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A Study of CO_2 Emissions Reduction Effect in UK Non-Domestic Buildings according to Energy Performance Certificate Mandate

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Abstract: To establish effective policies for reducing CO_2 emissions in the building sector, it is essential to analyze the feasibility of regulations. In this regard this study seeks to analyze the effectiveness of Energy Performance Certificate (EPC), Display Energy Certificate (DEC), and Minimum Energy Efficiency Standard (MEES) regulations implemented in the UK. In particular, it analyzes the effectiveness in terms of mandatory issuance of the building energy rating certificates (i.e., EPC and DEC) and the minimum energy performance regulations (i.e., MEES regulation) of the building. To this end, the effectiveness of the system implemented in the UK was analyzed using 31,915 EPC and 31,715 DEC data. The analysis found that the CO_2 emissions of properties due to the EPC and DEP issuance obligations decreased further in 2022 than in 2013. It was also found that starting in 2018 when the MEES regulation was implemented, the CO_2 emissions by property type continued to decrease. This is because property owners were highly motivated to improve building energy performance due to the implementation of the MEES regulation. Therefore, it is expected that the findings of this study will serve as important basic data for the policymakers of the government to develop more effective building energy performance improvement policies.

Key words: CO_2 emissions; Energy performance certificate; Display energy certificate; Minimum energy efficiency standard, Effectiveness of the policy.

1. INTRODUCTION

According to the statistics of the European Union's energy-related greenhouse gas (GHG) emissions in 2021, the building sector is responsible for over 35% of the total GHG emissions [1]. In particular, GHG emissions from the building operational phase account for about 28% of the total [2]. To reduce the GHG emissions in the building sector, the world has established various policies and set up building energy efficiency targets [3]. In a related move, the South Korean government has made it mandatory for public buildings with a total floor area of 1,000m^2 or more to obtain the grade 5 of zero energy building (ZEB) certification (Energy production ratio based on energy consumption: 20% and building energy efficiency rating: 1++) since 2020, and considered expanding the scope of application. To track changes in building energy performance is an essential step to understand and achieve carbon neutrality [4, 5].

Previous studies carried out analysis to determine the effect on building energy rating certificates. Hong et al. (2018) analyzed the energy use patterns of public non-domestic buildings in the UK with DEC issued between 2010 and 2016 [4]. Francesca Pagliaro et al. (2021) investigated changes in the CO_2 emissions of residential and non-residential buildings due to the issuance of EPC in Italy from 2015 to 2020 [6]. However, in relation to building energy rating certificates, there is a lack of research to analyze changes in building energy performance over a long period of time. In particular, it is difficult to obtain data due to the recent implementation of ZEB certification in South Korea, which poses limitations in analyzing the effectiveness of the policy. Accordingly, this study seeks to indirectly confirm the effectiveness of the policy based on real data from the UK with the building energy rating certificates introduced. Also, it attempts to analyze the effects of reducing CO_2 emissions according to the mandatory issuance regulations of the building energy rating certificates (i.e., EPC and DEC) and the minimum energy performance regulations (i.e., MEES) of the building.

2. RESEARCH METHODS AND RESULTS

2.1 Establishment of the database

To analyze the effect of CO_2 emissions reduction due to the introduction of the building energy rating certificates in the UK, this study collected EPC and DEC data from the Energy Performance of Buildings (EPB) Register in Department for Levelling Up, Housing & Communities [7]. The scope of analysis was limited to the UK non-domestic buildings, including both EPC and DEC data. To conduct the longitudinal analysis, 215,496 EPC data and 61,415 DEC raw data were collected. However, raw data are highly vulnerable due to outliers, noise, and missing values. Therefore, in this study, data preprocessing is to be performed according to the following criteria. First, data from 2008, the first year of the EPC and DEC issuance, is excluded from the analysis. This is because the problems of data uncertainty are likely to occur in the first year of implementation of the building energy rating certificates [8]. Second, because this study aims to analyze changes in CO_2 emissions according to regulations pertaining to the mandatory issuance of the EPC and DEC, property data with the EPC and DEC issued voluntarily are excluded. Third, only properties that use the fossil fuel based-heating system are included in the analysis. This is because, unlike in the fossil fuel based-heating system, heating energy use patterns may vary in the electric heating system [4]. Fourth, EPC or DEC, which contains uncertain data such as missing values or errors, is excluded [4]. Finally, a boxplot outlier method was used to remove statistical outliers [9]. When the CO_2 emissions($kgCO_2/m^2 \cdot yr$) of EPC and DEC certificate data are outside the upper inner fence(i.e., $Q_3 + 1.5 \cdot$(interquartile range)) and lower inner fence(i.e., $Q_1 - 1.5 \cdot$(interquartile range)), the corresponding values were determined as outliers (refer to Eq. (1)). As a result, 215,496 EPC data and 61,415 DEC data were filtered into 31,915 EPC data and 31,715 DEC data, respectively (refer to Table 1).

$$X_0 < Q_1 - 1.5 \times IQR \cup X_0 > Q_3 + 1.5 \times IQR \quad (1)$$

Where, X_0 is the outlier data, Q_1 is the lower quartile (25th percentile), Q_3 is the upper quartile (75th percentile), and IQR is the interquartile range.

Table 1. EPC and DEC data collction and filtering

Class	Number of EPC data	Number of DEC data
Raw data	215,496	61,415
Filtered data	31,915	31,715

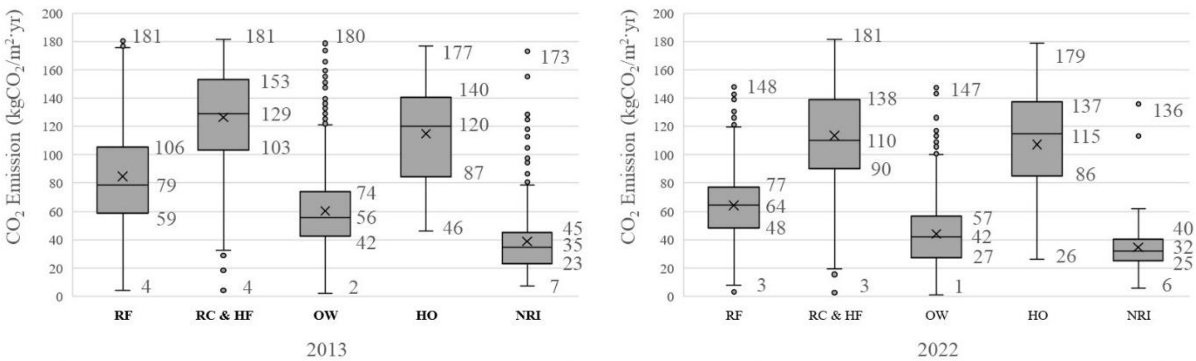
2.2. Variations in CO_2 emissions according to the issuance of EPC and DEC

Table 2 shows the trend in average asset rating changes by property type according to EPC issuance from 2013 to 2022. In the short term, the average asset rating by property type showed increasing and decreasing trends. However, in the long term, the average asset rating by property type decreased by an annual average of 0.8% (i.e., Non-residential Institutions – Education building (NRI) to 4.3% (i.e., Retail and Financial/Professional servies (RF)), thus improving the building energy performance. Accordingly, as shown in Figure 1, CO_2 emissions by property type were found to decrease further in 2022 than in 2013. That is, the reduction rate of the CO_2 emissions was the highest in the offices and Workshop businesses building (OW) (i.e., 24.8%), followed by RF (i.e., 18.1%), Restaurant and Cafes/Drinking Establishments and Hot Food takeaways buildings (i.e., 14.9%), NRI (i.e., 7.3%), and Hotel (i.e., 4.5%). This is because the design standards related to the building energy efficiency in the UK were continuously strengthened during the analysis period [10].

Table 2. Trend in average asset rating changes by property type according to EPC issuance

Property type	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
RF	84	81	77	78	77	70	65	64	64	56	-4.3%
RC&HF	76	75	76	74	74	65	63	64	60	60	-2.7%
OW	99	95	101	94	91	88	82	82	77	73	-3.4%
HO	58	55	56	51	54	53	47	54	52	49	-1.8%
NRI	71	51	61	52	55	62	60	55	61	66	-0.8%

Note. RF is the retail and financial/professional servies; RC&HF is the restaurant and cafes/drinking establishments and hot food takeaways; OW is the offices and workshop businesses; HO is the hotels; and NRI: Non-residential Institutions – Education.



Note. RF is the retail and financial/professional services; RC&HF is the restaurant and cafes/drinking establishments and hot food takeaways; OW is the offices and workshop businesses; HO is the hotels; and NRI: Non-residential Institutions – Education.

Figure 1. CO_2 emissions changes by property type following the issuance of EPC

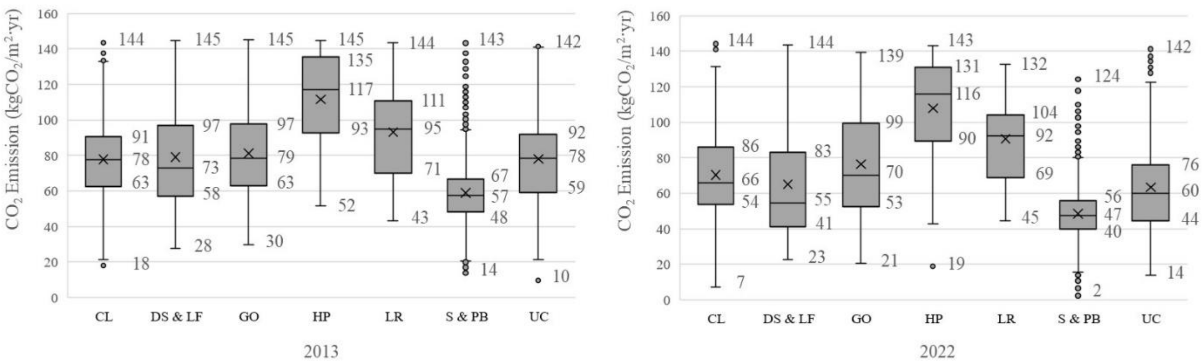
Table 3 shows the trend in average operational rating changes by property type according to DEC issuance from 2013 to 2022. In the short term, the average operational rating by property type showed increasing and decreasing trends. However, in the long term, the average operational rating by property type decreased by 0.5% to 2.2% for five property types (i.e., clinic (CL), dry sports and leisure facility (DS&LF), general office, schools and seasonal public buildings, and university campus), whereas it increased by 0.1% to 0.3% for two property types (i.e., hospital-clinical and research (HP), and long term residential (LR)). As shown in Figure 2, CO_2 emissions of all property types decreased further in 2022 than in 2013. However, the reduction rate of CO_2 emissions for five property types with the operating rating decreased ranged from 14.9% (i.e., CL) to 25.0% (i.e., DS&LF)), while that of CO_2

emissions for two property types with the operating rate increased ranged from 1.3% (i.e., HP) to 2.8% (i.e., LR). The operational rating is calculated as the ratio of CO_2 emissions in the target building to the standard CO_2 emissions. Because of this, the relatively small CO_2 emissions reduction rate has no significant impact on reducing the average operational rating. For example, if CO_2 emissions per unit area of 'A' building, the HP type, is 115.09 $kgCO_2/m^2 \cdot yr$ in 2013, the operational rating is calculated at 95 points. However, even when CO_2 emissions per unit area of 'A' building is 114.54 $kgCO_2/m^2 \cdot yr$, a 0.5% decrease from 2013, the operational rating is the same as 95 points.

Table 3. Trend in average operational rating changes by property type according to DEC issuance

Property Type	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	CAGR
CL	97	100	96	96	93	94	102	95	98	89	-1.0%
DS& LF	60	59	60	58	55	53	55	51	44	50	-2.2%
GO	101	105	102	103	105	98	103	99	98	97	-0.5%
HP	86	92	80	82	81	87	92	86	80	87	0.1%
LR	81	81	79	78	85	84	89	84	78	83	0.3%
S&PB	110	110	108	104	105	103	101	97	93	97	-1.4%
UC	81	88	80	77	73	76	75	73	69	72	-1.4%

Note. CL is the clinic; DS&LF is the dry sports and leisure facility; GO is the general office; HP is the hospital – clinical and research; LR is the long term residential; S&PB is the schools and seasonal public buildings; UC is the university campus; and CAGR is the compound annual growth rate.



Note. CL is the clinic; DS&LF is the dry sports and leisure facility; GO is the general office; HP is the hospital – clinical and research; LR is the long term residential; S&PB is the schools and seasonal public buildings; UC is the university campus.

Figure 2. CO_2 emissions changes by property type following the issuance of DEC

2.3. Analysis of the trend in CO_2 emissions changes according to the implementation of MEES regulation

This study seeks to analyze changes in CO_2 emissions and average asset ratings due to the application of the MEES regulation. To this end, properties with EPC issued for the purpose of rent among the 31,915 EPC data were determined as be the subjects of analysis. Also, in order to eliminate uncertainty in the analysis results, two type of properties (i.e., hotels and NRI) whose total number of data was less than 50 were excluded from the analysis. As a result, a total of 16,829 EPC data (RF: 4,374, RC&HF: 10,417, and OW: 10,417) were used for analysis (refer to Table 4).

Table 5 shows the trend in average asset rating changes by property type according to MEES implementation. When compared to the asset rating before the implementation of MEES (2013~2017), the asset rating after the implementation of MEES (2018~2022) decreased by 15.2% (i.e., OW) to 17.3% (i.e., RF). In particular, as shown in Table 6, the annual average CO_2 emissions before the implementation of MEES (2013~2017) was calculated at -0.2% to 1.1%, whereas the annual average CO_2 emissions after the implementation of MEES (2018~2022) was calculated at -3.5% to -6.3%, showing a rapid decrease in CO_2 emissions after the implementation of MEES. This in turn suggests that the minimum energy performance regulation of the building is effective.

Table 4. Overview of data by property type for analyzing the effects of MEES regulation

Property Type	Number of data	Proportion
Retail and Financial/Professional servies (RF)	4,374	26%
Restaurant and Cafes/Drinking Establishments and Hot Food takeaways (RC&HF)	2,038	12%
Offices and Workshop businesses (OW)	10,417	62%
Total	16,829	100%

Table 5. Trend in average asset rating changes by property type according to MEES implementation

Property Type	Asset rating before the implementation of MEES (2013~2017)	Asset rating after the implementation of MEES (2018~2022)	Rate of change (%)
RF	81	67	-17.3%
RC&HF	74	62	-16.2%
OW	99	84	-15.2%

Note. PT is the property type; RF is the retail and financial/professional servies; RC&HF is the restaurant and cafes/drinking establishments and hot food takeaways; and OW is the offices and workshop businesses.

Table 6. CO_2 emissions changes by property type according to MEES regulation implementation

Property Type	Asset rating before the implementation of MEES						Asset rating after the implementation of MEES					
	2013	2014	2015	2016	2017	CAGR	2018	2019	2020	2021	2022	CAGR
RF	79	83	86	82	82	1.1%	76	72	69	67	65	-3.9%
RC&HF	129	133	136	131	135	1.1%	127	121	122	119	110	-3.5%
OW	56	57	62	58	55	-0.2%	54	49	47	45	42	-6.3%

Note. PT is the property type; RF is the retail and financial/professional servies; RC&HF is the restaurant and cafes/drinking establishments and hot food takeaways; and OW is the offices and workshop businesses.

3. CONCLUSION

To achieve carbon neutrality goals, countries worldwide are making various institutional efforts to reduce energy consumption during the operational phase of buildings. The South Korean government has implemented building energy rating certificates represented by ZEB certification since 2017, which poses limitations in analyzing the feasibility of the policy. In this regard, this study seeks to analyze the effect of introducing EPC, DEC and MEES regulations implemented in the UK, and to indirectly confirm the effectiveness of building energy rating certificates implemented in South Korea. To this end, this study collected 215,496 EPC and 61,415 DEC data from EPB, and the results are as follows. First, the CO_2 emissions of properties, which require mandatory issuance of the EPC and DEC, decreased further in 2022 than in 2013. The CO_2 emissions according to EPC issuance decreased from 4.5%(i.e., Hotels) to 24.8% (i.e., OW), while the CO_2 emissions according to DEC issuance decreased from 1.3% (i.e., HP) to 25.0% (i.e., DS&LF). This is because the building energy efficiency-related design standards were continuously strengthened during the analysis period. Second, the effectiveness of the MEES regulation in the UK, which prohibits the rent of properties below the EPC 'E' grade, was analyzed, and it was found that the CO_2 emissions by property type decreased by 18.3 to 20.8% before and after the implementation of the MEES regulation. In conclusion, the effect of CO_2 emissions reduction was obvious both in terms of mandatory issuance of the building energy rating certificates (i.e., EPC and DEC) and in terms of the minimum energy performance regulation (i.e., MEES regulation) of the building. In particular, it can be confirmed that the effect of the minimum energy performance regulation of the building was significant as CO_2 emissions decreased rapidly after the implementation of MEES. This suggests that a system to regulate building energy performance can have a positive impact on the reduction of national building energy. The findings of this study are expected to serve as important basic data for the policymakers of the government to understand the carbon neutrality goal and develop effective measures to improve building energy performance.

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