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Impact of Adding Comfort Cooling Systems on the Energy Consumption and EPC Rating of an Existing UK Hotel

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Abstract: In light of the recent launch of the Minimum Energy Efficiency Standard and its expected impact on the commercial buildings sector, this study investigated the impact of adding cooling systems on the annual energy consumption, carbon dioxide emissions and energy performance certificate (EPC) rating of an existing UK hotel. Thermal Analysis Software (TAS) was used to conduct the study, and the baseline model was validated against the actual data. As is the current accepted procedure in EPC generating in the UK, the cooling set points of the guest rooms were set to 25 °C, resulting in a small increase in the annual energy consumption and emission rates, but not enough to change the energy performance certificate rating. Also, it was found that an improvement in energy consumption and energy performance certificate rating of the hotel would be achieved if the new systems replaced the existing heating systems in the guest rooms. Further simulations investigated more realistic situations, in which occupants may decide to keep their rooms at cooler temperatures. The results from this round of simulations showed considerable increase in the energy consumption and emissions of the building; however, these results would not be considered in the current approved procedure for EPC generating.

Keywords: MEES; EPC rating; hotels; cooling systems; cooling set points; CO_2 emissions

1. Introduction

1.1. Overview

In recent years, with the growing concern over the potential impacts of global warming, the UK government, alongside other European countries, has announced its commitment to the goal of 80% reductions in greenhouse gas (GHG) emissions by 2050, compared to the levels of GHG emissions in the 1990s [1]. As one of the main means of reducing GHG emissions is efficient use of energy [2], high levels of energy efficiency need to be pursued in different sectors. However, with a share of 40% of total energy consumption in the European Union (EU) [3–5] and a 19% share of global energy-related GHG emissions in 2010 [6], the building sector has huge opportunities for contributing towards GHG emission reductions [7–9]. In recent years, energy labelling for domestic and commercial buildings has become compulsory in different countries in the EU as a step forward [10].

Alongside other EU members, the UK government has set stricter energy efficiency requirements for both new and existing buildings, in order to tackle the issue of climate change. One of the most recent requirements, targeting mostly the existing buildings, came into effect in April 2018. It is called the Minimum Energy Efficiency Standard (MEES) and it requires the owners of commercial buildings to ensure an energy performance certificate (EPC) of minimum E or above for the property, before they can sell it or make a new lease on it [11].

Within the commercial sector, hotels are one of the types being affected by this new legislation. With their constant operation and ongoing need for heating/cooling and hot water, the challenge to provide high quality indoor environment and the guests' expectations for different services, hotels tend to be very energy intensive [12,13]. This high level of energy consumption results in high CO_2 emission rates for hotel buildings [14,15].

As the optimum goal in the hospitality industry is guests' comfort [16], hoteliers might take extra measures for ensuring high levels of satisfaction among their customers in the hope of future revisits and positive recommendations and feedback. Additionally, there is evidence that the occupants at a hotel (guests) tend to develop more extravagant patterns of energy consumption during their stay as opposed to more energy-considerate choices at their own homes [17,18]. It therefore remains a challenge to hotel owners/managers to meet guests' comfort while meeting the new strict requirements.

1.2. Energy Performance Certificate (EPC)

The EPCs are tools for comparing the energy performance of comparable buildings and they can send market signals to potential buyers and tenants about what the heating, cooling and lighting bills of a particular building will be like [19]. EPCs are the key players in mapping and identifying the energy performance of building stock in different countries [20]. They are an integral part of the Energy Performance Building Directive (EPBD)—introduced in 2002 and revised in 2010—and are currently a good source of information about the energy consumption and the impact of energy efficiency improvement works all over Europe [21]. The EU Parliament defines EPC as "a certificate recognised by the Member State or a legal person designated by it, which indicates the energy performance of a building or a building unit calculated according to a methodology" [22] (p. L153/18) based on a general framework discussed later in the Directive.

The approaches towards data collection, as well as generating EPCs and deciding on the parameters to include, differ from one country to another [23–25]. As an example, in Swedish EPC procedure, measured energy use and data on the energy bills are included [3,26,27]. In the UK, the process of generating EPCs—which became mandatory in 2008—is carried out under the guidelines of the National Calculation Methodology (NCM). A brief summary of EPC generating process in the UK is presented in the following section.

1.3. EPC Generating Process in the UK

In the UK, a factor called Asset Rating (AR) is considered when generating EPCs. The AR rates the CO_2 emissions from the 'actual' building according to a Standard Emission Rate (SER). SER is calculated by applying a fixed factor to the emission rate from the 'reference' building, which is a building with the same size, orientation and zoning arrangement as the actual building. For the consistency of comparable buildings' EPCs, there are some default specifications for the reference building. For example, irrespective of the situation in the actual building, there are set assumptions for the cooling systems and fuel type in the reference building. Full description of reference buildings' specifications can be found in the NCM Modelling Guide [28].

The reference building emission rate (RER) that is calculated by applying the specific factors described fully in NCM Modelling Guide is adjusted by a factor of 23.5%. The resulting parameter is translated into SER, as seen in Equation (1):

$$SER = RER \times 0.765 \quad (1)$$

The next step toward generating the EPC is calculating the AR, which needs a normalizing factor of 50. In equation 2, BER is the actual building's emission rate:

$$AR = BER/SER \times 50 \quad (2)$$

Based on the results from Equation (2), the EPC rating of the building will be generated as shown in Table 1.

Table 1. EPC rating bands (England and Wales) [28].

Scale	EPC Band
$0.00 \leq AR \leq 25.0$	A
$25.0 < AR \leq 50.0$	B
$50.0 < AR \leq 75.0$	C
$75.0 < AR \leq 100.0$	D
$100.0 < AR \leq 125.0$	E
$125.0 < AR \leq 150.0$	F
$150.0 < AR$	G

1.4. Existing Literature

Since their introduction in the EPBD in 2002, studies have been carried out regarding different aspects of EPCs. A brief summary of some of these studies is presented in the following paragraphs.

Arcipowska et al. [21] carried out extensive research on different national approaches around the EU for lodging and registering the EPCs. In their research, they labelled the EPCs as an information and marketing tool for those involved in the real estate sector. Fuerst et al. [10] named the EPC a tool to be used for a combination of marketing and policy. In their large-scale study of more than 300,000 dwellings in the UK, they found that there was a positive correlation between the EPC rating of a dwelling and its price per square meter [10]. Contrary to this finding, an earlier study on 708 commercial properties in the UK could not find any impact from EPC ratings on the market, rental or capital values of the properties [29]. Another study suggests that while the EPC ratings might be of interest to some people, they are far from having a heavy impact on the purchase of a property (dwelling) [24].

Despite appreciation of the EPC as a policy tool, some studies have questioned the effectiveness of EPCs in contributing to improving actual energy efficiency. These studies claim that the mere act of generating and acquiring an EPC is not enough, and that in order to improve the energy efficiency beyond theoretical values, the EPCs need to be applied within specific frameworks [7,24]. Some other studies suggest that although noncompliance could still be observed in some cases, overall the building codes imposing EPCs have been successful in reducing the measured energy consumption in all building categories, including schools, hotels, multidwelling buildings and healthcare facilities [26]. The impact of applying selected measures for improving the energy efficiency and EPCs of 24 dwelling typologies in Greece was investigated by Droutsa et al. in 2014 [30]. Based on the available data to the national database, the study focused on reducing heating (space heating and domestic hot water) energy consumption. The choice of measures was based on low investment costs and short payback time.

The process of generating EPCs involves independent energy assessors evaluating the property, followed by the use of software to conduct a thermal analysis of the building based on a set of input data. The energy assessors' evaluation and judgment of the building's performance can affect the EPC and subsequently the building's financial value [31]. In a study carried out in 2012 in Italy, 162 energy assessors were asked to evaluate the energy performance of one building—a residential one-floor building—through selected accredited software. The study found that out of the 162 results, no two numerical values were the same. One of the potential reasons behind this was attributed to how each participant interpreted the input data. However, around 72% of the assessors found the EPC rating of the building to be D [31]. It is also important to mention that the EPC rating scale used in this study is based only on energy performance indices of heating and domestic hot water. Similar to the previous study, Jenkins et al. [32] studied the consistency of EPCs generated in the UK for a number of dwellings by using the approved software Standard Assessment Procedure (SAP). The study found that subjective judgments from different assessors can change the results, to an extent where assessments from different assessors on the same property varied noticeably in terms of EPC ratings.

Balaras et al. [20] compared the existing EPCs with the actual energy consumptions of 8,500 Hellenic dwellings, divided to several groups based on their typologies. They found that the calculated energy consumptions overestimated the actual energy consumption by 44% on average. Some studies demonstrate that in energy efficient buildings, the EPC is likely to underestimate the heating energy consumption, while in energy-inefficient buildings (i.e. buildings with poor energy efficiency) the EPC tends to overestimate the heating energy consumption [7,33]. It has been claimed by one study that a dwelling with a good EPC rating does not necessarily function as a low-energy property [7].

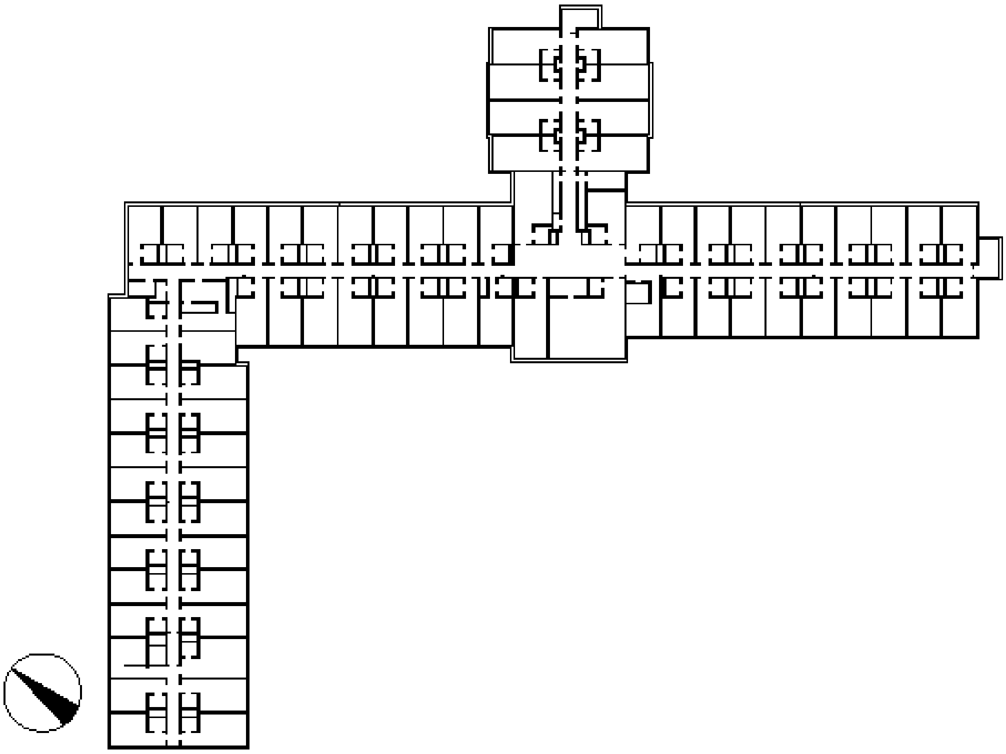
As shown in the short summary above, the existing literature about energy performance certificates offer contradictory ideas about applicability and reliability of EPCs and how much they contribute to energy savings in reality. Also, the existing literature is mostly focused on domestic buildings and housing stocks around the EU, and research concerning the commercial building sector is relatively scarce. This can be partly explained by the fact that until recently, commercial buildings' contribution to total energy consumption in the EU has been half of the contribution made by domestic buildings—11% and 23%, respectively [34]. This paper intends to contribute to these gaps through the following:

- Investigating the potential impact on the EPC of an existing hotel—a commercial building—when cooling systems are added to its guest rooms; and
- Further discussing whether the change to EPC (or lack thereof) reflects real situations with regards to MEES requirements.

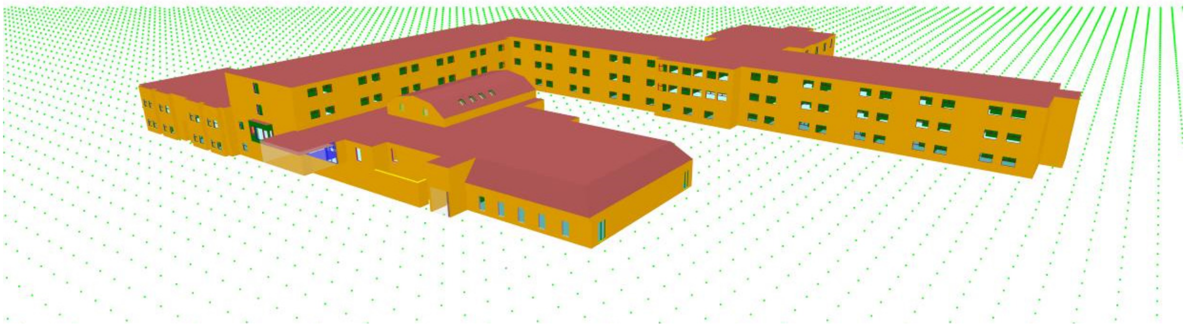
2. Materials and Methods

This section begins by investigating the EPC rating of an existing UK hotel in its current condition. Based on the actual situation of the building, the impact of adding cooling systems to the guest rooms on the building's holistic energy consumption and its EPC rating was investigated. This was due to the recent feedback from guests complaining about the lack of comfort cooling systems in the guest rooms. In order to carry out the study, the hotel building in its current condition was modelled in EDSL TAS V.9.4.4 software, a product of the Environmental Design Solutions Limited [35]. Equipped with different modules such as 3D Modeller, Ambiens, Building Simulator and UK Building Regulation 2013 Studio, the software simulated the thermal performance of the building based on the input data and predicted the energy consumption of the hotel in its current situation. This formed the baseline model. Further details about the software can be found in the works of Rotimi et al. and Amoako-attah and B-Jahromi [17,36]. The estimated energy consumption was then validated against the actual energy consumption of the hotel to ensure the reliability of the baseline model for further analyses.

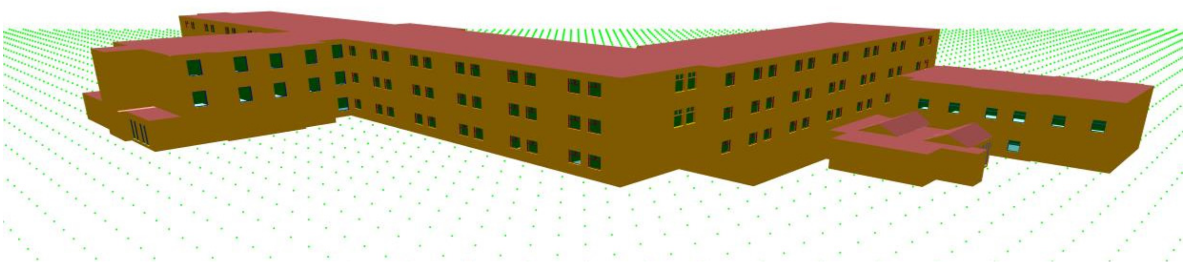
The hotel is in Watford, Hertfordshire and was built in early 1970s. The total floor area of the building is around 10,000 m^2, constructed in four levels. The lower ground floor level accommodates areas such as the kitchen, restaurant and bar, meeting rooms and a function room. The upper ground floor—the entrance level—accommodates reception and lounge area, conference rooms, and a gym. The 200 guest rooms are spread over upper ground floor, first and second floor. Twenty guest rooms have access to both heating and cooling through split units, and in the rest of the guest rooms there are no cooling systems. Heating to these guest rooms are provided through oil-filled radiators, electrical radiators and wet central radiator systems. Restaurant and bar areas receive heating and cooling through an air handling unit and an air-cooled scroll chiller, respectively. Other areas such as the meeting rooms, offices, reception and gym use split and multi split air conditioning units for both cooling and heating. Gas-fired boilers provide the building's domestic hot water (DHW). The building is not sealed and there is a double-glazed window set in every guest room (1.5 m wide and 1.15 m long), with two small openable parts on top. Figure 1 shows the building geometry and the first floor's plan.



(a) First floor plan.



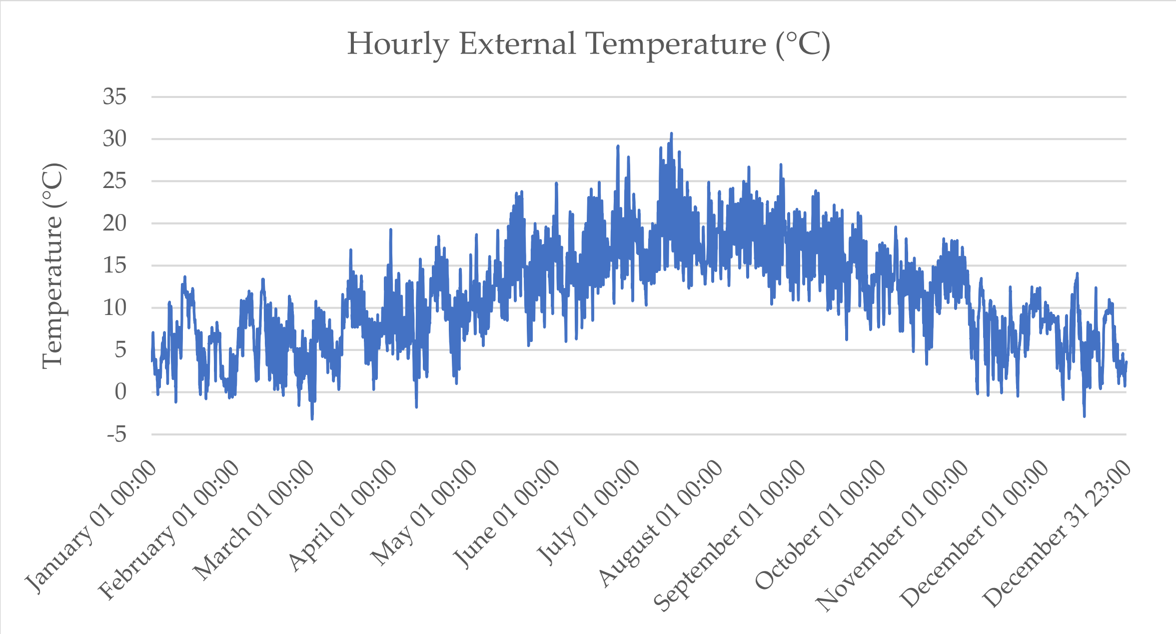
(b) Front view to the building.



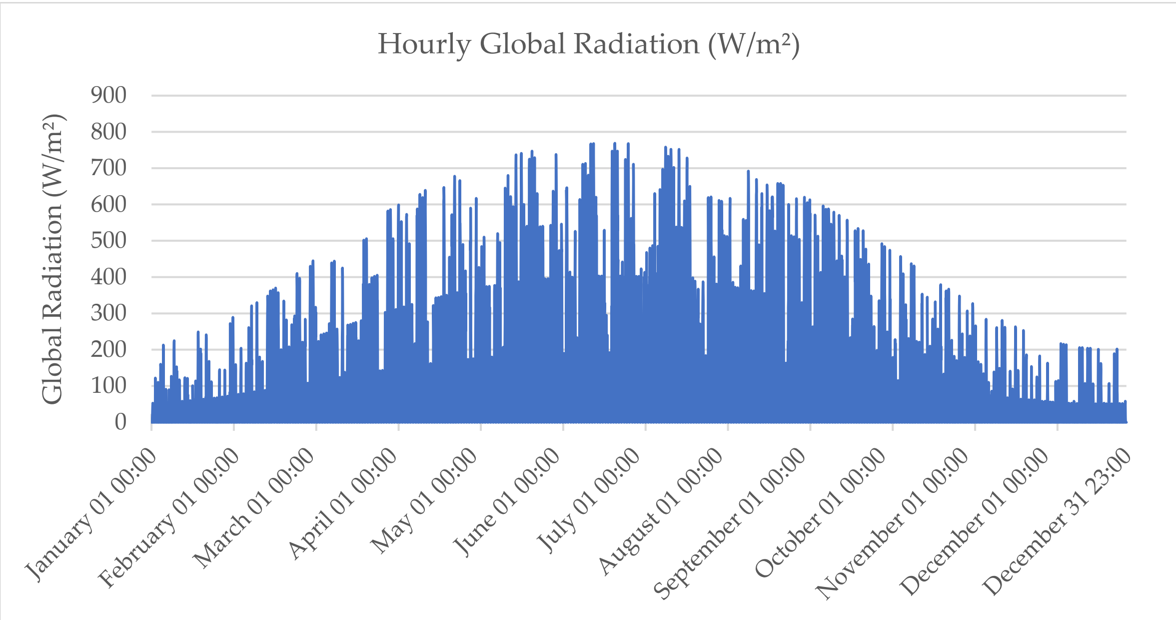
(c) Back view to the building.

Figure 1. Floor plan and views to the building geometry.

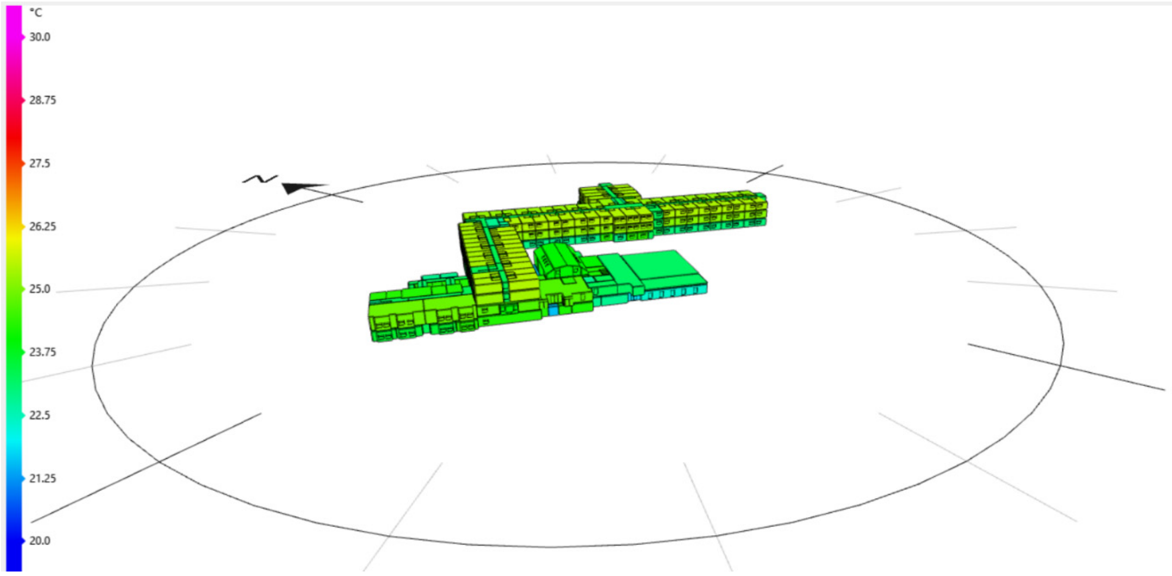
In order to simulate the energy consumption, Thermal Analysis Software (TAS) needs weather data. Test Reference Year (TRY) and Design Summer Year (DSY) weather files are compatible with TAS. While TRY files are used for predicting average energy consumption and compliance with the UK building regulations [37,38], DSY files are used for overheating analysis [38]. The hotel is less than 15 miles from central London; therefore, London TRY was used as the weather file, which was fully adopted without any alterations [39]. The minimum and maximum external temperatures are −3.2 and 30.7 ºC, occurring at March 2nd and July 14th respectively. Figure 2 shows some of the graphs related to this weather file.



(a) External temperature.



(b) Global radiation.



(c) 3D visualization of the resultant temperature when the highest external temperature (30.7 °C) occurs at July 14th, 17:00.

Figure 2. Weather specification from London TRY weather file.

In order to predict the energy consumption of the building, the software needed input data about the internal conditions of each thermal zone and occupancy profiles, which subsequently affect lighting and heating profiles. In order to overcome some limitations in collecting actual occupancy profiles and internal conditions of different spaces within the hotel, NCM's standard profiles for hotels were used fully and without any alterations. A summary of the simulation assumptions is presented in Tables 2 and 3.

Table 2. The National Calculation Methodology (NCM) standard profiles for hotels [40].

Zone	Metabolic rate (W/p)	People Density (per.m^2)	DHW (l/d/m^2)	Room illuminance (lux)
Changing area	140	0.119	120	100
Circulation	140	0.114	0	100
Eat/drink area	110	0.187	8	150
Ensuite bedroom	104	0.094	13.12	100
Fitness/gym area	300	0.140	0	150
Food prep/kitchen	180	0.108	0.33	500
Hall	140	0.183	0.6	300
Laundry	180	0.121	0	300
Office	123	0.106	0.22	400
Plant	180	0.11	0	200
Reception	140	0.104	0.03	200
Store	140	0.11	0	50

Table 3. Summary of the simulation assumptions: building fabric specification.

Building element	Calculated area-weighted average U-Values (W/m^{2}K)
Wall	1.45
Floor	0.84
Roof	1.99
Window	2.61

3. Results

3.1. Baseline Model

As it is a common practice within modeling and simulation studies, the first step was to model and simulate the building in its existing condition and estimate and validate its energy consumption. Results from TAS simulations accounted for heating, cooling, DHW, lighting, equipment and auxiliary energy consumption. Figure 3 shows a breakdown of energy consumption estimated by TAS. As it is shown, with the hotel being in a heating dominant area, most of the energy consumption goes towards heating and DHW. Another point to be considered is that despite several areas, e.g., restaurant, halls and offices, having access to the cooling systems, the amount of energy consumed for cooling is less than 2% of the annual energy consumption.

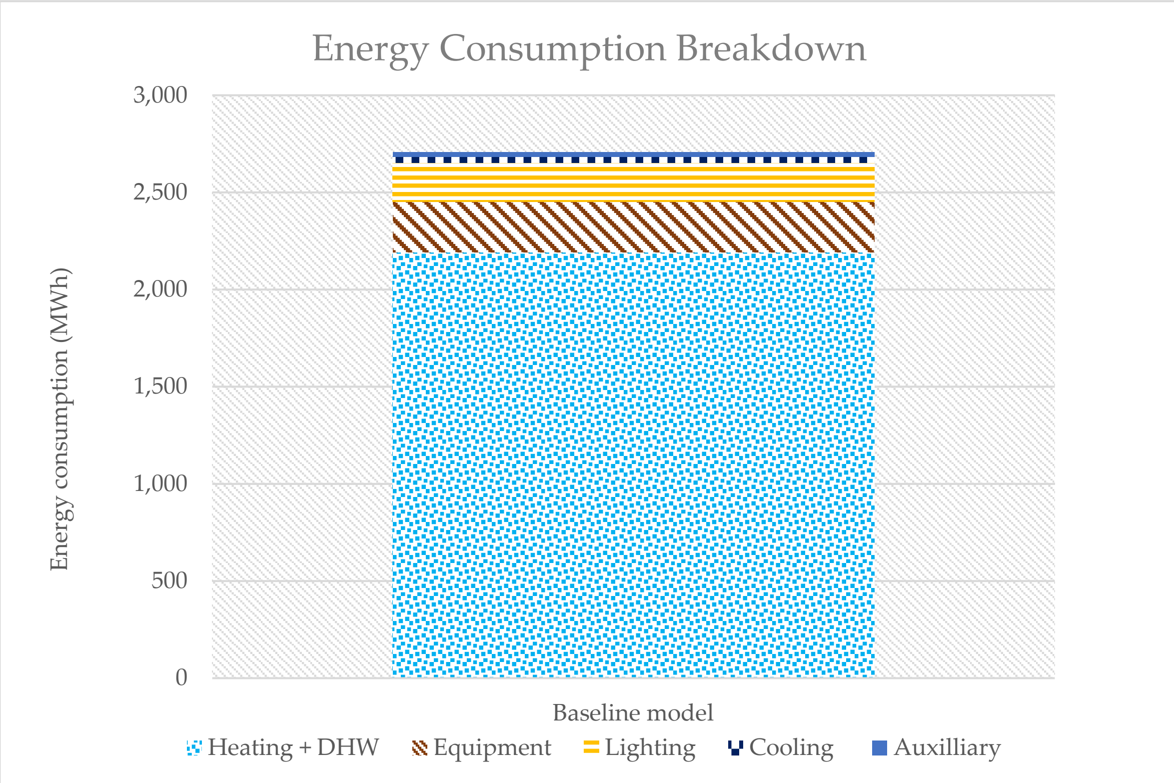


Figure 3. Energy consumption breakdown of baseline model.

As briefly mentioned in the previous section, the baseline model needed to be validated against the actual energy consumption data to ensure that it was reliable and made a robust foundation for further analysis. The process of validation was based on comparing the estimated values against the actual consumptions. The actual energy consumption of the hotel varies from one year to another, (Figure 4), due to changes in weather situation and occupancy rates. In the case of significant difference between annual consumptions from one year to another, e.g., when extreme weather conditions occur, using the average annual consumption can be a better choice for validating the simulated/estimated data [41].

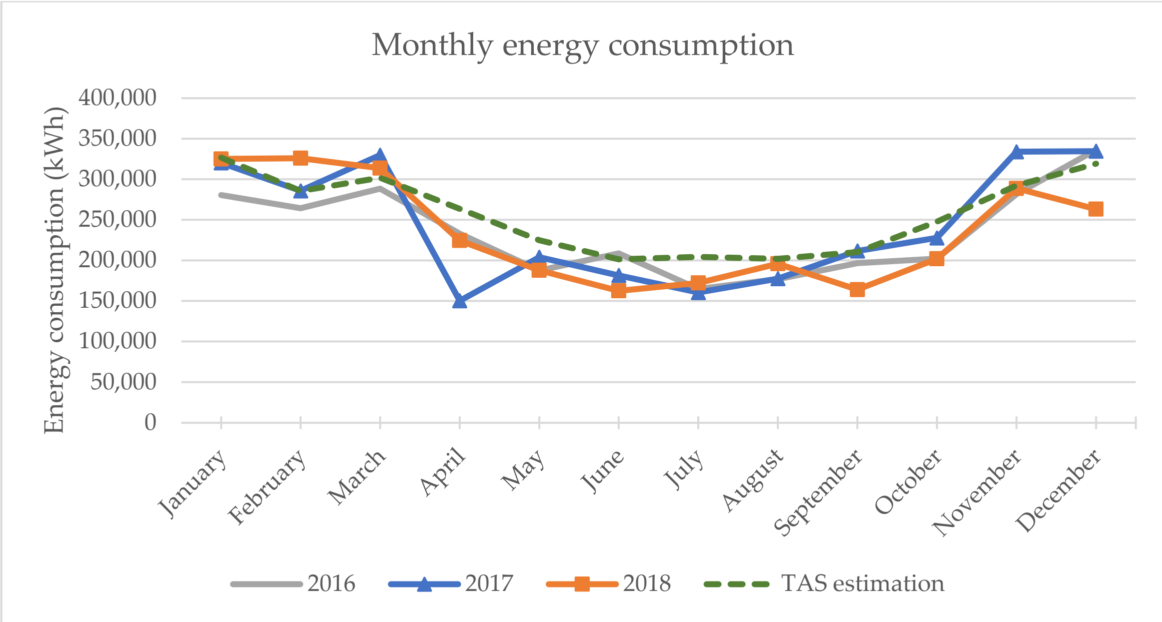


Figure 4. Actual and estimated energy consumption of the hotel.

According to the guidelines for simulation validations [42], two statistical indicators are needed for simulation validations: mean bias error (MBE), and coefficient of variation of the root mean square error Cv(RMSE). While the first one shows how close the estimated values are to the measured data, the latter accounts for cancellation error (impact of positive and negative errors), see Equation (3) and Equation (4).

$$MBE_{(\%)} = \sum_{i=1}^{Np}(Si - Mi) / \sum_{i=1}^{Np}(Mi) \quad (3)$$

$$Cv(RMSE)_{(\%)} = \frac{\sqrt{\sum_{i=1}^{Np}(Si - Mi)^{\wedge}2/Np}}{Mav} \quad (4)$$

where Si and Mi are simulated and measured data points, respectively. Np is the number of data points at interval p, i.e., $N_{monthly}$=12. M_{av} is the average of measured data.

The acceptable ranges for monthly values of MBE and Cv(RMSE) are ±5% and 15% respectively; however, as this is the acceptable tolerance for locations with the weather data available for the exact location, slight exceedance for the case of this study should be acceptable (see Table 4).

Table 4. Calibration indicators for the simulation.

	2016	2017	2018
MBE	9.2%	5.5%	9%
Cv (RMSE)	12.3%	16.5%	14.8%

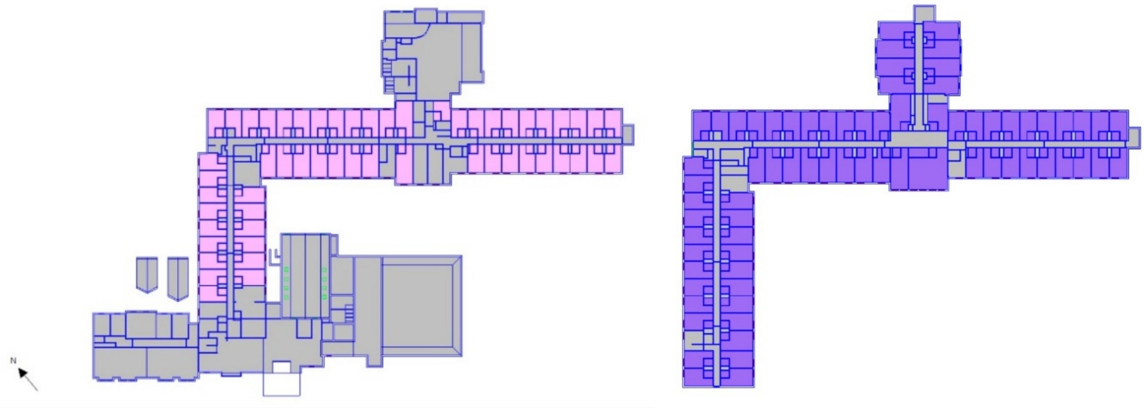
Having carried out the thermal analysis of the hotel in its existing condition, the EPC rating of the hotel was calculated as band B, with a numerical value of 47 and a total annual CO_2 emission rate of 89.27 Kg/m^2.

3.2. Model with Cooling Systems for Guest Rooms

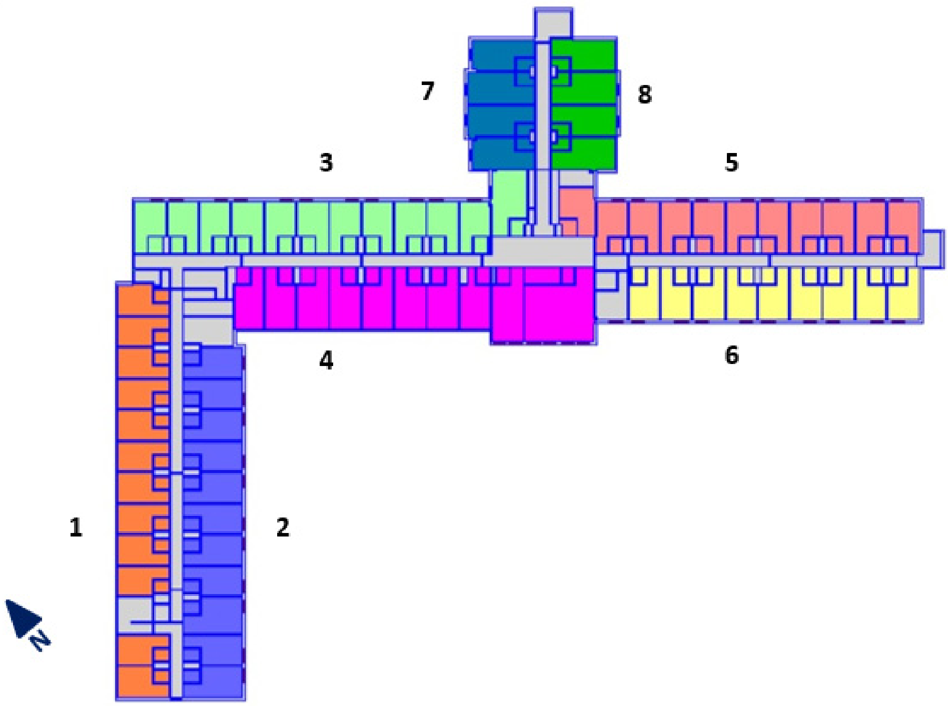
In recent years, the hotel management has received feedback from its guests about thermal discomfort during summer in guest rooms. In order to attend to guests' comfort, adding cooling systems to the guest rooms has been brought up as an option. However, its impact on energy consumption and the building's EPC has been a matter of concern.

In order to estimate the extra energy consumption caused by adding cooling systems to the guest rooms, the cooling load of these areas needed to be calculated. Cooling load is "the rate of energy removal required to maintain an indoor environment at a desired temperature and humidity condition" [43] (p.18.1). In order to calculate the cooling load, the gains from the following factors needed to be considered: solar, lighting, infiltration and ventilation, air movement, building heat transfer, external conduction and sensible occupancy and equipment gains. Among these factors, those determined by the NCM standard internal conditions, i.e., lighting, occupancy and equipment gains (see Table 2), were the same for all the guest rooms, and the rest were different for each of the guest rooms. For example, the solar gain of each room depended on that room's orientation and location, while the building heat transfer gain depended on the type of adjacent environment (heated or unheated). Table 5 shows the cooling loads for the guest rooms based on their planar orientation and vertical location, which are depicted in Figure 5. The loads were calculated based on NCM standard profiles for hotel buildings. The assumptions of these standard profiles should be followed for the purpose of EPC generating in the UK. Based on the standard profile for hotels' guest rooms, the cooling set point (CSP) should be set at 25 °C.

As shown in Table 5, the guest rooms on the second floor—i.e., the top floor—had the highest levels of cooling loads. This can be explained by the fact that guest rooms on this level have their roofs exposed to solar radiation, while the rooms on the upper ground floor have the least amount of cooling loads due to being in the shaded area of the rest of the building. The total cooling load for all 200 guest rooms, with CSP of 25 °C, is 3,533 kW. That means in order to cool down the guest rooms to 25 °C (from any higher temperature), 3,533 kW of heat should be removed from guest rooms. As mentioned earlier, split units are already in place in 20 guest rooms (zone five on the first floor and zone six on the second floor), therefore the cooling loads for the rest of the guest rooms is 3,190 kW. Depending on the chosen cooling system's energy efficiency ratio (EER), the amount of electricity needed to meet this cooling load will be different. Installing split units with EER of 2.6—the minimum recommended values set by the nondomestic building services compliance guide [44]—would result in 872 kWh electrical energy consumption. Choosing cooling systems with higher EER would result in meeting the cooling load with less electricity consumption.



(a) Guest rooms on the upper ground floor. **(b) Guest rooms on the first and second floor**



(c) Dividing the guest rooms according to their planar orientation.

Figure 5. Illustration of guest rooms on different levels and orientations.

Table 5. Cooling loads for guest rooms with the cooling set point (CSP) of 25 °C.

Cooling Loads (kW)	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Total per level
UGF[1]	61.26	75.59	0	0.6	0	1.32	-	-	138.77
FF[2]	190.53	284.51	79.69	192.71	75.09	104.28	71.36	74.59	1,072.76
SF[3]	319.83	410.99	290.63	439.52	253.37	269.58	160.78	176.92	2,321.60
Total per zone	571.63	771.10	370.32	632.82	328.46	375.18	232.14	251.50	3,533.13

[1] UGF: Upper Ground Floor
[2] FF: First Floor
[3] SF: Second Floor.

The energy consumption from adding cooling systems to the rest of the guest rooms with default CSP would emit an extra 452.56 kg of CO_2, and the annual emission rate would undergo a slight increase of 0.047 kg/m^2. However, the overall increase in the energy consumption and emission rate would not be considerable—less than 0.5%-- and therefore the EPC rating would remain at band B, with no significant change to the numerical value. The conclusion is that adding cooling systems such as split/multi split units, packaged air conditioners and variable refrigerant flow systems (VRFs) that come with an EER of at least 2.6 would not adversely affect the EPC rating of the hotel, or its compliance with MEES requirements. On the other hand, if the same systems were also used for heating, as is a common practice in this business, the heating energy consumption would be reduced significantly (see Tables 6 and 7). This is due to their higher efficiency compared to the current heating systems' efficiency in the guest rooms, 2.5 and 0.91 respectively. Subsequently, the CO_2 emissions would decrease, and as this reduction is larger than the increase caused by adding the cooling systems, the annual emission rate would drop to 76.2 kg/m^2. The EPC rating would remain at band B, with its numeric value reaching to 41.

Table 6. Heating energy consumption in the guest rooms in current situation.

Heating System Type	Standards Heating Efficiency	Heating Energy (kWh)	CO_2 factor (kg/kWh)	CO_2 emissions by the system (kg)
Electrical radiators	0.91	74,309.5	0.519	15,038.08
Oil-filled radiators	0.91	290,830	0.519	106,040.26
Wet-central radiators	0.91	274,539	0.216	25,073.36
Split units	2.5	21,718.6	0.519	6,233.41
Total (current situation)	-	661,397.2	-	260,079.8

Table 7. Heating energy consumption in the guest rooms when split units are installed.

Heating System Type	Standards Heating Efficiency	Heating Energy (kWh)	CO_2 factor (kg/kWh)	CO_2 emissions by the system (kg)
Split systems in all guest rooms	2.5	268,454.4	0.519	139,327.8

The CSP for the guest rooms in the above simulation was kept at 25 °C, as it is the default assumption of the NCM and required for the MEES compliance analysis and comparability of EPCs. However, in order to further investigate the potential increase in the energy consumptions when the guests choose to have a cooler indoor environment in their room, extra rounds of simulation were carried out with lower CSPs for guest rooms. The choice of the temperature range was based on the Chartered Institution of Building Services Engineers' (CIBSE) recommendations for summer temperature in hotel guest rooms [45]. The EER for the cooling system was considered to be 3 for these rounds of simulations, as it was intended to investigate the more realistic situations beyond compliance. Currently in the UK, the split units can have much higher EER.

Table 8 shows the cooling loads and cooling energy consumptions for lower CSPs. Those 20 guest rooms with cooling systems already in place were not included in the calculations demonstrated in Table 8.

As the heating set point for the guest rooms was 21 °C, choosing the same value for the CSP would result in an unrealistically huge amount of energy consumption. This is because it would mean that at every given hour, if the room temperature was below 21 °C, the heating systems would operate to heat the room and then immediately after reaching 21 °C, the cooling would be needed. To avoid this, the CSP for May to September—i.e., the time period when the building is likely to have cooling loads—was set to 21.2 °C, while for the rest of the year it was set to 22 °C. As Table 8 shows, lower CSPs resulted in higher cooling loads for the guest rooms, and essentially higher levels of energy consumption would need to occur to meet those loads. Despite this increase in CO_2 emissions, the annual emission rate was still lower than that of the baseline model—which was 89.27 kg/m^2—due to the improved efficiency of the guest rooms' heating systems.

Table 8. Cooling demand and energy consumption for a range of cooling set points.

CSP (ºC)	24	23	22	21.2
Cooling load (kW)	9,122.82	20,495.48	39,189.87	60,391.29
Cooling energy consumption (kWh)	1,757.89	4,093.69	8,318.03	48,309.84
Increase in cooling-induced CO_2 emission compared to the default CSP (Kg)	459.78	1,672.06	3,864.49	24,620.24
Annual CO_2 emission rate (kg/m^2) [1]	77.59	77.74	78.09	83.44
Increase in cooling-induced CO_2 emission compared to the baseline model (kg)	912.34	2,124.62	4,317.05	25,072.80

[1] when the split systems are used for both heating and cooling.

4. Discussions

As mentioned in Section 3, the result of the baseline model simulation showed the EPC rating of the building as band B, with a CO_2 emission rate of 89.27 kg/m^2. A commercial energy assessment carried out in 2015 found the EPC rating to be C, with a CO_2 emission rate of 159.17 kg/m^2. This significant discrepancy with the results of the current study can be partially explained as below:

- The commercial assessment was carried out when there was a swimming pool in the building, which has since been turned into a dry gym. As swimming pools are considered very energy intensive, including them in the simulation increases the estimated energy consumption and the CO_2 emission rate.
- The CO_2 conversion factors for the fuel types might have been higher back then, compared to the current values which are 0.216 kg/kWh for natural gas and 0.519 kg/kWh for electricity.

While contributing to some extent to this discrepancy, the points suggested above are not enough to cause this huge difference. Also, Figure 6 demonstrates that the gap between the TAS prediction of CO_2 emissions and the actual emissions during 2016 to 2018 (when the swimming pool was already converted to the dry gym) was relatively small, while the commercial assessment's prediction of CO_2 emission is considerably higher than the actual emissions during 2012 to 2015 (when swimming pool was still in use).

The software used for the commercial assessment was Simplified Building Energy Model (iSBEM), which is approved by the government and used by many energy assessors in the UK for EPC generating of nondomestic buildings. Although it has been mentioned by the literature that assessors' judgement and interpretation of input data can have an impact on the result of the EPC generating process [31,32], and despite the fact that the two assessments for this building were carried out at different stages with different level of services, the above figure implies that the estimation from TAS is closer to the actual situation than iSBEM's estimation was. With the MEES requirement in action, and the potential penalties in case of failing to meet the required level, there should be more investigation into the comparability of different software packages accredited by the government for carrying out the EPC generating task. This could be the subject of a future study.

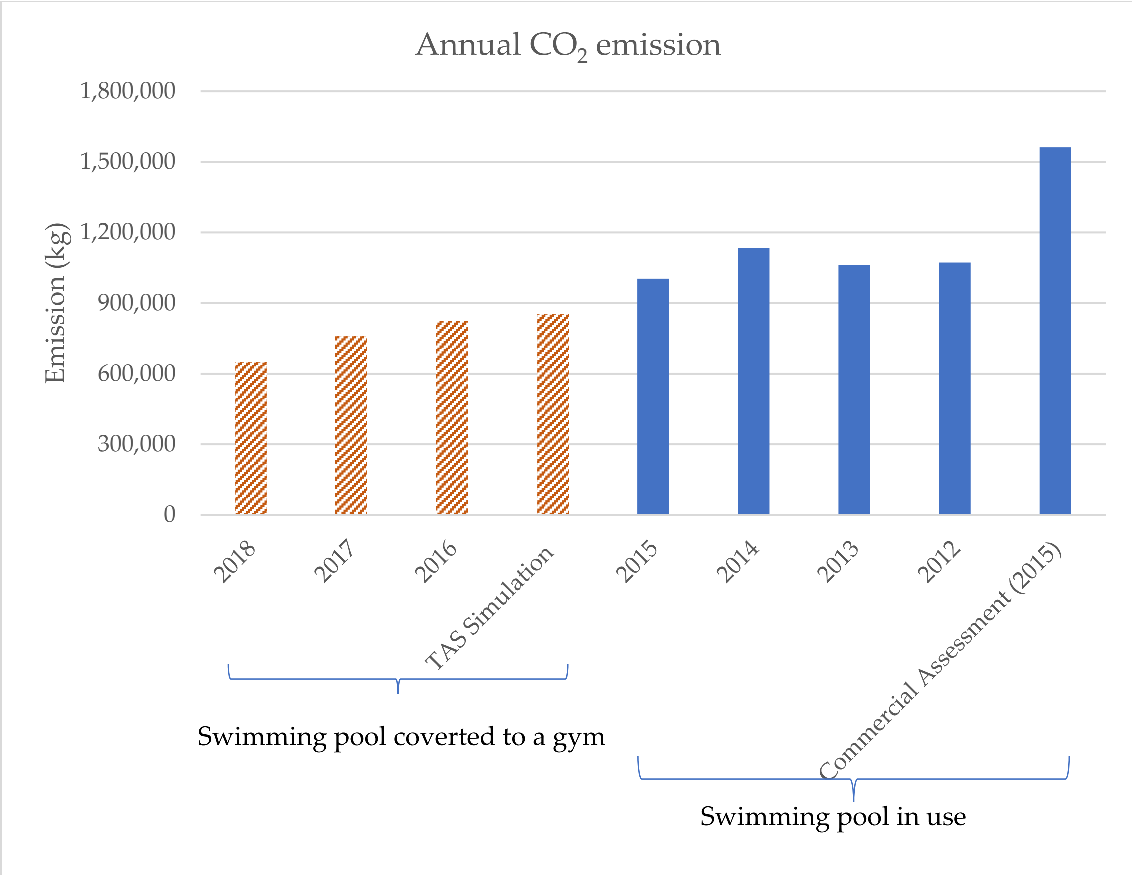


Figure 6. CO_2 emissions in actual and prediction models.

As discussed in the previous section, in order to generate the EPC, the standard internal conditions of the NCM should be followed, including the default cooling set point of 25 °C for hotel guest rooms. As demonstrated, the resulting energy consumption and CO_2 emissions are not significant enough to change the EPC when default values are used. However, in real situations, there is no guarantee on what temperature the occupants decide to have in their rooms, and as shown in Table 8, the energy consumption and CO_2 emissions for temperatures below the default value can increase without leaving any impact on EPC rating. Although an improvement in heating energy efficiency, achieved by the new AC system, would improve the overall energy consumption and annual emissions of the building, the point is that the current procedure in EPC generating fails to recognize the impact of adding cooling systems in a realistic manner.

With the points discussed above about the impact of adding cooling systems on increasing the CO_2 emissions—even in the absence of an adverse effect on EPC—it is worth considering other measures for improving guests' thermal comfort. Currently, the windows to the guest rooms have a relatively small openable area, less than 30% of the total glazing area in each guest room. It is possible that increasing the openable part of the windows would help the occupants to experience a higher level of thermal comfort. Although the natural ventilation may not always be enough to fulfill the occupants' thermal comfort levels, some studies suggest that hotels' guests tend to have a higher tolerance of and flexibility towards their environment for sustainability and energy conservation reasons [46,47]. However, the cost of changing the windows for all the guest rooms might hinder its application.

5. Conclusion

Following the recent launch of MEES requirements in the UK, this paper investigated the impact of adding cooling systems on the annual energy consumption, CO_2 emissions and EPC rating of an existing hotel in the UK. Applying the current approved procedure in EPC generating, the CSP for the guest rooms was set to 25 °C, as required by NCM standard profiles. The increase in the energy consumption and CO_2 emissions resulting from this assumption is small, and therefore there is no change in the EPC rating of the hotel compared to the baseline model. Also, an improvement in energy consumption and EPC rating would be achieved if the new systems were to provide heating with an efficiency rate higher than the current heating systems in the guest rooms. To check the impact of occupants' behavior in choosing to have lower temperatures in the guest rooms, further simulations were run using CSPs from the range 24–21.2 °C. Despite the obvious increase in the energy consumption and CO_2 emissions, these assumptions are not considered in the process of EPC generating.

Based on the results of the simulations and what has been discussed in this paper, the EPC generating process in the UK does not reflect the real consequences of adding cooling systems to guest rooms. In order to achieve the goal behind launching the MEES requirements—which is to effectively reduce CO_2 emissions—steps need to be taken towards improving the current procedure in EPC generating and making them more realistic.

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