Evaluating the potential of using energy certification models to assess decarbonisation pathways for primary healthcare buildings

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Abstract

The National Health Service (NHS) aims to reduce its direct carbon emissions by 80% between 2028 and 2032 and achieve net-zero emissions by 2040. To reach this target, evaluations of the current conditions of NHS properties and the effects of different refurbishment measures are needed. Due to the large number of NHS properties, creating individual models for each building is not practical. Instead, energy certification models (SBEM models) and the data they include offer valuable resources for evaluating the impact of various refurbishment measures on building performance. This study explores the potential of using data from SBEM models to develop dynamic simulation models and assess decarbonisation pathways through a case study building. For this purpose, an SBEM model of a healthcare centre located in London was adapted to create a performance model. After tuning the model based on measured data, it was used to simulate different refurbishment measures. The results indicate that to achieve the net-zero target, the building should be equipped with PV panels, in addition to refurbishments to the building envelope and technical systems. Moreover, to prevent overheating, especially under future climate change, additional measures should be considered, such as adding external shading or even active air conditioning. Overall, the results demonstrate the usefulness of SBEM models in assessing the decarbonisation measures. This approach can be scaled up and extended to all NHS properties that possess energy performance certificates to develop a stock model and gain a better understanding of the measures needed to achieve the net-zero target at scale.

Keywords Energy Performance Certificate (EPC), healthcare buildings, decarbonization, dynamic simulation, Net-Zero target

1.0 Introduction

Primary care services are the first point of contact in the National Health Service (NHS) for people seeking healthcare in the UK. Healthcare buildings are often among the most energy- and carbon-intensive due to the need for specialised medical equipment and strict indoor environmental requirements [1]. In the UK, various standards and guidelines have been developed to support healthcare building design, such as Health Building Note (HBNs) and Health Technical Memoranda (HTMs) [2, 3], which provide recommendations for building performance and systems design. Additionally, the UK NHS has set ambitious goals, becoming the first national health system in the world to commit to net-zero emissions. It aims to reduce its direct carbon emissions by 80% between 2028 and 2032 and achieve net-zero emissions by 2040 [4]. However, many existing healthcare buildings, including primary healthcare facilities, are still far from achieving net-zero emissions and require significant energy-efficiency improvements.

A primary strategy for decarbonisation of primary healthcare buildings is identifying refurbishment measures that can upgrade buildings with poor energy performance. Building energy models provide a robust approach for evaluating and prioritising energy-saving refurbishment measures by assessing their potential to reduce energy consumption [5]. Developing these models involves gathering building information (e.g., geometry, construction, technical systems, and occupancy), creating the models, calculating energy consumption, and analysing the results [6]. Building energy models have been used for various types of healthcare buildings to investigate energy savings from refurbishment measures [7-11], such as increasing envelope insulation, upgrading HVAC systems, and integrating renewable energy production systems. However, developing building energy models for primary healthcare buildings, particularly dynamic simulation or performance models, can be time-consuming and costly, especially when the models are created from scratch [12].

The European Union (EU) launched the Energy Performance of Buildings Directive (EPBD) to promote energy efficiency improvements in both existing and new buildings across European countries. In response, the member state governments developed their national Energy Performance Certificate (EPC) schemes to provide transparent information about building energy performance to the public [13]. These certificates still play an important role in energy policy making in the building sector in the United Kingdom even after exiting the EU. An EPC indicates a building's energy efficiency rating (from A to G), calculated energy performance, and recommendations for improvements. In most European countries, a valid EPC is required when a building is completed, and when a property is rented or sold. The generation of an EPC, or asset rating, for a building, is carried out by certified energy assessors, who conduct a site visit to collect energy-related data about the building's fabric and technical systems [13]. This information is then used to calculate the building's energy efficiency and provide indicative ratings through standardised compliance modelling approaches [14]. The EPC data, stored in a structured and standardised energy certificate model, offers a practical solution to the challenges of data collection in building model development, as it can be automated, significantly reducing the workload involved in gathering data.

In the UK, compliance modelling for buildings is primarily based on Simplified Building Energy Models (SBEMs), which use default operating conditions specified in the National Calculation Methodology (NCM) alongside the building's fabric and technical systems' characteristics to calculate monthly energy use and associated carbon dioxide emissions. In contrast, dynamic simulations can account for a building's actual operating conditions, such as occupancy, temperature set points, and HVAC schedules, to evaluate energy use at a finer resolution, making them suitable for 'performance modelling.' Performance modelling, carried out in accordance with CIBSE TM54 or an equivalent protocol, provides estimates of the likely operational energy performance of buildings at the design stage [15]. Although EPC models are primarily compliance tools, they contain detailed data on building geometry, structure, and systems. This data can theoretically be adapted to develop dynamic simulation models, which provide reliable predictions of a building's energy performance under current conditions or various refurbishment scenarios. These predictions can support informed decision-making regarding refurbishment interventions. However, the potential of this approach, particularly in the primary healthcare sector, remains largely unexplored.

Additionally, dynamic simulation models developed using data from EPCs provide a practical approach for rapidly assessing overheating risks associated with various refurbishment measures, as they enable hourly simulation of indoor temperatures. Addressing overheating in primary healthcare facilities is crucial due to its potential health impacts. Heat stress, heat exhaustion, and heatstroke are common conditions that can be exacerbated by high temperatures, leading to serious health complications [16]. In the UK, most primary healthcare buildings rely on natural ventilation and are seldom equipped with mechanical cooling systems. While refurbishment measures such as increased insulation and airtightness can reduce energy consumption during the heating season, they may inadvertently cause indoor overheating during the non-heating season. Furthermore, climate change is exacerbating these issues, making it essential for primary healthcare professionals to play a role in managing these impacts [17]. Therefore, assessing overheating risks within future climate scenarios should be a critical component of evaluating refurbishment measures for primary healthcare buildings. Various studies have explored solutions to this issue in UK healthcare buildings, assessing the effect of measures such as nighttime ventilation, external shading, and air conditioning (AC) as potential mitigations for overheating [18-21].

This study proposes an approach for utilising SBEM models to create building performance models. A healthcare building located in London was selected as a case study to test this, and its most recent SBEM model was used to develop a dynamic simulation model. The primary aim of the study is to assess the energy-saving potential and overheating risks of various refurbishment packages for the analysed building, under future climate change scenarios. The proposed approach is scalable to other NHS properties with EPC and can also be applied to different building types in the UK and across Europe, supporting broader decarbonisation efforts.

2.0 Case Study Building

The case study building is an NHS property located in London. It has two floors with a total gross internal area of around 2,800 m^2 and relies on natural ventilation. Heating is primarily provided by three condensing gas-fired boilers, which supply heat for space heating and domestic hot water. Radiators serve as heating terminals in different zones. Cooling is mostly not provided to the building, except for 23 rooms equipped with individual comfort cooling systems.

Figure 1 shows the building geometry based on the SBEM model, along with few images of the building, and the percentage of total area dedicated to different activities within the building. The activities are categorised according to the activity types defined for primary healthcare buildings in the NCM, with each activity type having its own occupancy schedule, heating and cooling setpoints, occupant density, minimum fresh air requirements, lighting lux levels, and equipment loads, all of which are included in the SBEM model. The most dominant activity type is related to office and medical consulting functions, occupying 55% of the total area, followed by circulation areas (18%) and storage rooms (12%). The latest SBEM model of the building was used in this study to conduct dynamic simulations.

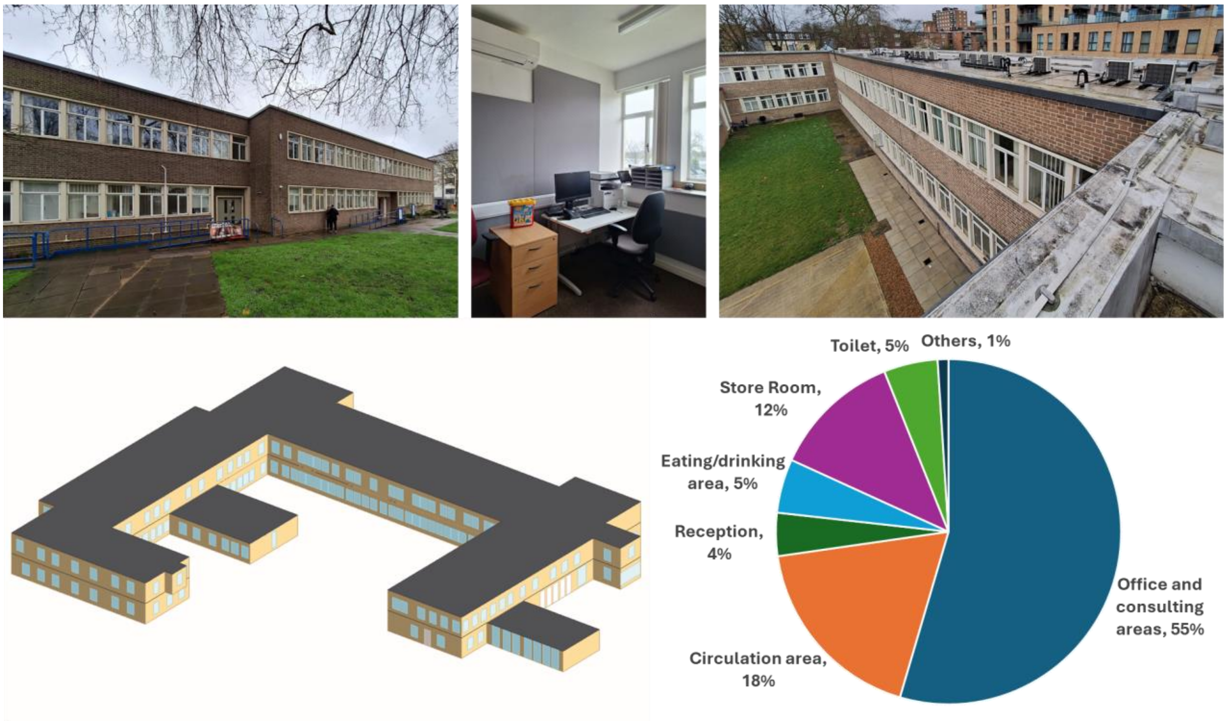

Figure 1 Case study building SBEM model and activity types

3.0 Methodology

The SBEM model for this property was created by an accredited energy assessor using the DesignBuilder software. DesignBuilder provides multiple modelling modules, including SBEM for EPC rating/compliance and an interface to EnergyPlus for dynamic simulation. To enable detailed performance modelling through dynamic simulation, this study opted to convert SBEM models into EnergyPlus Input Data Files (IDFs).

In DesignBuilder, the SBEM and EnergyPlus modules function as separate environments, each hosting models with distinct data sets that may not align perfectly. Switching from the SBEM module to EnergyPlus does not guarantee a seamless translation of SBEM data into accurate EnergyPlus IDFs. During this switch, only limited data—such as building geometry, zone activities, and equipment loads—can be successfully transferred. Other input data may be lost or replaced with default software values, which may not accurately represent the building's characteristics. Therefore, these missing data are gathered from the SBEM model and used to modify the EnergyPlus file.

Regarding building constructions, SBEM models provide only general information, such as the total construction U-Value and heat capacity. These values are typically based on the assessor's observations and the building's age. In contrast, defining opaque construction in EnergyPlus requires detailed data on the materials of each layer, which are not included in the SBEM model data. To model building constructions in EnergyPlus, the notional building construction layers used in the England and Wales National Calculation Method (NCM) are employed. However, the total U-Value of these constructions differs from those defined in the SBEM model (Table 2). To align these values, the thickness of the thermal insulation layer in the notional building construction was adjusted. Additionally, glazing specifications, including U-Value and G-Value, are correctly transferred from the SBEM files to EnergyPlus during the conversion. The infiltration rate used in SBEM models is based on pressure test results or standard air permeability values, depending on the building's age (measured in $m^3/h/m^2$ at a 50 Pa pressure gradient). However, to define the infiltration rate in EnergyPlus, it must be converted to air changes per hour (ACH^{-1}). For this conversion, the value provided in the SBEM model was divided by a divisor factor (22), as suggested in the simplified method outlined in CIBSE Guide A (Figure 4.15, divisor factor selected based on the volume of the enclosed space) [22].

For building services, the EnergyPlus ideal load method is used to simulate heating and cooling systems within the model. During post-processing, the seasonal efficiency of these systems and the type of fuel used are factored in to calculate the building's energy consumption. The ventilation rate for each zone is determined based on the minimum fresh air requirements set in the SBEM model for different NCM activity types. The building's auxiliary energy consumption is calculated using data from the SBEM file, which follows NCM assumptions for various building service strategies. Domestic Hot Water (DHW) consumption in the SBEM file is based on a standard consumption rate. In the post-processing stage, the efficiency and fuel type of the DHW system are also considered. Additionally, energy loss from the hot water tank is accounted for, based on the tank size and the minimum insulation required by building regulations [23]. For the lighting system, the SBEM model's data includes the target illuminance required for the space, as well as the lighting type and efficacy. To incorporate this information into the simulation, the lighting power density was calculated and applied to the model.

To ensure the accuracy of the developed model, a site visit was conducted, and the SBEM model's input data were compared with the building's actual conditions. Adjustments were then made to improve the accuracy of the dynamic simulation model. The prepared IDF file was used to run energy simulations and conduct post-processing on the results to obtain the final outcomes. The building's energy performance simulation results are represented by the annual electricity and gas consumption values. These results were then compared with measured data to evaluate the accuracy of the simulations in predicting building energy consumption and to perform model fine-tuning. This model, which represents the building's energy performance, was subsequently used to generate different files based on various refurbishment scenarios. These files were used to assess the effect of these interventions on building energy performance and to determine if the target defined in the NHS Net Zero Building standard [24] could be met.

In addition to the energy simulation, this study also includes an overheating assessment to evaluate the building's thermal comfort conditions. To conduct the overheating assessment, modifications were made to the IDFs created for the building's energy performance to run new simulations. Since the case study building relies on natural ventilation, and most rooms have several windows that can be fully opened, the simulations assume that windows are open during summer and occupied periods, providing a ventilation rate of up to 4 ACH^{-1} for single-sided ventilation [25]. Overheating performance was assessed by evaluating the building's different zones according to the criteria defined in CIBSE TM52 [26]. The entire process of the method used in this study is illustrated in Figure 2. The process of data extraction and model conversion from the DesignBuilder compliance module to EnergyPlus simulation module is automated using a computer code developed in Python to enable scaling up of this process and applying it to several buildings in the future.

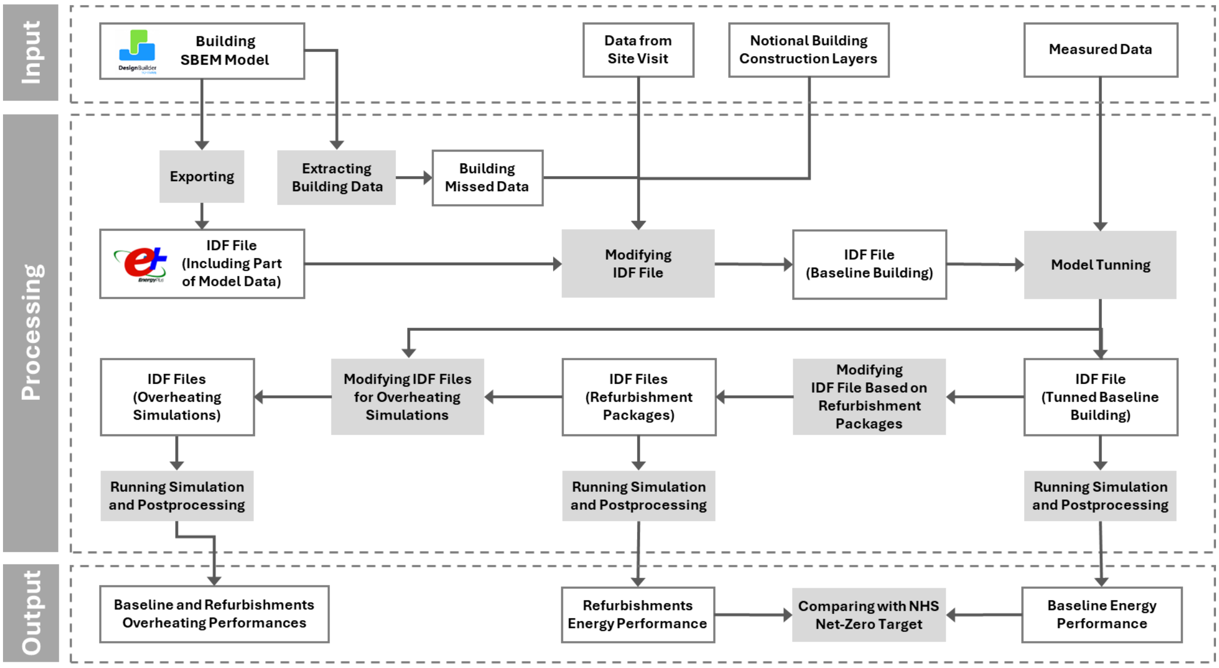

Figure 2 The workflow for using the SBEM model to run dynamic simulations for the baseline building and refurbishment scenarios.

3.1 Refurbishment scenarios

To explore the impact of building refurbishment on energy performance, a baseline building model was used to generate new EnergyPlus files incorporating various refurbishment packages. Six main refurbishment packages were considered, based on the minimum requirements defined in the NHS Net Zero Building standard for building components, including the building envelope and services (Table 1).

The first package focuses solely on replacing the lighting, with minimal intervention to the building structure. The second scenario includes both lighting and window replacements, while the third package adds improvements to the building’s opaque constructions. The remaining three scenarios build on these interventions by upgrading the HVAC system, including replacing the gas-fired boiler with an electric heat pump. The aim here was to allow flexibility in refurbishment scenarios and evaluate their impact, accounting for several technical, economic, and practical constraints that may prevent a deep refurbishment.

It should be noted that for changes in the infiltration rate, which is related to the refurbishment of opaque constructions, two values were considered. When opaque construction is part of the refurbishment packages without any upgrades to the HVAC system, the infiltration rate is set to 8 ($m^3/h/m^2$ @ 50 Pa), the current regulatory target. However, when both the opaque construction and HVAC system are part of the refurbishment packages, the infiltration rate is set to 1 ($m^3/h/m^2$ @ 50 Pa), which is the minimum requirement in the NHS Net Zero Building standard and can only be used where minimum background ventilation is supplied to the building mechanically. Additionally, mechanical ventilation is provided in the building with demand-controlled ventilation (DCV) and heat recovery. Table 2 shows the input data used for the various components of the baseline building and the refurbishment packages.

Table 1 Refurbishment packages considered in the study.

L	Lighting	+	Renewable Energy Generation (PV)
LW	Lighting and Windows		
LWO	Lighting, Windows, and Opaque Construction		
LH	Lighting and HVAC		
LHW	Lighting, HVAC, and Windows		
LHWO	Lighting, HVAC, Windows, and Opaque Construction		

Table 2 Detailed assumptions for the input data of the baseline building and refurbishment measures.

Building Component	Baseline Building	NHS Net Zero Building Standard
Opaque Construction		
External Walls U-Value	1.6 (W/m^2K)	0.12 (W/m^2K)
Roof U-Value	1.4 (W/m^2K)	0.11 (W/m^2K)
Ground Floor U-Value	0.58 (W/m^2K)	0.1 (W/m^2K)
Infiltration Rate	25 ($m^3/h/m^2$ @ 50 pa)	8 or 1 ($m^3/h/m^2$ @ 50 pa) *
Windows		
Glazing U-Value	3.5 (W/m^2K)	1.2 (W/m^2K)
Glazing G-Value	0.76	0.35
HVAC		
Heating System Efficiency	Gas Boiler: 0.83	Electrical Heat Pump: 3.5
Cooling System Efficiency	4.55	No Change
DHW Efficiency	Gas Boiler: 0.83	Electrical Heat Pump: 2.5
Ventilation	Natural Ventilation : Minimum Fresh Air	Natural Ventilation: Minimum Fresh Air or Mechanical Ventilation with DCV and Heat Recovery **
Lighting		
Lighting Power Density	3.3 to 5 (W/m^2-100 lux)	1.5 (W/m^2-100 lux) - LED
Renewable		
PV Panel	No PV Panel	50% of the Roof Area (Solar panel output per m^2 = 186 kWh per annum on average)

* Based on the availability of mechanical ventilation.
* * Adding mechanical ventilation if opaque construction and HVAC is part of the refurbishment scenario.

3.2 Weather conditions

In the assessment of the effect of different refurbishment packages on building performance, in addition to the current weather conditions, two sets of future weather files predicting conditions for 2030s and 2050s were also used. The current and future weather files were generated by the Centre for Energy and the Environment at the University of Exeter (The Prometheus Project [27]). For the future weather files, data based on medium emission scenarios and the 50th percentile (i.e. the central estimate) of mean temperature change were used. It should be noted that for energy analysis, the Test Reference Year (TRY) files were used, while for overheating analysis, the Design Summer Year (DSY) files were used.

4.0 Results and Discussion

The dynamic building simulation model was developed based on the SBEM model, with necessary adjustments made using data collected from the site visit to improve its accuracy. These adjustments included adding a comfort cooling system to zones omitted in the SBEM model, correcting the building orientation, and updating the efficiency of the DHW system. Simulations were then conducted using the refined model, and the results were compared against measured data. Generally, there is a performance gap between the measured and simulated data, which can largely be attributed to variations in occupant behaviour and building use. For the simulations, standard assumptions regarding occupancy, equipment loads, and schedules were applied based on the NCM assumptions. However, actual occupant behaviour often deviates from these standards, significantly influencing the building's energy consumption.

As shown in Figure 3, the simulated results indicate an underestimation of gas consumption, and an overestimation of electricity consumption compared to the measured data. The lower electricity usage in the measured data could be attributed to lower actual occupancy, which reduces equipment and lighting loads. This also impacts the building's heating demand due to changes in internal gains. The evidence from the site visit, such as observations of unoccupied rooms, supports this conclusion. To tune the model, various occupancy factors were considered, reflecting changes in the number of occupants as well as adjustments to equipment and lighting loads accordingly. The results show that decreasing the occupancy factor leads to a reduction in electricity consumption and an increase in gas consumption. At an occupancy factor of 0.85 (i.e. 85% building utilisation compared against the NCM default assumptions), there is a strong correlation between the simulation results and the measured data. Therefore, the model with an occupancy factor of 0.85 was selected as the baseline for developing simulation models for various refurbishment scenarios.

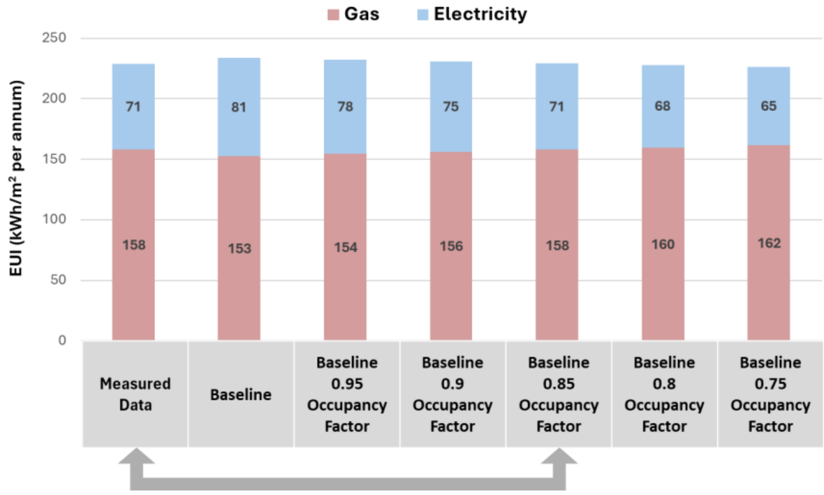

Figure 3 Measured gas and electricity consumption compared to simulation results with varying occupancy factors.

The models for different refurbishment scenarios were developed using the baseline model. Simulations were conducted using current weather data as well as projected weather data for 2030 and 2050. Figure 4 presents the results for the baseline and refurbishment scenarios. Replacing the current lighting system, which has a power density of 3.3–5 W/m²-100 lux, with LED lighting (1.5 W/m²-100 lux) reduces the lighting load from 25.2 kWh/m² to 10.2 kWh/m². However, this change increases the heating load from 156 to 164 kWh/m² under current weather conditions due to reduced internal gains. Consequently, this lighting upgrade only reduces the building's total energy consumption by 3% under current weather conditions.
Combining lighting system upgrades with window replacements further reduces the building's total energy consumption by 4% compared to the baseline under current weather conditions. However, the impact of window replacement is limited due to its effects on the window's U-Value and G-Value. While a lower U-Value reduces heat loss, a lower G-Value reduces solar heat gain, offsetting one another, which minimizes the overall impact on energy consumption.
Refurbishments targeting the building's opaque construction, such as walls, significantly reduce energy consumption by lowering heat conduction and infiltration rates. When combining upgrades to lighting, windows, and opaque construction, the building's total energy consumption decreases by 41% under current weather conditions. Most of this reduction is attributed to improvements in the opaque components. It is important to note that in this scenario, the post-refurbishment infiltration rate is assumed to be 8 m³/h/m² @ 50 Pa, as explained in section 3 (Methodology).
Switching the gas boiler to an electric heat pump significantly impacts the building's heating load and total energy consumption due to the high efficiency of heat pumps. Refurbishing the lighting and HVAC systems together can reduce the building's total energy consumption by 57% under current weather conditions. While lighting upgrades alone have a limited impact—since the reduction in lighting load is offset by an increase in heating load—combining them with efficient HVAC systems enhances the effectiveness of the lighting system replacement. This is because the reduction in lighting load outweighs the increase in heating load, thanks to the improved efficiency of the heating system. In the last scenario, which includes all refurbishment measures, the heating load decreases to approximately 1 kWh/m². This significant

reduction is achieved by introducing a mechanical ventilation system with DCV and heat recovery, alongside lowering the infiltration rate to 1 m³/h/m² @ 50 Pa. However, this scenario results in higher auxiliary energy use due to the mechanical ventilation system. It should also be noted that in future weather conditions, rising ambient temperatures will reduce the building's heating demand and, consequently, its total energy consumption in all scenarios as demonstrated in Figure 4.

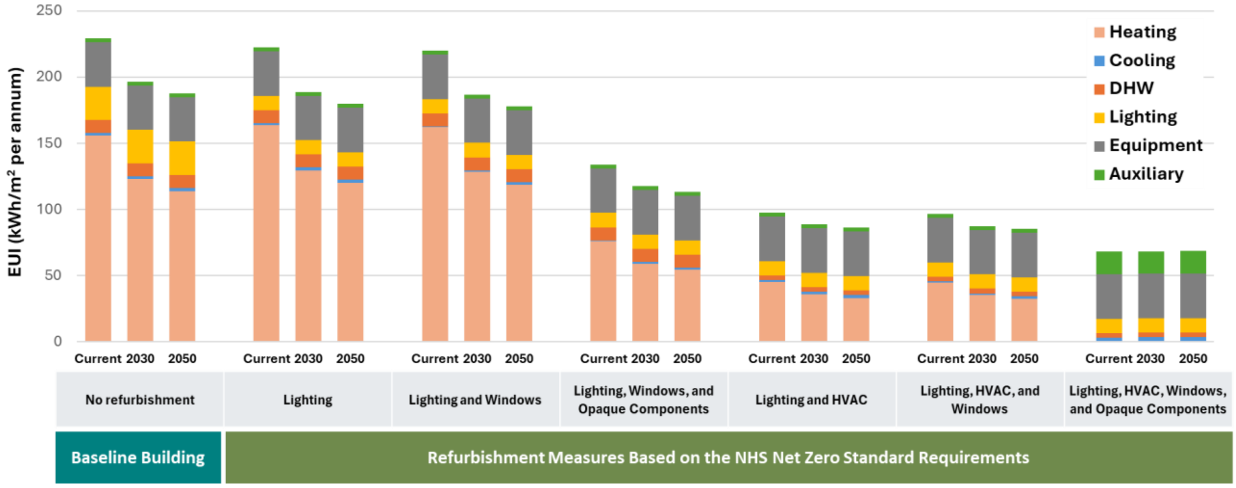

Figure 4 Impact of refurbishment measures on building end-use energy consumption by EUI

The results of different refurbishment measures were compared against the targets defined in the NHS Net Zero Building standard [24]. The energy limits specified for various activities in this standard were used to calculate the building's total target energy consumption. The NHS Net Zero Building standard defines three types of spaces: Low-Tech, Medium-Tech, and High-Tech, each associated with specific activities. Since this building is a primary healthcare facility, it does not include Medium-Tech or High-Tech spaces. Therefore, the energy limits defined for two types of Low-Tech spaces were applied to calculate the building's net-zero energy target. For Type 1 Low-Tech spaces, which include activities such as circulation, reception, and waiting rooms, the energy limit is 35 kWh/m²/year. For Type 2 Low-Tech spaces, which cover non-clinical areas with low equipment requirements, such as offices and consultation rooms, teaching spaces, and dining areas, the energy limit is 70 kWh/m²/year. Based on these criteria, the building must achieve an energy consumption of less than 56 kWh/m²/year to meet the net-zero target.

Figure 5 presents the energy consumption of the baseline building and refurbishment scenarios, categorized by fuel type, across different weather conditions. The chart also illustrates the impact of covering 50% of the building's roof with PV panels on energy consumption and compares it to the net-zero target. As shown in the results, achieving the net-zero target is not feasible through the building envelope and lighting system refurbishments alone. To meet the target, replacing the building's HVAC system must be included in the refurbishment plan. Furthermore, even with various refurbishment measures, achieving the target without PV panels is not feasible. However, it is possible to reach the net-zero target without any building envelope improvements, which could potentially be challenging and disruptive to the building’s operation. For instance, by upgrading the lighting system and HVAC system and incorporating PV panels, the building's energy consumption can be reduced to 48 kWh/m²/year, which is below the target specified above.

Another important point is that, in this study, the equipment load was assumed to remain constant across all scenarios. Incremental improvements in the efficiency of electrical equipment, ICT systems, and medical equipment could help reduce equipment loads and, consequently, overall building energy consumption. Therefore, it might be possible to achieve the net-zero target without onsite microgeneration (PV panels in this case) by solely refurbishing the building envelope and HVAC system. However, this would require a significant reduction in equipment loads.

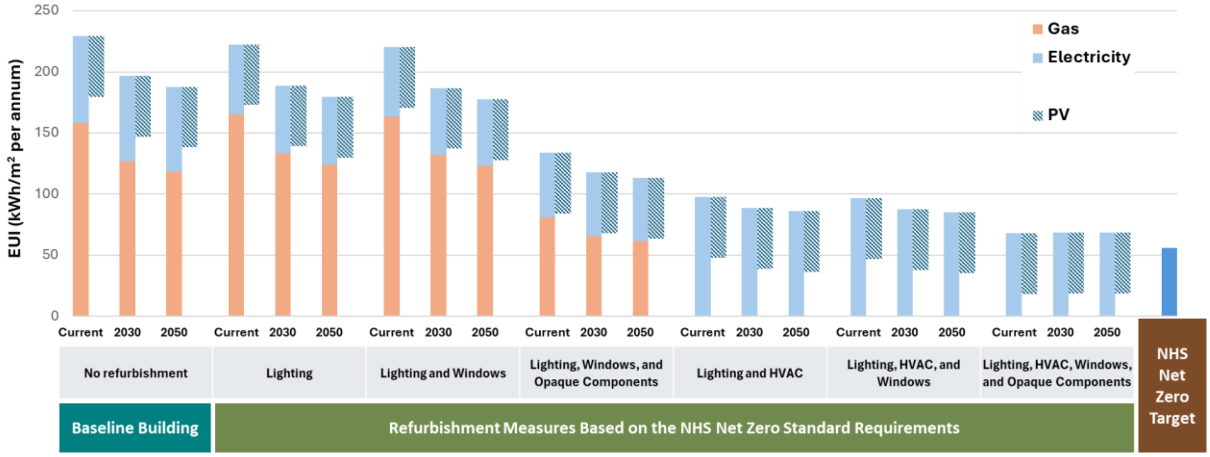

Figure 5 Impact of refurbishment measures on building gas and electricity consumption compared to the NHS Net Zero target

To analyse the building's performance in providing thermal comfort under different refurbishment scenarios, simulations were conducted for summertime across various weather scenarios. Figure 6 presents the results of the building's overheating assessment using the TM52 criteria. Approximately 12% of the building's indoor area is equipped with AC, meaning these zones do not experience overheating issues.

For the baseline building using current weather data, only 16% of the building's area meets the TM52 criteria, while 71% fails. This issue was evident during site visits, where several portable fans were observed in the rooms (Figure 7). Under future weather conditions, the situation intensifies, with only 7% of the area meeting the TM52 criteria.

Refurbishments can improve the building's thermal comfort. For instance, upgrading the lighting system to reduce internal heat gains increases the percentage of the area passing the TM52 criteria to 28% under current weather and 11% under future weather conditions. Similarly, upgrading the building's windows enhances overheating resilience. It is worth noting that while changes to the lighting system and windows do not significantly impact the building's total energy consumption, they positively affect thermal comfort. Improvements to the opaque construction also help mitigate overheating. However, when the infiltration rate is reduced to 1 $m^3/h/m^2$ @ 50 Pa in scenarios combining HVAC and opaque construction refurbishments, overheating worsens compared to scenarios where HVAC is excluded, and the infiltration rate is 8 $m^3/h/m^2$ @ 50 Pa. This indicates that high airtightness can negatively impact overheating conditions.

Based on the overheating analysis, even with the implementation of refurbishment measures, overheating persists in most parts of the building, particularly under future weather conditions. To significantly improve thermal comfort, additional measures are necessary beyond the studied refurbishment packages. These include implementing passive strategies, such as installing external shading devices or adopting active strategies, such as extending the use of comfort cooling systems.

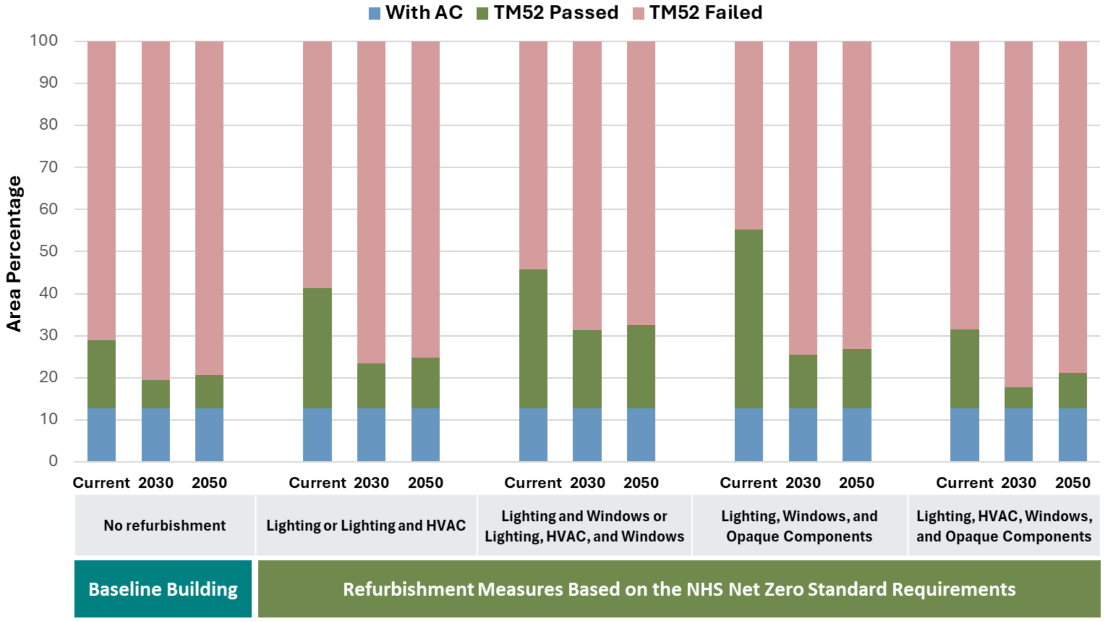

Figure 6 Overheating assessment results of the baseline building and refurbishment measures

Figure 7 Presence of portable fans in various rooms of the case study building

As mentioned, one solution to mitigate overheating in buildings is the installation of comfort cooling systems. This can be achieved by adding Direct Expansion (DX) systems to zones with a high risk of overheating or by utilising polyvalent heat pumps, which offer greater efficiency and use low-GWP (Global Warming Potential) refrigerants, aligning with sustainability goals. However, this approach can lead to increased energy consumption. To assess the impact of incorporating comfort cooling systems, the last refurbishment scenario was considered which includes upgrades to HVAC systems, lighting, windows, and opaque construction. The results of this refurbishment scenario, both with and without the comfort cooling system, along with the NHS Net Zero target, are presented in Figure 8. Adding a cooling system to the building increases energy consumption by approximately 6%, 7%, and 8% for the current, 2030, and 2050 climate conditions, respectively. Nonetheless, the results demonstrate that equipping the building with PV panels covering 50% of the roof area is sufficient to achieve the NHS Net Zero target, even when a cooling system is added.

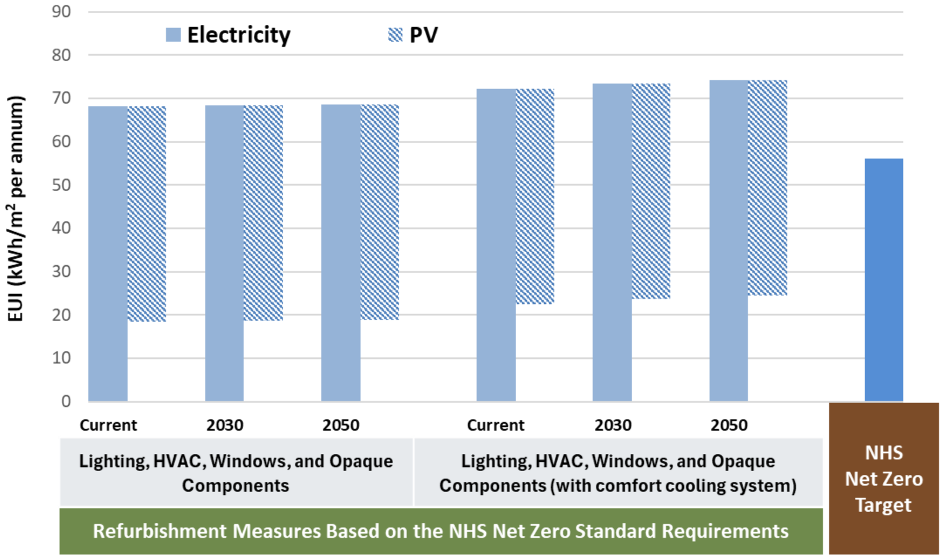

Figure 8 Impact of adding comfort cooling system to the building energy consumption

SBEM models can be valuable tools for assessing the impact of different refurbishment measures on building performance and for determining which measures are most suitable for a specific building. This is particularly useful when dealing with a large number of buildings, such as NHS properties, where creating individual models from scratch for each building would be impractical. In such cases, SBEM models can be adapted and used as dynamic performance models to evaluate the potential effects of various refurbishment measures at a stock level and assess how these measures can help buildings achieve net-zero energy targets. They can play a crucial role in decision-making, especially when considering large-scale building stocks.

5.0 Conclusion

This study evaluated the potential of using energy certificate models (SBEM models) to generate dynamic simulation models and assess the impact of different refurbishment measures. For this purpose, an SBEM model of a health centre located in London, created by an energy assessor, was used to develop a dynamic simulation performance model. A site visit was conducted to evaluate the accuracy of the SBEM model, and necessary adjustments were made to the dynamic simulation model based on the data collected during the visit to improve its accuracy. Additionally, the model was fine-tuned, based on the information gathered in the site visit, using an occupancy factor to align the simulation results with the measured data. Based on the findings, the following conclusions can be drawn:

- SBEM models and the building data included in these models can be useful for developing dynamic building simulation models and assessing the impact of various refurbishment measures on building performance. However, the case study analysis revealed potential discrepancies between the SBEM model and the actual building conditions. To obtain accurate results from dynamic simulations, greater effort should be placed on the SBEM model generation process to minimize errors. Additionally, dynamic models should be calibrated using measured data to improve their accuracy in reflecting the building's actual performance.

- In the case study building, achieving NHS net-zero targets requires the addition of onsite micro-generation (e.g., PV panels), in addition to refurbishments to the building envelope and technical systems.
- Overheating appears to be an issue in the case study building, and the refurbishment measures considered in this study cannot fully address this problem. Additional strategies are needed, such as adding external shading devices as a passive solution and installing comfort cooling systems as an active strategy. The balance between meeting energy performance objectives and mitigating the risk of overheating which may necessitate the use of active cooling should therefore be an important consideration in building retrofits.
- Further investigation is required, considering more case studies and stock-level studies, to evaluate the effectiveness of using the SBEM model's data in developing dynamic simulation models and assessing the performance of different refurbishment measures at scale. The approach tested in a single case study in this paper, including the automated codes developed, is currently being applied to around 1,000 primary healthcare facilities to investigate the scalability and effectiveness of this approach for building stock modelling and analysis.

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Acknowledgements

This study was supported by funding from UCLPartners through the Connecting for Change programme. The authors are also grateful to NHS Property Services for their collaboration and support throughout the project and for providing the EPC models and the available measured energy data for their buildings. The EPC models were originally developed by Compliance365 for compliance purposes.