Energy Proceedings
Vol 43, 2024
ISSN 2004-2965

Characterisation of hotel stock for climate change mitigation in England and Wales

Jingfeng Zhou[1*], Pamela Fennell[2], Ivan Korolija[1], Kaixuan Wang[3], Paul Ruyssevelt[2]

1 Institute for Environmental Design and Engineering, University College London

2 Energy Institute, University College London

3 Institute for Sustainable Heritage, University College London

(*Corresponding Author: jingfeng.zhou.20@ucl.ac.uk)

ABSTRACT

The hotel sector, which accounts for 1% of global carbon emissions, remains an under-researched sector of the non-domestic building stock. This study focuses on the characterisation of the hotel stock in England and Wales, targeting the data needed to assess options for climate change mitigation. The analysis utilises public datasets including Energy Performance Certificates (EPCs), Valuation Office Agency (VOA) rating lists, UK Buildings, 2011 Rural and Urban Classification (RUC), and AddressBase Premium. The study aims to provide a comprehensive description of the hotel building stock, to identify sustainability challenges and opportunities, and to support the development of relevant policies and measures. The findings of the study show that there is scope to improve the energy performance of the hotel sector in England and Wales, with historic buildings accounting for a sizeable proportion of this. These historic buildings present carbon emission challenges, highlighting the need to improve energy efficiency while preserving their historic significance. This study helps to break down the data barriers of non-domestic stock studies to aid energy management and climate change response in the hotel sector, providing insights into the realisation of a low-carbon economy and sustainable development goals. The limitations of the data are recognised to improve the accuracy and reliability of future studies.

Keywords: Building Stock Study, Hotels Characterisation, England and Wales, Public Datasets, Climate Change

NONMENCLATURE

Abbreviations	
EPC	Energy Performance Certificate
GIS	Geographic Information System
LSOA	Lower Super Output Area
RUC	Rural-urban Classification
SDGs	Sustainable Development Goals
SQL	Structured Query Language
UARN	Unique Address Reference Number
UPRN	Unique Property Reference Number
UNFCCC	United Nations Framework Convention on Climate Change
VOA	Valuation Office Agency

1. INTRODUCTION

Research on the impact of climate change on human activities and livelihoods has always been a crucial area of study. In addition to its effects on the natural environment, such as temperature rise and sea level increase, climate change also has significant economic implications. Economically, gradual climate change can lead to infrastructure damage and cause disruptions in industrial operations (Gasper et al., 2011), compromised environmental resources in tourist destinations (Scott et al., 2008), and disruptions in retail supply chains (Wilbanks et al., 2007), among others. As a result, governments and international organizations have implemented policies to address environmental concerns and set several targets to achieve, such as the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations, 2015), and the seventh Sustainable Development Goals (SDGs), which ensures that all people have access to affordable, reliable, sustainable and modern energy, outlined by the United Nations (United Nations, 2023). Within this context, the hotel sector, as a substantial contributor to energy consumption and

This is a paper for 15th International Conference on Applied Energy (ICAE2023), Dec. 3-7, 2023, Doha, Qatar.

carbon emissions, accounting for approximately 1% of global carbon emissions (ARUP, 2021), must respond positively to the calls for further research from governments and the international community.

Hotels may also choose to reduce carbon emissions as part of a marketing strategy emphasizing clean nature and an unpolluted environment as core values, attracting visitors who prioritize eco-friendly accommodation options and sustainable destinations (Cingoski & Petrevska, 2018). Green, environmentally friendly, low carbon, and low energy consumption will therefore be the trend in hotel development. The analysis of individual hotel buildings allows for a refinement of their retrofitting potential, achieving the goal of reduction in operational energy consumption and carbon emissions. Stock-level studies, on the other hand, can extract relevant characteristics of the entire stock for large-scale analysis, enabling benchmarking of the buildings, the development of appropriate directives and the assessment of relevant climate change strategies (Geraldi & Ghisi, 2020). The characterisation of building stock could provide a comprehensive understanding of the stock performance, offering the opportunity to develop robust models of building complexes and to identify ways to effectively reduce carbon emissions (Hong et al., 2022). Stock-level building physics-based models can be used to estimate the energy demand of the existing building stock, explore the impact of different decarbonisation strategies over time for the technical and economic needs of the existing building stock, and achieve the ultimate goal of efficient and rational implementation of decarbonisation strategies and policies for the entire building stock (Kavgic et al., 2010).

However, in the specific context of England and Wales, there is still a gap in the research on the energy consumption and carbon emissions of hotel buildings at the stock level. Research is needed to characterise the hotel building stock and provide a comprehensive analysis of the current state of hotel buildings, uncover existing sustainability challenges and opportunities, and provide a foundation for the development and implementation of relevant policies and measures. A review of the existing literature indicates that most hotel building studies are currently based on dynamic simulation software to measure hotel performance or estimate energy efficiency performance, such as near-zero hotel building retrofits (Buso et al., 2017; Salem et al., 2020). In addition, some studies have researched specific brands of hotels, outlining their overall resource consumption (Bohdanowicz et al., 2005). But research on hotel buildings at the stock level, across brands is still unexplored. This study, based on publicly available government data sets to characterise existing stock, can break down data barriers and gain a clear understanding of the distributions of hotel buildings. Overall, this research can offer guidance and support to the hotel sector as it strives to move towards a more sustainable trajectory within the framework of climate change and contribute to the achievement of a low-carbon economy and sustainable development goals. Meanwhile, the results of this study can be used as a basis for subsequent stock-level physical building modelling. For stock-level building performance studies, representative building types, or archetypes, are identified to represent the entire building stock and be used to reduce the physical modelling effort (Dong et al., 2023). Detailed characterisation of hotel buildings would assist in the subsequent identification of representative archetypes.

2. DESCRIPTION OF THE DATASETS

The availability of data has always been one of the issues that have plagued building stock-level research. To address this issue, some public datasets are utilized. Their brief introductions are shown in Table 1. Here the data is divided into building information data and geographical data based on the most valuable information provided by each collection.

Table 1. Descriptions of the datasets.

Category	Source Name	Description	Reference
Building Information	Energy Performance Certificates	Contain information on the energy efficiency of buildings, provide information on their environmental impact and energy saving potential	(Department for Levelling Up Housing & Communities, 2023)
	Valuation Office Agency Rating List	A comprehensive register that assigns a rateable value to non-domestic properties in the UK to determine business rates	(Valuation Office Agency, 2023b)

	UK Buildings	A comprehensive collection of data that provides information about the building geometry in the UK	(Verisk, 2023)
	2011 Rural-urban Classification	A classification system that divides geographical areas in the UK into distinct categories based on their level of urbanization	(Office for National Statistics, 2016)
Geographic Information	AddressBase Premium	A national address database in the UK offering detailed information on domestic and non-domestic properties	(Ordnance Survey, 2023)

2.1 Energy Performance Certificates (EPCs)

EPCs refer to the collection of information that assesses and rates the energy efficiency of buildings. These certificates are typically obtained during the process of selling, leasing, or constructing properties, and for hotels, they are commonly triggered when listing properties on the sales or rental markets. In England and Wales, non-domestic EPCs are determined using the Simplified Building Energy Model incorporating the UK National Calculation Methodology; in contrast to domestic EPCs, these non-domestic EPCs utilize a standardized "reference building" representing the same size, shape, and usage for all buildings of a given type to ensure comparability, created during the asset rating calculation process, with these reference buildings designed to match relevant legislation including natural ventilation, gas-fuelled systems, fixed space strategy, and consistent insulation levels and main parameters (Yuan & Choudhary, 2023). These certificates quantify a building's specific impact on the environment and can help individuals, businesses, and policymakers to make informed decisions about energy use and sustainability, helping them to become more environmentally aware, promote energy efficiency actions and facilitate the transition to more sustainable and energy-efficient buildings.

2.2 Valuation Office Agency (VOA) rating list

VOA is an executive agency of the UK government, which is responsible for assessing and maintaining the valuation of non-domestic properties in England and Wales. This office provides impartial and independent valuation services to determine the taxable value of all types of non-domestic property. The VOA rating list is a comprehensive register maintained by the VOA that includes information about the taxable value and attributes of non-domestic properties. For hotels, where there is significant variation between scales of operation, VOA collects data from detailed analyses of transaction accounts for large hotel chains and self-reported information from independent hoteliers, respectively. This database can be used as the cornerstone of sectoral analysis to determine the number and distribution of specific buildings. However, in contrast to many sectors of the building stock, property tax for hotels is not a direct function of floor area, consequently, this data set does not include measured floor area for hotels.

2.3 UK Buildings

UK Buildings is a comprehensive commercial dataset at its core it is based on observational observations of aerial imagery and analyses of published open data to obtain disaggregated information on all buildings. Non-domestic buildings can be classified based on ownership, use or age and can have one or more addresses associated with them, leading to a complexity of buildings. The UK Buildings property mapping database supports this complexity while maintaining accessibility, incorporating age, use, building type, footprint, and height.

2.4 RUC2011

Rural-Urban Classification 2011, or RUC2011, is a UK classification system that categorizes urban-rural areas into six groups based on factors like population density and proximity to city centres, to classify and understand the urban-rural continuum across the country. It is a valuable tool for urban planning and regional development. The study uses RUC data at the Lower Super Output Area (LSOA) level, a small geographical unit in the UK used for data analysis and reporting with around 1,500 to 3,000 residents, allowing analysis at a neighbourhood level within larger administrative areas.

2.5 AddressBase Premium

This is a commercial product provided by Ordnance Survey, the national mapping agency of the UK, containing accurate and up-to-date information about domestic and non-domestic addresses, including property names, numbers, street names, postcodes, and geospatial coordinates. This dataset is widely used for a range of activities like service planning, location analysis, asset management, and customer identification.

3. DATABASE CONNECTIVITY AND CLEANUP

For non-research-oriented public datasets, linking and cleaning different databases has always been cumbersome. Although the properties are all located in England and Wales, the same property may have different identifying information in different databases. For the VOA rating list, Unique Address Reference Number (UARN) is used for building identity. UARN is a 14-digit numeric code for business rates valuation. It remains constant and tracks taxation and valuation of non-domestic properties. The EPCs and UK Buildings use the Unique Property Reference Number (UPRN) as the building identifier. UPRN is a 12-digit alphanumeric code associated with specific properties. It remains consistent even when properties undergo changes or updates. UPRN and UARN are crucial for accurate property records, communication, and management. AddressBase Premium, provided by Ordnance Survey, integrates all these identifiers, facilitating the integration of information from different sources.

To effectively manage the extensive dataset, a structured query language (SQL) approach using DataGrip2022.3.3 software is employed. The VOA rating list includes a column called special category that categorizes building use, with specific values 136, 137, and 138 indicating hotels (Valuation Office Agency, 2023a). Hotel-specific data, including UARN, is extracted and used to search the AddressBase Premium database for additional building identification, latitude, and longitude information. The UPRN information from AddressBase Premium is used to match with the EPC data and retrieve relevant information from the UK Buildings database.

Hotel information, along with LSOA level RUC data, is imported into QGIS3.28.2, a Geographic Information System (GIS) software, to map and classify hotel locations based on proximity to different areas. Following data cleaning and linking processes, a total of 7250 hotel data was collated.

4. RESULTS AND DISCUSSIONS

This study focuses on the age, location and building energy ratings of hotels, both for direct targeting of appropriate energy and carbon reduction initiatives, and as a direct contribution to the subsequent development of relevant sector-wide physical models. After collating all the information, the priority task is to analyse the missing data; the results are shown below in Figure 1. The 7250 records extracted from the VOA rating list are considered as the baseline, representing the entire hotel stock buildings. Due to the lack of data quality, there are only 5622 hotels with data in the AddressBase Premium database. The hotels with EPCs are even smaller, with only 1096 records. The sparsity of available EPC data in this case can be attributed to the fact that hotels may have a relatively low turnover rate, meaning that EPCs are not required very often. Another potential reason may be that hotels could be packaged for sale as part of a group, leading to the EPC inspection not being triggered. The distribution of all 7250 hotels across different regions can be visualized using maps, as shown in Figure 2, providing a clearer understanding of their geographic spread and concentration.

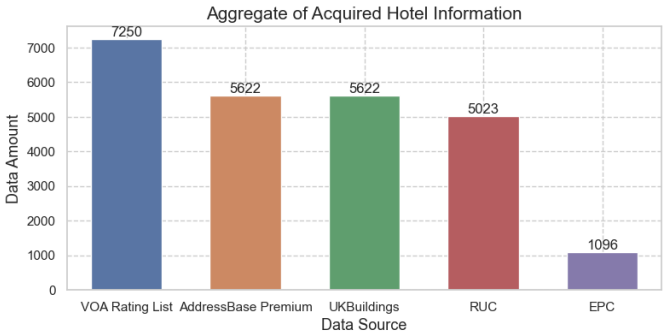

Figure 1. Aggregate of Acquired Hotel Information.

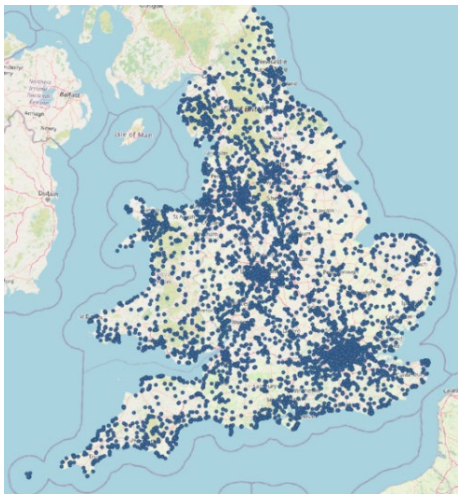

Figure 2. Distributions of Hotels.

The relationship between the age and location of the hotel buildings is summarised in Figure 3 below. All buildings that have not been given age information or

ruralisation information are excluded from the statistics in the figure, where these hotel buildings are concentrated in rural areas.

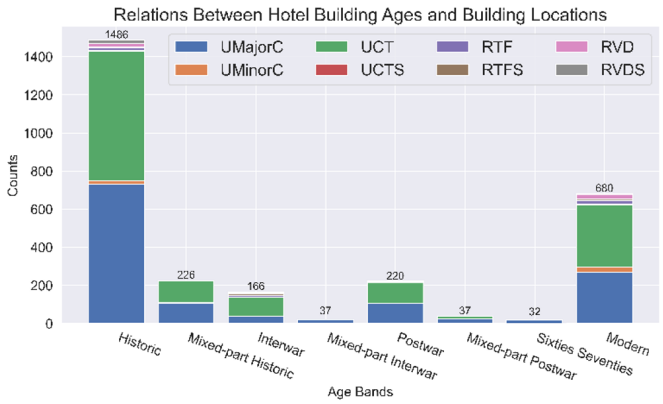

Figure 3. Relations Between Building Ages and Building Locations with Invalid Attributes Discarded. UMajorC: Urban major conurbation; UMinorC: Urban minor conurbation; UCT: Urban city and town; UCTS: Urban city and town in a sparse setting; RTF: Rural town and fringe; RTFS: Rural town and fringe in a sparse setting; RVD: Rural village and dispersed; RVDS: Rural village and dispersed in a sparse setting.

Based on what is available, the overall sector has a high number of historic and modern buildings, mostly located in cities or major urban agglomerations. Here historic building pertains to those constructed before 1837, while modern building refers to properties built between 1980 and 2000. The data here also demonstrates the predominance of old city centre refurbished hotels and newly built hotels in the UK hotel stock, echoing the main component of UK hotels expressed by Taylor et al. (2010). For the entire hotel stock recorded in the VOA rating list, hotels whose buildings are classified as historic buildings account for 20.4% of the total, which is the largest and cannot be neglected. Historic buildings often exhibit poor energy performance, posing significant challenges in terms of carbon emissions. The thermal modernisation of the historic hotel to adapt it to current energy standards is a great challenge for the designers (Borowski et al., 2022). Collaboration between preservationists, climate scientists, and stakeholders is essential to foster sustained conversations and enable the greening of historic hotel buildings. This hotel building typology has unique construction methods and materials that require a delicate balance between preservation and energy efficiency (Webb, 2017). Policies should be developed with a specific focus on carbon emissions to promote the retrofitting of historic hotel buildings, including developing guidance, decision-making processes, and cost-optimal assessments tailored to the specific requirements of historic buildings. By prioritizing policies that target carbon emissions and promote energy retrofitting, society can preserve the historical significance of these hotels while fostering a sustainable future (Fouseki & Cassar, 2014).

Although there is a lot of information contained in EPC certificates, the focus here is on the most important attribute, the asset rating of the buildings. The energy performance of a hotel can be directly quantified using an asset rating score. The asset rating is usually a value from 0 to 150, with a score of 0 indicating zero net energy consumption of the building and higher values indicating poorer performance. When assessing the collective non-domestic building stock, the average performance is represented by a D rating, corresponding to a score ranging from 76 to 100, serving as a benchmark. Geographical location is also a potential influence when analysing the energy performance of a hotel. The figure below shows an analytical plot of energy consumption for hotels of different ages and geographic locations. All invalid information, such as unclassified hotel buildings, has been discarded.

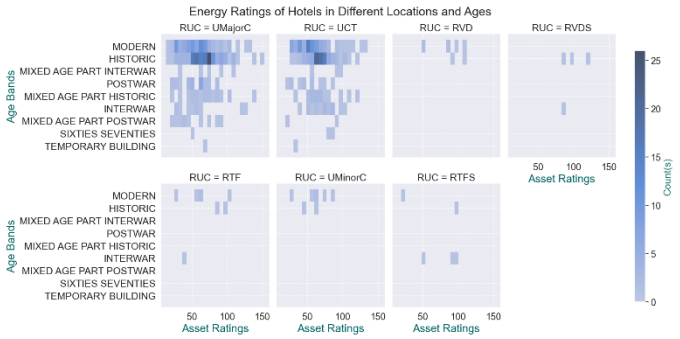

Figure 4. Energy Ratings of Hotels in Different Locations and Ages.

The seven subplots here represent the seven different levels of rurality, with the horizontal coordinates representing the different asset ratings and the vertical coordinates the age bands. The asset rating ranges are divided equally into bins of the square root of the total sample size. The number of hotels falling in each bin is indicated by the colour, with darker colours representing more hotels in the corresponding region, age, and asset rating interval. This figure demonstrates that only a few hotels exhibit excellent ratings, while most still fall within the D category. Moreover, despite many existing hotels being categorized as modern buildings, they still exhibit less-than-optimal energy performance. In rural locations, there is a smaller count

of hotels possessing EPC, with only 238 out of 1643 rural hotels having EPCs, constituting 14.4 per cent; this figure is lower than the urban areas where the percentage of hotels with EPCs stands at 19.8 per cent, encompassing 688 out of 3380 hotels. This can be attributed to the more stable residential environment and limited turnover in locations distant from city centres (Wu et al., 2018). For the results of this study, the accuracy of EPC certificates could potentially lead to some systematic errors in the classification of building energy ratings. Previous research on non-domestic EPCs in the UK has indicated that different assessors may have a significant impact on the outcomes of EPCs (Yuan & Choudhary, 2023). Therefore, it is advisable to validate the building ratings in existing EPCs in subsequent research before establishing archetypes, for example, by conducting telephone surveys on a sample of hotels to verify their specific energy performance.

To undertake subsequent sector-level physical modelling analysis, it will be necessary to construct additional archetypes on both historic and newly built hotels within urban settings, owing to their energy performance exhibiting significant volatility, often surpassing, or falling short of the average. Moreover, given the intricate urban milieu characterised by diverse forms of hotel architecture, a greater number of building archetypes becomes indispensable to effectively encompass the entirety of the building stock. Conversely, hotels situated in rural areas can rely on a reduced set of more generalized models to adequately represent the corresponding building stock. To establish a representative archetype for a building base, several key pieces of information, including building information, geographic data, occupancy details, and weather data, need to be collected and processed. Building information encompasses various physical attributes of the buildings, such as height, area, building envelope, interior appliances, and HVAC systems, among others. This data can be obtained from public datasets like the EPC mentioned in this paper, and sector-wide distribution can be then estimated using statistical or machine learning methods. Geographic information is crucial, and it can be obtained through GIS, which provides access to building footprints, elevations, and coordinates. Occupancy information relies on descriptions of internal activities outlined in the UK's National Calculation Methodology for non-domestic stocks (Department for Communities and Local Government, 2021). This helps determine how the buildings are utilized. As for weather information, it is easier to obtain compared to the others. The plan is to divide the building stock based on England and Wales's climate zones and extract weather data from local weather stations. Once all the data is gathered, clustering algorithms can be employed to calculate the optimal number of archetypes that adequately represent the building stock. These archetypes would be essential in modelling and analysing energy consumption patterns. To validate the accuracy of the model, the energy consumption outputs of the final archetype representation are planned to be compared with real building stock consumption data published by local authorities. This comparison will ensure the reliability and effectiveness of the established model.

5. CONCLUSIONS AND FURTHERWORK

The comprehensive examination of hotel stocks facilitates the extraction of energy consumption and carbon emissions features, enabling the development of targeted energy and environmental policies. The fundamental basis of a sector-wide analysis lies in the characterisation of the building stock. Drawing on a publicly available dataset, this study investigates the hotel stock in England and Wales, revealing the prevalence of historic hotels in urban areas and modern hotels as the dominant categories within the hotel stock. Furthermore, the results of the study show that the hotel sector in England and Wales has an average level of energy consumption and that there is room for improvement in energy performance. This provides an important reference for reducing carbon emissions and promoting energy efficiency measures and sustainable development. At the same time, historic buildings make up a relatively high proportion of the hotel stock and there is a need to improve energy efficiency while preserving historic significance. The results have practical implications for energy management and climate change response in the hotel sector and beyond. In the context of the present construction sector, the mere design and construction of nearly zero-energy buildings fall short of meeting the policy mandates for carbon reduction (Pracchi, 2014). Hotels must adopt appropriate strategies to conserve energy and reduce emissions, aligning with the government's ambitious target of achieving net zero across all sectors of the UK economy by 2050 (HM Treasury, 2021). This study effectively overcomes data limitations associated with non-domestic stock analyses and provides direct insights into the sector's pursuit of net-zero objectives. Moreover, it indirectly assists subsequent stock-level physical modelling efforts aimed at reducing carbon emissions for environmental mitigation purposes.

However, it is essential to acknowledge certain limitations in the analysis. One notable issue is the lack of available data on hotel properties. Having detailed Property Data Survey Programmes and Displaying Energy Certificates covering almost the entire sector, as is the case for school buildings in England (Hong et al., 2022), would undoubtedly help significantly in the physical modelling of hotel buildings. To overcome these limitations, future research endeavours could focus on filling data gaps using alternative sources. One potential avenue is leveraging data from online travel agents, where hotel detail pages could provide valuable information on specific services like swimming pools, gyms, saunas, etc. This data would be immensely beneficial in inferring the energy consumption associated with in-house facilities at hotels. Meanwhile, for hotels that are difficult to obtain data, such as hotels located in the RVD and RVDS levels of LSOA, it can be considered to select representative hotels and conduct telephone surveys to gather specific information on HVAC systems, occupancy rates, and other pertinent details. The availability of a more comprehensive and detailed database will undoubtedly support policymakers and researchers in gaining a more profound understanding of the hotel sector. This, in turn, will lead to the formulation of more targeted and effective policies and yield research results that are both accurate and reliable. By exploring additional data sources and employing innovative data collection methods, the potential to improve the quality of analysis and decision-making in the hotel sector could be significantly enhanced.

REFERENCE

ARUP. (2021). Existing Hotels to Net Zero Carbon Transforming. https://www.ihgplc.com/en/-/media/ihg/files/news/2022/transforming-existing-hotels-to-net-zero-carbon.pdf

Bohdanowicz, P., Simanic, B., & Martinac, I. (2005). Sustainable hotels : environmental reporting according to Green Globe 21, Green Globes Canada / GEM UK, IHEI benchmarkhotel and Hilton Environmental Reporting.

Borowski, M., Zwolińska, K., & Czerwiński, M. (2022, May 16). Energy consumption patterns in a hotel building: A case study. CLIMA 2022 Conference. https://doi.org/10.34641/CLIMA.2022.187

Buso, T., Becchio, C., & Corgnati, S. P. (2017). NZEB, cost- and comfort-optimal retrofit solutions for an Italian Reference Hotel. Energy Procedia, 140, 217–230. https://doi.org/10.1016/J.EGYPRO.2017.11.137

Cingoski, V., & Petrevska, B. (2018). Making hotels more energy efficient: the managerial perception. Economic Research-Ekonomska Istraživanja, 31(1), 87–101. https://doi.org/10.1080/1331677X.2017.1421994

Department for Communities and Local Government. (2021). National Calculation Methodology (NCM) modelling guide (for buildings other than dwellings in England). https://www.uk-ncm.org.uk/filelibrary/NCM_Modelling_Guide_2021_Edition_England_15Dec2021.pdf

Department for Levelling Up Housing & Communities. (2023). Energy Performance of Buildings Data England and Wales. https://epc.opendatacommunities.org/

Dong, J., Schwartz, Y., Mavrogianni, A., Korolija, I., & Mumovic, D. (2023). A review of approaches and applications in building stock energy and indoor environment modelling. Building Services Engineering Research and Technology, 44(3), 333–354. https://doi.org/10.1177/01436244231163084

Fouseki, K., & Cassar, M. (2014). Energy Efficiency in Heritage Buildings — Future Challenges and Research Needs. The Historic Environment: Policy & Practice, 5(2), 95–100. https://doi.org/10.1179/1756750514Z.00000000058

Gasper, R., Blohm, A., & Ruth, M. (2011). Social and economic impacts of climate change on the urban environment. Current Opinion in Environmental Sustainability, 3(3), 150–157. https://doi.org/10.1016/J.COSUST.2010.12.009

Geraldi, M. S., & Ghisi, E. (2020). Building-level and stock-level in contrast: A literature review of the energy performance of buildings during the operational stage. Energy and Buildings, 211, 109810. https://doi.org/10.1016/J.ENBUILD.2020.109810

HM Treasury. (2021). Build Back Better: our plan for growth. https://assets.publishing.service.gov.uk/media/6048fd05d3bf7f1d16e263fd/PfG_Final_Web_Accessible_Version.pdf

Hong, S. M., Godoy-Shimizu, D., Schwartz, Y., Korolija, I., Mavrogianni, A., & Mumovic, D. (2022). Characterising the English school stock using a unified national on-site survey and energy database. Building Services Engineering Research and Technology, 43(1), 89–112. https://doi.org/10.1177/01436244211030667

Kavgic, M., Mavrogianni, A., Mumovic, D., Summerfield, A., Stevanovic, Z., & Djurovic-Petrovic, M. (2010). A

review of bottom-up building stock models for energy consumption in the residential sector. Building and Environment, 45(7), 1683–1697. https://doi.org/10.1016/J.BUILDENV.2010.01.021

Office for National Statistics. (2016). 2011 rural/urban classification - Office for National Statistics. https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2011ruralurbanclassification

Ordnance Survey. (2023). AddressBase Premium | Data Products | Ordnance Survey. https://www.ordnancesurvey.co.uk/products/addressbase-premium

Pracchi, V. (2014). Historic Buildings and Energy Efficiency. The Historic Environment: Policy & Practice, 5(2), 210–225. https://doi.org/10.1179/1756750514Z.00000000052

Salem, R., Bahadori-Jahromi, A., Mylona, A., Godfrey, P., & Cook, D. (2020). Energy performance and cost analysis for the nZEB retrofit of a typical UK hotel. Journal of Building Engineering, 31, 101403. https://doi.org/10.1016/J.JOBE.2020.101403

Scott, D., Amelung, B., Becken, S., Ceron, J.-P., Dubois, G., Gössling, S., Peeters, P., & Simpson, M. (2008). Climate change and tourism: Responding to global challenges. World Tourism Organization, Madrid, 230, 1–38.

Taylor, S., Peacock, A., Banfill, P., & Shao, L. (2010). Reduction of greenhouse gas emissions from UK hotels in 2030. Building and Environment, 45(6), 1389–1400. https://doi.org/10.1016/j.buildenv.2009.12.001

United Nations. (2015). Paris agreement. Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change (21st Session, 2015: Paris). Retrived December, 4, 2017.

United Nations. (2023). Goal 7 | Department of Economic and Social Affairs. https://sdgs.un.org/goals/goal7

Valuation Office Agency. (2023a). VOA 2023 Draft Rating List Data Specification. https://voaratinglists.blob.core.windows.net/downloads?restype=container&comp=list

Valuation Office Agency. (2023b). VOA rating list downloads. https://voaratinglists.blob.core.windows.net/html/rlidata.htm

Verisk. (2023). UKBuildings | Property Mapping | 3D Buildings | Verisk Analytics. https://www.verisk.com/en-gb/3d-visual-intelligence/products/ukbuildings/

Webb, A. L. (2017). Energy retrofits in historic and traditional buildings: A review of problems and methods. Renewable and Sustainable Energy Reviews, 77, 748–759. https://doi.org/10.1016/J.RSER.2017.01.145

Wilbanks, T. J., Romero Lankao, P., Bao, M., Berkhout, F. G. H., Cairncross, S., Ceron, J.-P., Kapshe, M., Muir-Wood, R., & Zapata-Marti, R. (2007). Industry, settlement and society. Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 357–390.

Wu, Y., Blunden, L., & Bahaj, A. (2018). City-wide Building Energy Efficiency Assessment Using EPC Data. Future Cities and Environment, 4(1). https://doi.org/10.5334/fce.10

Yuan, M., & Choudhary, R. (2023). Energy Performance Certificate renewal — An analysis of reliability of simple non-domestic buildings ' EPC ratings and pragmatic improving strategies in the UK. Energy Policy, 178, 113581. https://doi.org/10.1016/J.ENPOL.2023.113581