in South Korea.

2.5. Research Trends Related to the Value Assessment Criteria Based on Green Remodeling of Public Buildings

Target public buildings for government-led green remodeling have been designated and items to be improved are limited. However, there are no prescribed criteria for target buildings for green remodeling or the timing of its implementation when it is expanded to the private sector. Thus, it is necessary for you to evaluate the feasibility of remodeling a building, etc. based on your own judgment in such case. In order to determine the possibility of remodeling aging buildings, AI-based rapid automated building condition assessment technologies are expected to be utilized throughout the course of remodeling aging buildings. However, existing research cases show that such methods as vision assessment techniques are limited in making an integrated judgment of the degree of aging of buildings. In addition, research cases for evaluating and predicting energy performance still remain inclined to use existing research methods such as multiple regression analysis. It is summarized in Table 3.

Table 3. Summarized trends survey table of value assessment criteria.

Subclassification	Summary of Existing Research Studies	Complementary Points for Existing Research Results
Research case evaluating AI-based structural and aging performance and predicting the lifespan of buildings [15]	- The research case focused on the availability of AI vision analysis techniques to determine the physical degree of aging of buildings. - The methods and techniques used in the research case include a video acquisition method that can ensure proper image quality and size of video information, an image processing technique for crack identification, and a machine learning technique that can be learned by analyzing the identified crack patterns.	- It is judged by the phenomenon determination analysis results that residual life prediction is impossible in the future due to the limitations of vision analysis. - In a manner that enables residual life prediction, it is necessary to conduct research on one or more methodologies for predicting the residual lifespan of any assessment target by analyzing the definition of independent variables that affect its lifespan and the degree of impact of each defined element on its lifespan. - Seismic performance evaluation needs to be distinguished from aging prediction, because it is intended to predict the structural stiffness of the target building that will be displayed in case of a seismic event. - It is necessary to conduct research on one or more methodologies that can make an integrated prediction of changes in the characteristics of architectural elements dependent on or correlated to the aging of the relevant structure.

Table 3. *Cont.*

Subclassification	Summary of Existing Research Studies	Complementary Points for Existing Research Results
Research cases evaluating AI-based energy performance and predicting the energy efficiency of buildings [16–20].	- To identify the most highly correlated input variables, various basic methods and nonparametric statistical analysis tools were used to analyze correlations between each input variable and each output variable. - How to evaluate the energy efficiency of buildings was described by applying ICT and data analysis techniques. - AI-based prediction research has been conducted and is currently applied to the building energy management system (BEMS). - Research results showing universality are insufficient in relation to AI-based building energy performance evaluation.	- In the investigated research cases, AI-based load prediction shows no difference from existing arithmetic-based load calculations. Even the accuracy of AI-based load prediction is evaluated by its error ratio as compared to existing load calculation methods. - The independent variable elements for load prediction do not deviate from the predefined ranges such as windows, walls, internal heat generation, and external heat acquisition, and thus there can be no difference in the prediction results. - AI-based prediction requires the development of a methodology that can predict the energy usage by reflecting external elements that affect energy consumption, not just by making a judgment within the physical performance of the building. - The current prediction methodology is suitable for load prediction in the case of non-existent new buildings, but the prediction results are meaningless in the case of existing buildings because there are energy usage data on them.

3. Analysis of Energy Usage Data Patterns of Public Buildings and Correlation Analysis of Major Strategies of Green Remodeling

3.1. Analysis of Energy Usage Patterns of Public Buildings in Korea

3.1.1. Overview of Public Building Data Collection

Monthly electricity and gas consumption in domestic public institutions from 2015 to 2019 was collected. The data on public buildings are available on the public institution data portal (https://www.data.go.kr/ (accessed on 12 January 2021), and data were collected using the crawling technique by providing an open API (Application Program Interface) [21]. The Python code crawled using the API is shown in Appendix A.

As can be seen in Table 4 and Figure 5 below, it was found that the highest proportion of the public buildings in the collected data were used as educational facilities, accounting for 63%. Second, public service facilities accounted for 22% of the total collected data.

Table 4. Proportions by the use of public buildings subject to energy usage analysis.

Use	Count	Frequency (%)
Educational facilities	1222	63.4%
Office facilities	425	22.0%
Cultural facilities	149	7.7%
Training facilities	86	4.5%
Medical facilities	46	2.4%
SUM	1928	100.0%

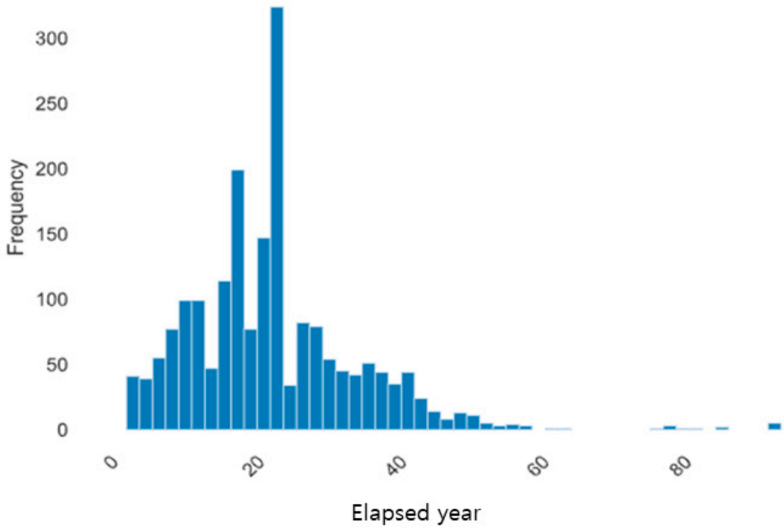


Figure 5. Histogram of the number of buildings according to the year of public buildings.

As shown in Table 5 below, the periods of use of the public buildings in the data collected using the crawling technique were found to have a median value of 22 years, a minimum value of 2 years, and a maximum value of 94 years. As shown in the histogram of the numbers of years of use, the number of buildings built before 2000 and aged 20 years or so was found to be high according to information on the completion and use of public buildings in Korea.

Table 5. Quantile of the number of buildings according to the years of use of public buildings.

Quantile	Value (Number of Buildings)
Min	2
5-th percentile	6
Q1	15
Median	22
Q3	28
95-th percentile	43
Maximum	94
Range	92
Interquartile range (IQR)	13

3.1.2. Establishment of a 'Vintage Group' for Each Revision Year for the Legal Minimum Insulation Performance Criteria in the Energy Saving Design Standards

The Energy Saving Design Standards are currently in force under the current legal system in the field of architecture. The building data collected based on the revision year for the insulation performance standards in the Energy Saving Design Standards were clustered as shown in Table 6 [22]. Due to the oil crisis that occurred in the 1970s, the government first enacted thermal insulation standards in September 1979 with the aim of reducing energy consumption in buildings. Subsequently, buildings can be classified into buildings before 1979, buildings before 1987, buildings before 2001, and buildings before 2013 based on the time when the Energy Saving Design Standards were greatly strengthened in 2013. By analyzing the characteristics of each group of buildings clustered according to this classification, it is possible to grasp the energy performance characteristics that an existing building has according to the year of its completion. As an example, it can be ascertained that the performance standards for windows were strengthened by 28% in 2008 in comparison with the previous standards, and by 30% in 2011 and 2013 in comparison with the standards immediately before the revision.

Table 6. Reference years for vintage group classification.

Vintage Group	Year	Period
Vintage Group 1	Before 1979	-
Vintage Group 2	1979~1987	8
Vintage Group 3	1987~2001	14
Vintage Group 4	2001~2013	12
Vintage Group 5	After 2013	7

The insulation performance standards in the Energy Saving Design Standards require that the minimum insulation performance value should be designated by law and applied when designing not only public buildings but also private buildings. Therefore, this can serve as a criterion for estimating the legal values for the envelope performance of each building based on the year of its completion. By examining the 1928 public building data collected in this study by cluster, it can be seen that vintage group 3 built between 1987 and 2001 accounts for the largest proportion with 46.6%, as shown in the vintage group proportions in Table 7 and the insulation standards for each building part in vintage groups in Figure 6.

Table 7. Proportions of public buildings by vintage group.

Vintage Group	Count	Frequency (%)
Vintage Group 1	183	9.5%
Vintage Group 2	216	11.2%
Vintage Group 3	898	46.6%
Vintage Group 4	552	28.6%
Vintage Group 5	79	4.1%
SUM	1928	100.0%

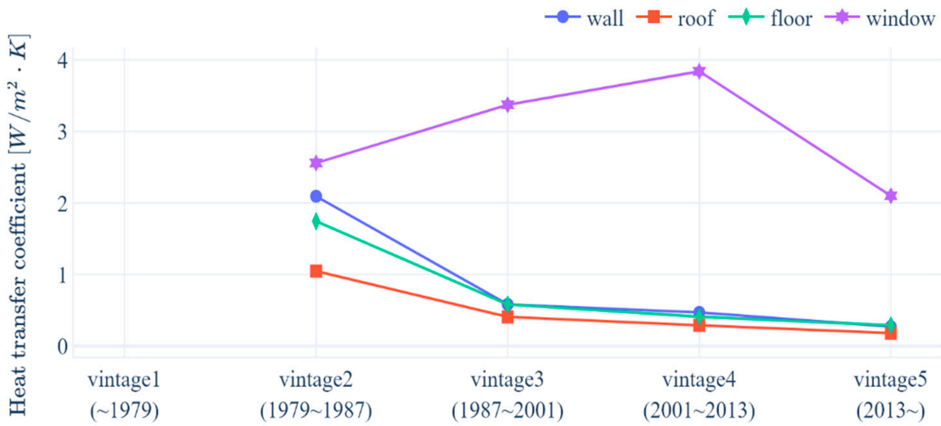


Figure 6. Insulation standards for each building part in vintage groups.

3.1.3. Amounts of Energy Usage by Year in Each Vintage Group

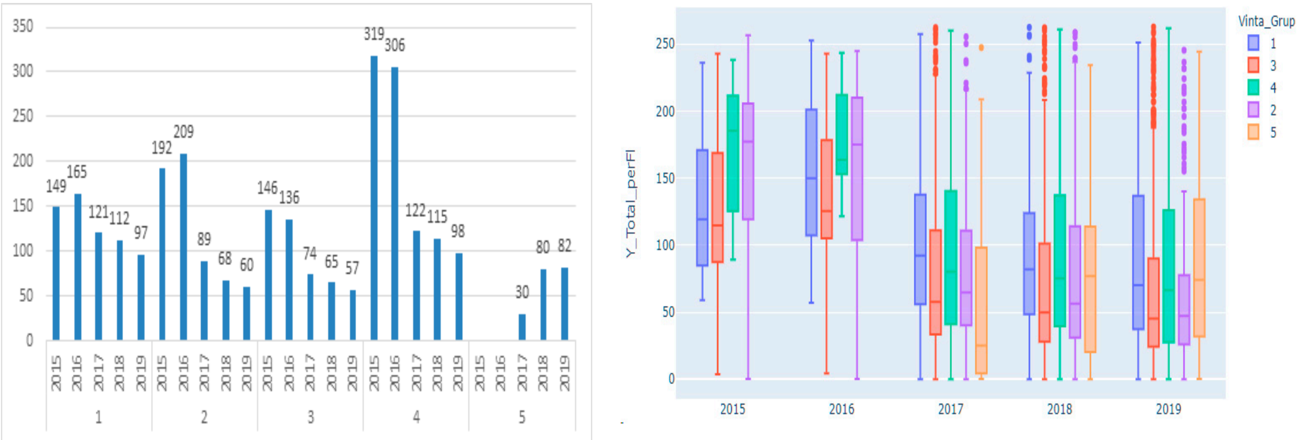
The amounts of energy usage by year in each vintage group were analyzed as shown in Table 8 below. No difference in the annual energy usage per unit area in each vintage group showed the characteristics of any significant change. However, the energy usage in public buildings has showed a trend of declining sharply in all vintage groups since 2017. The characteristics of such a trend can be seen not simply as energy saving but as a result of energy saving practiced by public building users and managers in compliance with the energy saving campaign based on the government's policy stance [23,24].

Table 8. Descriptive statistics of the amounts of energy usage by year in each vintage group.

Vintage Group	Year	Standard Deviation (kW/m^2y)	Minimum Value (kW/m^2y)	Maximum Value (kW/m^2y)	Median (kW/m^2y)	Mean (Average of VALUE) (kW/m^2y)
1 Before 1979	2015	125	59	565	149	183
	2016	133	57	646	165	200
	2017	866	0	6836	121	399
	2018	845	0	5985	112	410
	2019	1499	0	16,508	97	504
2 1979~1987	2015	99	0	391	192	212
	2016	112	0	422	209	213
	2017	826	0	6125	89	358
	2018	694	0	7095	68	275
	2019	1532	0	12,294	60	444
3 1987~2001	2015	401	4	2243	146	251
	2016	183	4	1060	136	197
	2017	3563	0	98,040	74	495
	2018	4085	0	113,143	65	395
	2019	4109	0	96,962	57	719
4 2001~2013	2015	158	89	585	319	322
	2016	154	122	586	306	325
	2017	1090	0	15,554	122	432
	2018	2195	0	40,807	115	452
	2019	2555	0	40,109	98	643
5 After 2013	2015	-	-	-	-	-
	2016	-	-	-	-	-
	2017	12,978	0	101,461	30	1812
	2018	13,282	0	107,831	80	1918
	2019	7510	0	62,468	82	1198

2016 recorded the highest temperatures for the Republic of Korea in 22 years. The minimum reserve rate for stable power supply dropped to 15% or even to 6%, and the Ministry of Trade, Industry and Energy launched a campaign asking the public to refrain from using air conditioning to prevent a blackout [25].

It can be ascertained from the result of implementing a campaign to refrain from using air conditioning to prevent a blackout that there is a possibility of the lost value being greater as compared to the value of reducing electricity consumption. As shown in Figures 7 and 8 as a result of the campaign to refrain from using air conditioning, the occupants of public buildings used individual electric fans instead. At the time of on-site measurement surveys, it was also confirmed by PMV measurements that indoor thermal environments were very hot and outside the comfortable range [26].



(**a**) (**b**)

Figure 7. (**a**) Visualization of the bar chart in Table 5; (**b**) Visualization of the box plot in Table 5; Ascertainment of the decreasing trend in the median (kW/m2y) in the amounts of energy usage by year from 2017, as compared to 2015 and 2016

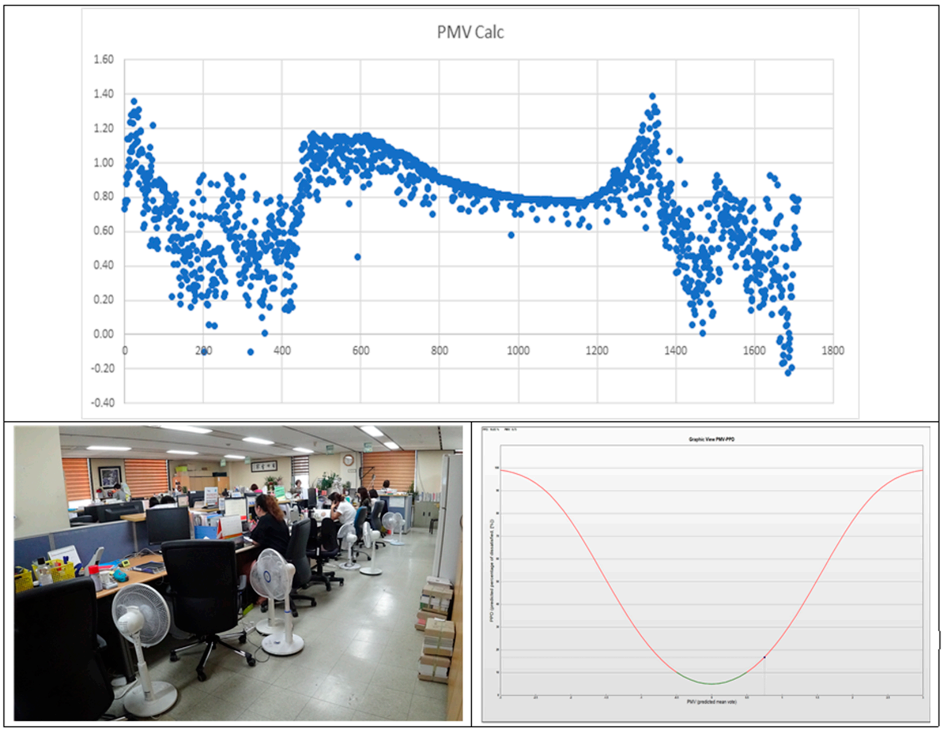


Figure 8. PMV in the energy saving environment in a public institution building against a blackout.

The occupants, i.e., main users of public buildings, are public officials who mainly provide services for the convenience of citizens. Other users of public buildings are an unspecified number of citizens. An energy saving plan that does not take into account the indoor thermal environment of a building may result in the loss of its value its value as a building [27,28].

As can be seen from the box plot of annual energy consumption per unit area by vintage group in 2019 in Figure 9, no significant difference occurred in the annual energy consumption per unit area among the vintage groups with different years of completion. This demonstrates that there is a need for partial revision in setting the promotion direction for designating targets of green remodeling for the Green New Deal, which requires green remodeling of buildings with high energy consumption due to aging. The following may be one method of doing so: revising the criterion for regarding an existing building as aging from the concept that 'it has undergone a long lapse of time' to the concept that 'it can no longer sustain the value of its use as a public building and has reached the end of the lifespan of its corresponding value' [29]. If the concept as a criterion for determining the degree of aging of public buildings and designating them as targets for green remodeling is revised in such direction, it is also judged possible to increase the value of a building itself that meets its fundamental purpose in addition to improving the energy aspect of green remodeling as well as securing the validity of the selection of target buildings for green remodeling.

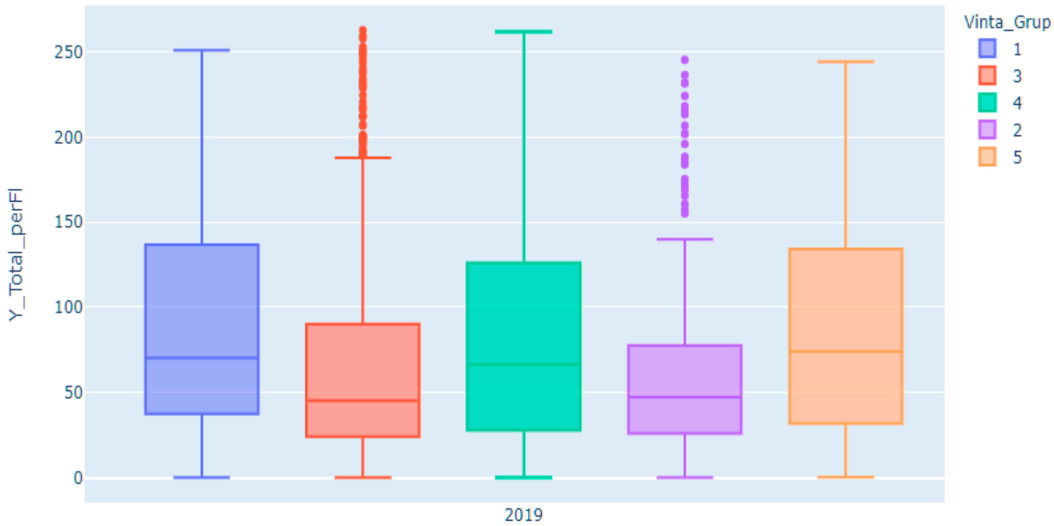


Figure 9. A box plot of annual energy consumption per unit area by vintage group in 2019.

3.1.4. Amounts of Energy Usage by Facility Use in Each Vintage Group

When carrying out analyses through Figure 10 and Table 9 which show the amounts of energy usage by facility use in the vintage groups, the annual energy usage per unit area was found to be the highest in Group 3 in terms of cultural facilities. It was found to be highest in Group 4 in terms of both educational and cultural facilities, and in Group 1 in terms of office facilities. As for training facilities, it was highest in Group 2.

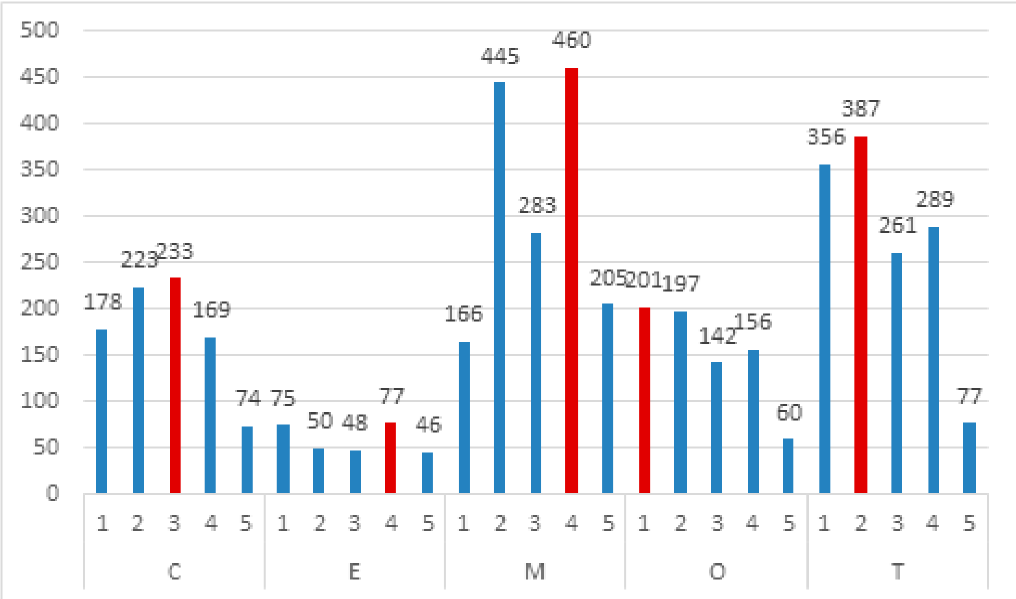


Figure 10. Visualization bar chart of vintage groups by highest energy use among the medians (kW/m^{2}y) by vintage group in the amounts of energy usage by facility use in each group in Table 9.

Table 9. Amounts of energy usage by facility use in each vintage group.

Use	Vinta_Group	Standard Deviation (kW/m^{2}y)	Minimum Value (kW/m^{2}y)	Maximum Value (kW/m^{2}y)	Median (kW/m^{2}y)	Mean (Average of Value) (kW/m^{2}y)
Cultural facilities	1	708	0.11	2671	178	498
	2	861	0.04	3227	223	542
	3	998	0.00	6727	233	556
	4	485	0.09	3089	169	327
	5	2388	0.43	11,725	74	664
Educational facilities	1	1286	0.03	16,508	75	384
	2	943	0.01	12,294	50	243
	3	1672	0.00	18,931	48	371
	4	1222	0.00	13,656	77	382
	5	633	0.29	2753	46	305
Medical facilities	1	1674	8.60	6484	166	676
	2	430	0.08	1112	445	508
	3	1196	37.92	6206	283	700
	4	643	2.73	3051	460	582
	5	46	126.85	247	205	191
Office facilities	1	446	0.02	2610	201	312
	2	1428	0.13	11,543	197	508
	3	1486	0.00	16,710	142	470
	4	3989	0.13	40,807	156	1029
	5	17,323	0.13	107,831	60	3303
Training facilities	1	1240	0.42	3715	356	946
	2	794	0.06	2581	387	677
	3	18,532	1.44	113,143	261	3749
	4	300	9.08	1505	289	353
	5	73	2.29	189	77	84

Also, in the results of analyses carried out by classifying the vintage groups according to the classified types of use of public buildings, it was difficult to find a logical basis as a criterion for the policy that green remodeling should be performed on aging buildings that have undergone a longer lapse of time, on the grounds that they use more energy.

3.2. Analysis of the Correlation between the Major Strategic Elements of Green Remodeling and the Amount of Energy Usage

The correlation factor was explored by analyzing how much the current major strategic approaches of green remodeling and its applicable elements correlate with the actual amount of energy usage [30,31].

In general, the correlation coefficient of a sample is indicated by the letter r. When r = 1, it means that there is a complete positive linear correlation. When r = −1, it means that there is a complete negative correlation. When r = 0, it means that there is no linear correlation between the two variables. Guilford [32] and Cohen [33] present the same criteria as Table 10 by means of the absolute values of correlation coefficients. A table of the contents of 80 cases in which nominal variables were converted into ratio scales for correlation analysis was added to the Appendix B.

Table 10. Criteria for evaluation of correlation coefficient.

Guilford [32]		Cohen [33]	
Value	Level of Agreement	Value	Level of Agreement
$\lvert r \rvert < 0.2$	None	-	-
$0.2 \le \lvert r \rvert < 0.4$	Week	$0.5 \le \lvert r \rvert \le 1$	Week
$0.4 \le \lvert r \rvert < 0.7$	Moderate	$0.3 \le \lvert r \rvert < 0.5$	Moderate
$0.7 \le \lvert r \rvert < 0.9$	Strong	$0.1 \le \lvert r \rvert < 0.3$	Strong
$0.9 \le \lvert r \rvert \le 1$	Almost perfect	-	-

As a result of ascertaining the amounts of energy usage in public buildings and cases in which wall and window insulation improvements, LED replacements, and the application of new renewable energy, the major strategic elements of green remodeling, were actually carried out, the degree of negative correlation between the amount of energy usage and the major strategic elements was found to be highest in the window area ratio as a positive correlation of 0.16 among the strategic elements as shown in Table 11, but it can be seen in Table 10 that the degree of correlation represented by the numerical value ‘0.16′ is interpreted to mean ‘no correlation’.

When looking at the results of comparing the correlation coefficients between the amount of energy usage and the green remodeling implementation strategy as shown in the visualization bar chart in Figure 11, it was found that there was a positive correlation of 0 to 0.2 in the window area ratio, the sun blind, and the insulation thickness, but a negative correlation was found in the amount of energy usage in buildings with a higher LED replacement rate. As for public buildings that underwent remodeling, it can be inferred that the annual amount of energy usage has either increased or that the actual amount of energy usage has not been reduced as compared to before remodeling [34].

The actual energy usage in aging existing public buildings shows a correlation of 0.06 with the insulation thickness closely linked to the outer skin insulation, whereas it’s correlation with the window area ratio and its correlation with the shade are 0.161 and 0.088 respectively, thus showing little correlation between them. Even when replacing fluorescent lights with LED lights, the correlation between the actual energy usage and them was found to be −0.216. It is likely that these figures have improved the living environment by adding energy capacity rather than by simply replacing existing equipment with high-efficiency equipment when remodeling aging building.

Table 11. A table showing the results of analyzing the correlation between the amount of energy usage and the green remodeling implementation strategy.

	Completion Time	Floor Area	Insulating Material	Insulation Thickness	Glass Types	Window Wall Ratio	Shading (Applicable or Not)	Heat Exchanging Type Ventilation (Applicable or Not)	LED (Applicable or Not)	Renewable System (Applicable or Not)	Energy Usage
Completion time	1.00	0.16	0.16	0.25	−0.08	−0.03	−0.02	0.16	0.10	0.05	−0.04
Floor area	0.16	1.00	0.07	0.10	−0.11	0.17	−0.05	0.28	0.12	0.09	−0.11
Insulating material	0.16	0.07	1.00	0.80	0.42	−0.02	−0.01	−0.11	0.33	0.28	−0.09
Insulation thickness	0.25	0.10	0.80	1.00	0.38	−0.04	−0.05	−0.05	0.27	0.28	0.06
Glass types	−0.08	−0.11	0.42	0.38	1.00	0.02	−0.03	−0.34	0.22	0.20	−0.01
Window Wall Ratio	−0.03	0.17	−0.02	−0.04	0.02	1.00	0.07	0.09	−0.03	0.34	0.16
Shading (applicable or not)	−0.02	−0.05	−0.01	−0.05	−0.03	0.07	1.00	−0.11	0.02	0.09	0.09
heat ex-changing type venti-lation (ap-plicable or not)	0.16	0.28	−0.11	−0.05	−0.34	0.09	−0.11	1.00	−0.14	−0.10	−0.15
LED (applicable or not)	0.10	0.12	0.33	0.27	0.22	−0.03	0.02	−0.14	1.00	0.21	−0.22
Renewable system (applicable or not)	0.05	0.09	0.28	0.28	0.20	0.34	0.09	−0.10	0.21	1.00	−0.09
Energy Us-age(kW/m2)	−0.04	−0.11	−0.09	0.06	−0.01	0.16	0.09	−0.15	−0.22	−0.09	1.00

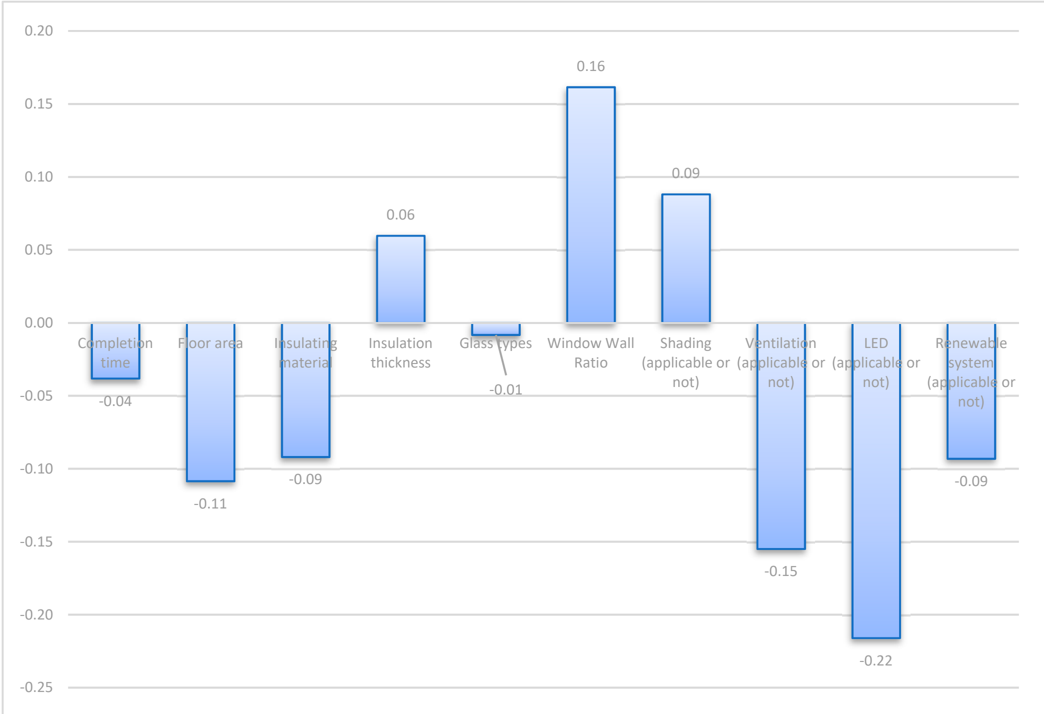


Figure 11. A visualization bar chart comparing correlation coefficients between the amount of energy usage and the green remodeling implementation strategy.

4. Conclusions

The green remodeling implementation strategy, one of the representative themes of the Green New Deal policy currently in force, and the methodology based on it were applied by expanding the generalized model results derived from a number of cases, and it is judged that when they are applied again to individual events (cases), there are feasibility problems.

To ensure the feasibility of the expected performance from applying the improvement elements for the performance of buildings undergoing green remodeling (improvement results in terms of the building value), it is judged necessary to clarify the scope and limitations of utilizing applicable elements for respective improvement purposes and then provide sufficient guidelines and examples regarding this, thereby setting a direction for helping to enhance the value of public buildings across the board through actual remodeling.

To demonstrate this argument, this study collected and analyzed data on the actual energy usage in public buildings, and also analyzed the relationship between the main application techniques of green remodeling and the actual amount of energy usage.

The analysis results are summarized as follows:

(1) The actual energy usage in aging existing public buildings shows a correlation of 0.06 with the insulation thickness closely linked to the outer skin insulation, whereas its correlation with the window area ratio and its correlation with the shade are 0.161 and 0.088 respectively, thus showing little correlation between them. Even when replacing fluorescent lights with LED lights, the correlation between the actual energy usage and them was found to be -0.216. It is likely that these figures have improved the living environment by adding energy capacity rather than by simply replacing existing equipment with high-efficiency equipment when remodeling aging building.

(2) The median actual energy usage in the group of public buildings after 2001 (Vintage Group 4) was found to be 114% higher as of 2015 and 85% higher as of 2016 than that of the group before 1979 (Vintage Group 1), which is expected to have aged the most.

(3) The groups of public buildings with high energy consumption were found to differ according to their aging by use of facilities: In cultural facilities, Vintage Group 3 used 215% more energy than Vintage Group 5. In educational facilities, Vintage Group 4 used 67% more energy than Vintage Group 5. In medical facilities, Vintage Group 4 used 177% more energy than Vintage Group 1. In business facilities, Vintage Group 1 used 235% more energy than Vintage Group 5. In training facilities, Vintage Group 2 used 403% more energy than Vintage Group 5.
(4) Actual energy consumption has decreased rapidly in public buildings in South Korea since 2017: The energy usage in Vintage Group 1 from 2017 to 2019 decreased by 30% from the median average in comparison with 2015 and 2016. The energy usage in Vintage Group 2 from 2017 to 2019 decreased by 64% from the median average in comparison with 2015 and 2016. The energy usage in Vintage Group 3 from 2017 to 2019 decreased by 54% from the median average in comparison with 2015 and 2016. The energy usage in Vintage Group 4 from 2017 to 2019 decreased by 64% from the median average in comparison with 2015 and 2016.

It is judged that such decreases in energy consumption were due to the Korean government's measures to reinforce energy conservation activities in the operation of the system, such as by designating more than one person as protectors of the energy of public buildings after the massive power outage in 2016. Based on the above-mentioned analysis results, our suggestions are as follows:

(1) The designation of public buildings subject to green remodeling should be evaluated in an integrated manner by preparing comprehensive value judgment criteria for buildings rather than starting with the oldest buildings.
(2) The green remodeling implementation strategy for public buildings should be carried out by preparing an integrated strategy implementation plan based on comprehensive value judgment criteria, such as by the use and purpose of buildings, rather than fragmentary strategies such as thermal insulation reinforcement and system repair or replacement with high-efficiency systems.
(3) The main users of public buildings are an unspecified number of citizens who use facilities and public officials who manage and operate facilities or perform public service activities. Therefore, in pushing ahead with green remodeling aimed at realizing zero-energy public buildings, it is necessary to set an essential and important goal of making it possible to maintain their basic value as public facilities which provide a pleasant thermal environment for the users of facilities, instead of one-sidedly focusing green remodeling only on the single purpose of reducing energy usage [35].

There are countries that recommend the implementation of/make it obligatory to implement thermal environment standards in office facilities under the policy initiative of government agencies, including the United States, France, Japan, Hong Kong, and China. According to the Energy Code in France, which makes it legally obligatory to implement such standards as Korea does, the scope of policy application regarding such standards also covers residential, office, and educational spaces in addition to the spaces of public institutions. However, the French policy is different from the Korean policy in that France makes it obligatory to implement only heating standards and regulates cooling so that the cooling system may operate only at a room temperature of 26 °C or above in accordance with Law R241-30 [36]. In the case of Japan and Hong Kong, indoor temperature limits in summer are being implemented on a pilot basis only in public institutions in accordance with government-made guidelines, and the two countries recommend that the eased indoor temperature regulations should be applied to shopping malls, general office facilities, etc. [37,38]. As for Korea's energy saving-related policies, including the Green New Deal policy, which are being pushed ahead with for the purpose of reducing the total amount of energy consumed in public buildings and also achieving a greenhouse gas reduction of 32.7% compared to the expected gas emissions of the building sector by 2030 in accordance with the emission targets of the greenhouse gas roadmap for the building sector on a broad basis, it is judged that the direction of policy promotion is focused on a somewhat biased goal in comparison with other advanced countries. It is not desirable that the value assessment criteria for aging buildings biased toward one goal of saving energy based on economic indicators become a single yardstick for assessing the value of public buildings through public use.

There is an ongoing policy that involves the application of a fragmentary value judgment criterion, i.e., whether to apply technical elements confined to the enhancement of the energy performance of target buildings and the prediction of improvement effects according thereto, thus resulting in the phenomenon of another important value criterion for green remodeling, i.e., the enhancement of the occupant (user) comfort in target buildings being neglected instead. In order to accurately grasp the current status of these problems and to promote 'expansion of the value judgment criteria for green remodeling' as an alternative, this study performed a comparison of various value judgment criteria and carried out correlation analyses, starting with a total analysis of energy-related data on buildings actually used by public institutions. The characteristics of energy usage were analyzed for each of the groups of buildings classified by their year of completion, thereby carrying out an analysis of the correlation between the non-architectural elements affecting the actual energy usage and the actual energy usage data. As a result of the relationship analysis, it was confirmed that the actual energy usage is more affected by the operating conditions of the relevant building than the application of individual strategic elements such as the performance of the envelope insulation and the performance of the high-efficiency system. In addition, it was also confirmed that the usage of public buildings does not increase in proportion to their aging. The primary goal of reducing energy usage in target buildings can be achieved if public sector (government)-led green remodeling is pushed ahead with in accordance with biased value judgment criteria, just as in the case of a campaign to refrain from operating cooling facilities in aging public buildings. On the other hand, however, it was possible to grasp through the progress of this study that it may also result in the deterioration of environmental comfort and stability, such as with the numerical value of the indoor thermal environment.

Seeking to reduce energy usage for the single purpose of saving energy in public buildings may be given a physical value in terms of energy cost, but it may also be directly connected to reduction in work productivity due to the uncomfortable heat sensation which public officials, the main users of public buildings, may experience and the inconvenience of ordinary citizens, an unspecified number of civilians who use public buildings. It should not be overlooked that the value of public buildings that can be lost due to the pursuit of one purpose of energy saving can be greater than the value of energy saving costs [39].

It is judged necessary to ensure that one purpose of green remodeling, which is to reduce energy usage in aging public buildings, and another purpose, which is to enhance their environmental performance for occupants' comfort, are mutually balanced and secured at the same time, thereby comprehensively evaluating alternatives for establishing a green remodeling strategy in the direction of enhancing the overall value of buildings and the performance of the detailed applicable elements of green remodeling accordingly, and then continuously proceed with the follow-up research proposed as a guideline.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Data crawling Python code for collecting energy data on public buildings

```
for bdgs_no in tqdm.tqdm(df_raw.index):
try:
sigunguCd = int(LocCd.loc[(LocCd['city, county, district name'] == df_raw.loc[bdgs_no, 'city,
county, district name']) &
(LocCd['raw rocation'] == df_raw.loc[bdgs_no, 'raw rocation']), 'city, county, district code'])
bjdongCd = int(LocCd.loc[(LocCd[' 'city, county, district name'] == df_raw.loc[bdgs_no, ' 'city,
county, district name']) &
(LocCd[' 'raw rocation'] == df_raw.loc[bdgs_no, ' 'raw rocation']), 'city, county, district code'])
bun = int(df_raw.loc[bdgs_no, 'top-street number'])
ji = int(df_raw.loc[bdgs_no, 'sub-street number'])
# electric charges api
# end_point = 'http://apis.data.go.kr/1611000/BldEngyService/getBeElctyUsgInfo'
# gas charges api
end_point = 'http://apis.data.go.kr/1611000/BldEngyService/getBeGasUsgInfo'
api_key = 'XXXXXXXXXXXXXXXXXXXXXXXX'
for Ym in ['20{}'.format(100*yr + mn) for yr, mn in product(range(17, 20), range(1, 13))]:
url = end_point + ?sigun-
guCd={:05d}&bjdongCd={:05d}&bun={:04d}&ji={:04d}&useYm={}&ServiceKey={}'.format(sigunguCd,
bjdongCd, bun, ji, int(Ym), api_key)
try:
reqURL = req.Request(url, headers={'User-Agent': 'Mozilla/5.0'})
response = req.urlopen(reqURL).read().decode('utf-8')
iter_tree = ET.fromstring(response).iter(tag='item')
for i in iter_tree:
df_raw.loc[bdgs_no, Ym] = float(i.find('useQty').text)
except urllib.error.HTTPError:
pass
except urllib.error.URLError:
pass
except ValueError:
pass
ed = time.time()
```

Appendix B

Table A1. Nominal variables converted into ratio scales for correlation analysis.

No.	Completion Time	Floor Area	Insulating Material (Resistance)	Insulation Thickness	Glass Types	Window Wall Ratio	Shading (Applicable or Not)	Ventilation (Applicable or Not)	LED (Applicable or Not)	Renewable System (Applicable or Not)	Energy Usage (kW/m^2)
1	1991	14,464	32	50	2	39	0	1	5	0	125
2	1988	7860	27	50	2	25	0	1	5	0	194
3	1992	5330	32	50	2	25	0	0	5	1	264
4	1993	6895	27	50	2	32	0	1	1	1	47
5	1979	8360	32	25	2	51	0	0	5	1	290
6	1989	722	32	40	2	23	0	1	5	0	45
7	1995	8684	27	50	2	36	0	1	1	0	210
8	1988	1697	32	50	4	35	0	0	5	0	60
9	1992	551	32	50	1	39	0	0	5	0	25
10	1989	400	32	40	4	32	0	0	5	0	57
11	2003	5867	32	60	1	34	0	0	5	0	60
12	1992	24,475	27	50	1	28	1	1	5	0	173
13	1993	7870	32	70	1	17	0	1	5	0	88
14	1981	5720	32	50	1	28	0	1	0	0	87
15	1982	9933	32	50	1	22	0	0	1	0	75
16	1997	6876	32	50	1	39	0	1	5	0	161
17	1989	6932	32	80	2	25	0	0	1	1	356
18	1982	6481	27	50	2	29	0	0	5	1	129
19	1997	5050	32	40	1	19	0	0	0	0	166
20	1997	240,951	28	50	1	41	0	1	5	0	162
21	1997	13,921	32	50	1	62	0	0	5	1	150

Table A1. *Cont.*

No.	Completion Time	Floor Area	Insulating Material (Resistance)	Insulation Thickness	Glass Types	Window Wall Ratio	Shading (Applicable or Not)	Ventilation (Applicable or Not)	LED (Applicable or Not)	Renewable System (Applicable or Not)	Energy Usage (kW/m^2)
22	1997	42,190	28	50	1	60	0	1	5	1	81
23	1978	3198	0	0	1	40	0	0	5	0	159
24	1995	6483	28	50	1	44	0	1	1	0	619
25	1997	8396	35	40	1	36	0	0	5	0	48
26	1989	4068	0	0	0	40	0	1	0	0	143
27	1981	4271	32	50	2	53	1	0	5	1	70
28	1977	2966	0	0	1	35	0	0	5	0	106
29	1984	6577	0	0	1	56	0	0	0	0	93
30	1995	9180	32	50	1	59	0	0	5	1	373
31	2003	3100	32	50	1	43	1	0	5	0	1045
32	1991	3315	0	0	1	24	1	0	5	0	34
33	1988	566	6	50	1	24	0	0	0	0	198
34	1981	3105	6	50	1	40	0	0	0	0	1529
35	1984	3533	32	50	2	31	0	0	5	1	194
36	1997	2237	6	0	1	33	0	0	5	0	92
37	1999	87,742	27	60	2	45	0	0	5	1	114
38	1988	1647	32	50	2	33	0	0	5	0	152
39	1977	2864	32	50	1	34	0	0	5	0	463
40	1993	19,270	32	50	1	33	0	1	1	0	367
41	1990	5443	28	50	3	46	0	0	1	0	487
42	1988	17,784	32	50	1	34	0	0	5	0	433
43	1985	731	32	50	1	24	0	0	5	0	433

Table A1. *Cont.*

No.	Completion Time	Floor Area	Insulating Material (Resistance)	Insulation Thickness	Glass Types	Window Wall Ratio	Shading (Applicable or Not)	Ventilation (Applicable or Not)	LED (Applicable or Not)	Renewable System (Applicable or Not)	Energy Usage (kW/m^2)
44	1995	19355	27	100	2	66	0	1	1	1	493
45	1996	9591	32	50	1	31	0	0	5	1	431
46	1985	7367	32	50	1	33	0	0	5	0	401
47	1989	495	6	20	2	32	0	0	5	0	454
48	1988	4124	32	50	2	13	0	0	0	0	336
49	1986	761	6	20	1	42	1	0	0	0	420
50	1994	1615	0	50	1	28	0	0	5	0	272
51	2003	630	32	50	2	25	0	0	1	0	396
52	1992	17,898	0	40	1	34	0	1	5	0	303
53	1992	17,898	0	40	1	34	0	1	5	0	303
54	1991	7357	0	40	1	24	0	0	5	0	251
55	1998	1016	0	30	1	22	0	0	1	0	249
56	1970	32,488	0	0	0	40	0	1	0	0	236
57	1994	6477	0	0	0	32	0	1	0	0	145
58	1987	21,240	0	0	0	40	0	1	0	0	180
59	1990	10,067	0	0	0	45	0	1	0	0	172
60	1999	34,460	0	0	0	40	0	1	0	0	275
61	1991	15,220	0	0	0	40	0	1	0	0	217
62	1980	13,062	0	0	0	40	0	1	0	0	367
63	2001	2191	0	0	0	31	0	0	0	0	505
64	1988	799	0	0	0	23	0	0	0	0	63

Table A1. *Cont.*

No.	Completion Time	Floor Area	Insulating Material (Resistance)	Insulation Thickness	Glass Types	Window Wall Ratio	Shading (Applicable or Not)	Ventilation (Applicable or Not)	LED (Applicable or Not)	Renewable System (Applicable or Not)	Energy Usage (kW/m^2)
65	1981	26261	32	50	2	40	0	0	0	0	324
66	1994	4396	27	100	2	40	0	0	0	0	321
67	1990	1424	32	50	2	40	0	0	0	0	389
68	1983	9345	32	50	2	40	0	0	0	0	333
69	1981	3369	0	0	1	40	0	0	0	0	405
70	1993	2655	0	0	2	40	0	0	5	0	256
71	1978	4546	0	0	2	40	0	0	0	0	408
72	1985	551	0	0	2	40	0	0	0	0	375
73	1990	2248	0	0	2	40	0	0	0	0	370
74	1977	3514	0	0	2	40	0	0	5	0	569
75	1997	3469	0	0	2	40	0	1	0	0	578
76	1982	13,605	0	0	2	40	1	0	0	1	324
77	1990	1739	32	50	2	40	0	0	0	0	309
78	1972	4563	32	50	2	40	0	0	5	0	266
79	1995	1896	32	50	2	40	0	0	5	0	337
80	1988	550	32	50	1	40	1	0	0	0	346

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