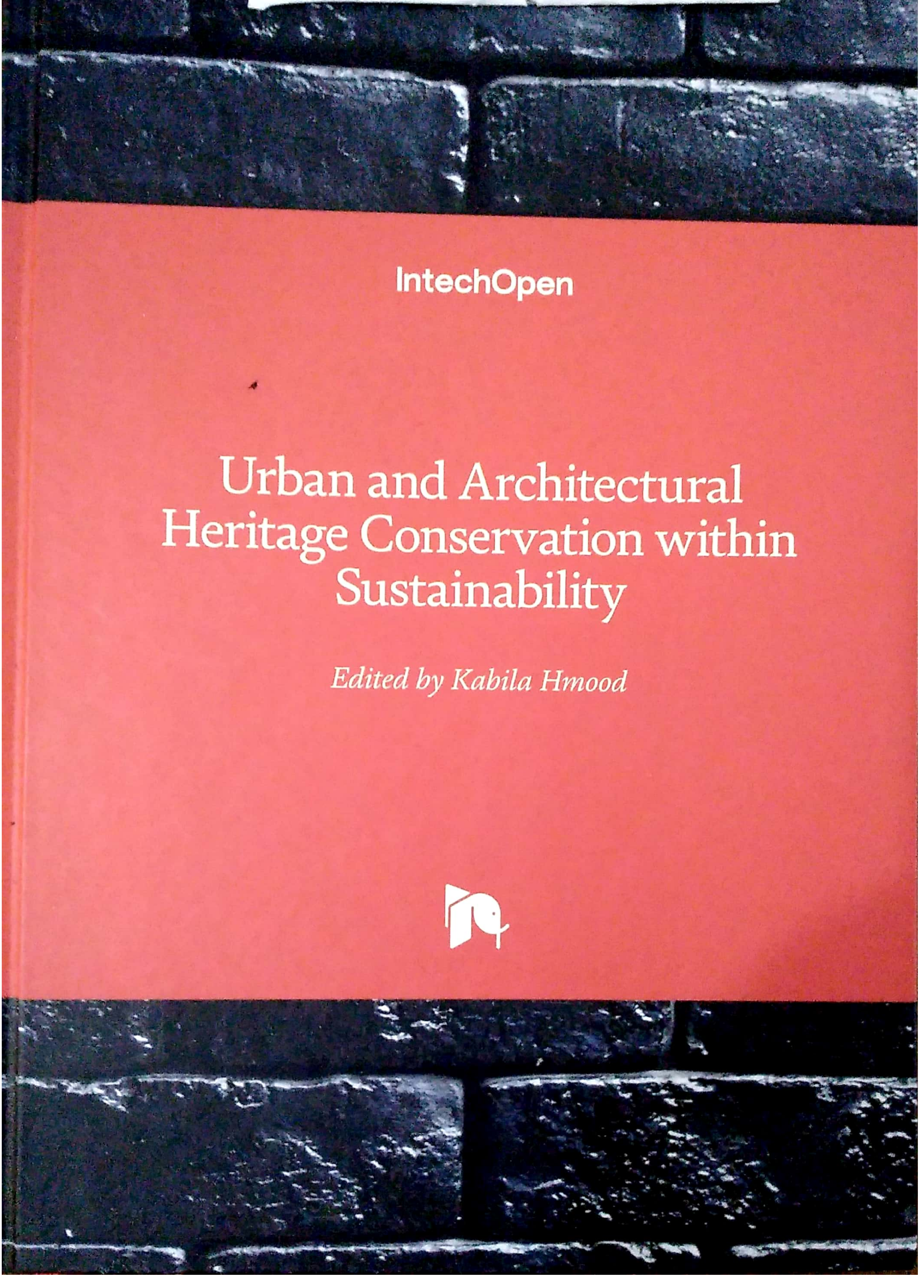

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Urban and Architectural Heritage Conservation within Sustainability

Edited by Kabila Hmood

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Improving Environmental Sustainability in Reuse of Some of England's Churches: Challenges and Options for Sustainable Practices

Oluwafemi K. Akande

Abstract

Considering the spontaneous growth in retrofitting practices, existing buildings, particularly those of historical significance are being transformed using a wide range of interventions. However, the pervasiveness of these interventions constitutes a serious challenge to retrofitting heritage buildings. The aim of this paper is to investigate current retrofitting strategies and interventions in heritage buildings. The purpose is to assess current performance through the viewpoint of energy efficiency. The paper adopted pragmatic analytic and comparative approach and methodology to investigating retrofitting interventions in the reuse of England listed churches. A top down approach method of data collection was employed to collect energy use data from monthly utility bills and meter printer outs from selected buildings. Findings show that in terms of energy performance, the majority of the surveyed buildings are currently under-performing. Recommendations for low energy use interventions for operational management of retrofitting projects were proposed. It concluded that the low operational energy use should be a key priority for effectiveness in any proposed retrofitting intervention on heritage building projects.

Keywords: heritage buildings, low energy, energy performance, rehabilitation, sustainability

1. Introduction

In Europe, 40% of the total energy use and 36% of CO_2 emissions originate from the building sector. The aim of the European Union (EU) is to reduce its greenhouse gas (GHG) emissions by 80% by 2050. This is reflected in all the EU Directive ([1–3], pp. 1–56). Thus, the building stock plays a major role in achieving the 20-20-20 strategic targets. However, unless other avenues are explored to reduce the environmental footprint attributed to the existing building stock, the EU target may not be met. Due to climate change protection, energy consumption is required to be checked through greater efforts and concentration on existing buildings. According to ([4], pp. 1–87) building professionals need to provide more energy-efficient refurbishment of existing buildings to bring them to modern sustainability standard. However, the possibility lies in adapting and retrofitting existing buildings to the optimum energy efficiency standard ([5], pp. 1–62). The concept of sustainable development could be applied to sustainability of Heritage buildings as any interventions to extend its lifespan without compromising its future and context. In conservation literature, different interventions are found and the term is used as a collective noun which encompasses any works to change, modify, repair or maintain the historic environment in good condition as well as preserve its historical and cultural value or significance. This is discussed in ([6], para 6.11) as "Interventions and Judgement" and as the "action that has a physical or spatial impact on a historic building or its setting."

Generally, the terms used to describe interventions create overlap with other definitions and are often used as synonyms. Prudon [7] defined retrofitting as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving the features which convey its historical, cultural and architectural values. More often, retrofitting could involve modernization and change in use (i.e. adaptive reuse). It is considered by [8] as the best way of preserving buildings. Meanwhile, ([9], pp. 155–157; [10], pp. 143–156) referred to retrofitting as similar to the term refurbishment, which does not only extend the life of a building, but also define a new purpose for it according to the demands of modern life. Thus, in this paper, retrofitting is used interchangeably with adaptive reuse.

2. Adaptive reuse of built architectural, cultural heritage

Several scholars ([11], pp. 287–94; [12], pp. 543–56; [13], pp. 529–42) have acknowledged the growing trend in the move to building re-use and adaptation in the built environment. They suggested that some form of adaptation might be able to reduce the impacts of climate change on the built environment. Other authors ([14], pp. 88–103; [15], pp. 43–66) have posited that adaptation is an effective strategy for improving the sustainability of existing buildings along with its potential of giving extension of life to a building. The authors argued that by reusing existing buildings, lower energy consumption can be achieved thus making a considerable contribution to sustainability. With the advantage and possibilities of extension of life for buildings, adaptive reuse could also play a significant role in meeting the growing demand for regeneration of the built environment ([16], pp. 554–70).

According to Langston et al. ([17], pp. 1709–18) adaptive reuse has become an essential strategy to improve the environmental, financial and social performance of buildings. The environmental concern in adaptive reuse of buildings has been acknowledged by other researchers [18–20] in historic preservation. Therefore, it is seen as vital to sustainable development ([21], pp. 1709–1718) and considered applicable to the present climate change adaptation agenda. It is acknowledged that reusing existing facilities are related to sustainable development and in order to promote sustainability within the built environment, many buildings of cultural and historical significance are being rehabilitated. However, little attention is given to improving their operational energy performance. Several factors have since been advanced to be driving the adaptive reuse of buildings such as its value as a practical approach for delivering buildings for new uses, cost-effectiveness and rising energy costs. Latham ([18], p. 8) noted that adaptive reuse is cheaper than new development as it is a way of banking the built environment. Further, he argues that "transforming uneconomic buildings using green materials have the potential to enhance efficiency, comfort and life span of the building". Meanwhile, van't Hof cited in

([15], 43–66) opined that economic considerations have been the major driver behind adaptive reuse although other motives might have also been considered.

2.1 The drivers of adaptive reuse of listed churches

In Europe, many religious heritages are under threat and the buildings are often ill adapted to the needs of modern society [22]. This is because a lot of these buildings are reaching the end of their useful life and in most cases do not respond well to contemporary needs. As a result, they are often less desirable to occupy, can remain empty and ultimately deteriorate. In England, three quarters of 16,000 parish churches of England are listed as buildings of architectural and historic interest. The churches listed Grade I comprises about 45% of all England's buildings (i.e. Castles, mansions, banks, railway stations, etc.). However, with the declining congregational sizes, a number of these buildings are becoming less used and closed for worship (**Table 1**). Thus, one of the drivers for retrofitting of heritage buildings is redundancy.

It can be seen from **Table 1** that from 1969 to 2014, over a thousand church buildings have been closed and considered for alternative use. Perhaps, this is as a result of historical factors such as population shifts, changes in religious practice and habits, or even the construction of new buildings for religious use. According to [24], redundant buildings are buildings that have reached the end of their original working lives, but often have huge potential to be adapted to economically viable new uses. It should be recalled that one of the Council of Europe's statutory duty is to safeguard the ideals and principles of the common heritage of member states and to which religious buildings bear witness ([25], p. 1). This brings to fore religious buildings' importance in terms of their architectural and historical

Alternative use	**1969–2010**	**2010–2014**
Adjuncts to adjoining estates	7	0
Arts, crafts	20	3
Civic, cultural or community	150	16
Educational	35	3
Light industrial	11	1
Monument	147	13
Museums	16	0
Music or drama	15	0
Office or shopping complex	58	4
Parochial or ecclesiastical	75	7
Private and school chapel	22	2
Residential	276	36
Sports	15	1
Storage	21	2
Worship (Christian bodies)	160	23
Other	5	0
Alternative use sub-total	1033	111

Source: Church Commissioner Report [23].

Table 1.
The future of closed church buildings since (1969–2014).

significance and their longstanding concern for the integrated conservation to ensure a future for the past. In the UK, heritage buildings such as churches and farm buildings are being reused. Meanwhile, due to their population (**Figure 1**) more listed churches are converted to alternative use and/or demolished.

When a religious building is no longer viable; efforts should be made to ensure a future use, whether religious or cultural, as far as possible. However, this should be compatible with the original intention of its construction and as such should be carried out with the understanding that a church or any other major religious building is often the focal point and central feature of a community and a local landmark. While there are numerous successful examples throughout Europe of the preservation and protection of redundant religious buildings, through their sensitive adaptation to new uses, thus this paper poses a challenge to responsible stakeholders (e.g. churches, government, local authorities and heritage building professionals) and other heritage building experts to (i) consider effective measures to preserve redundant religious buildings and secure wherever possible their appropriate future use; (ii) promote projects for reuse and re-adaptation not incompatible with the original function of the building and do not cause irreversible alteration to the original fabric; (iii) encourage a more imaginative use of existing religious buildings as well as (iv) encourage the research necessary for the continuous upkeep of religious buildings. This challenge provided the motivation behind this research and action required to implement strategies aimed at promoting energy efficiency and limiting energy consumption as a fundamental aspect of reuse of built heritage. Thus, informed by the aforementioned challenge, this paper seeks to investigate current retrofitting strategies and interventions in the reuse of heritage buildings with a view to assess the current performance of LCBs through the viewpoint of energy efficiency.

The adaptive reuse of church buildings becomes significant in conservation fostered by the economic benefits associated with tourism they could generate

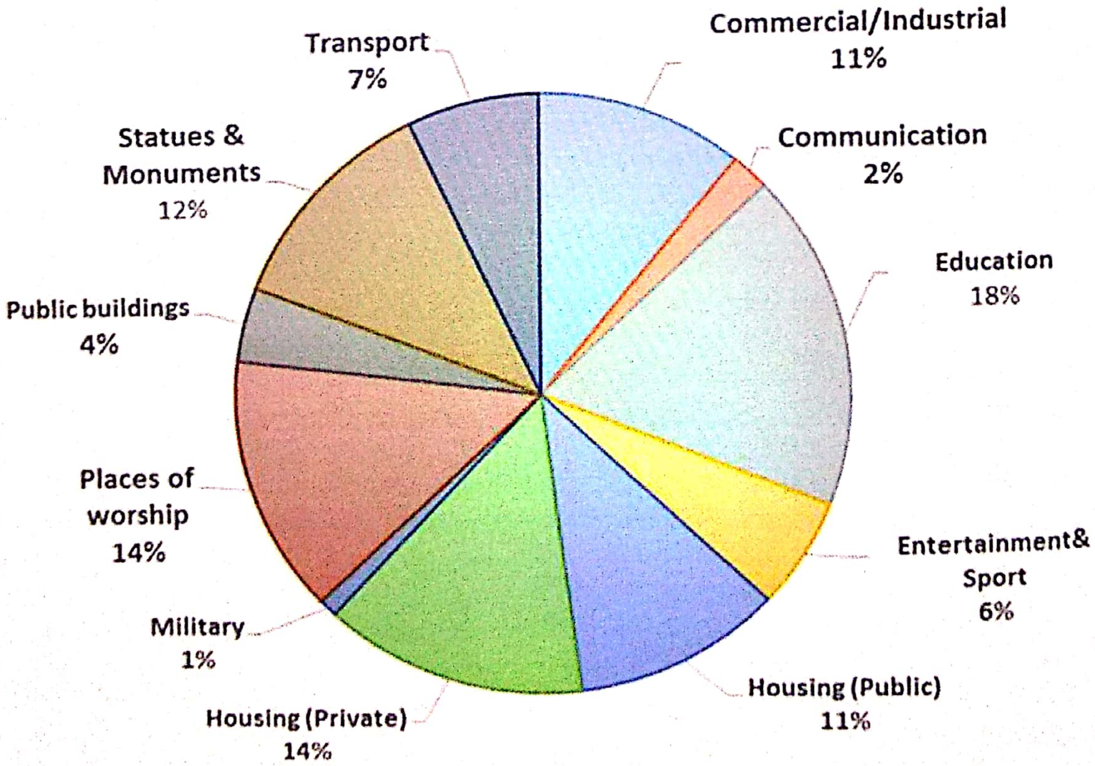

Figure 1.
Post war listed building types in England. Source: Author's survey [30].

[26, 27]. However, retrofitting of these buildings is faced with the challenges of meeting the global challenge of coping with climate change. A major challenge for heritage buildings is how they can successfully be rehabilitated and made energy efficient at a time that the need for their renovation and re-use appears to be urgent and make them fit for the twenty-first century. "In Europe, the legislation concerning this area is based on the certification of energy efficiency, developed in the early 1990s as a primary strategy to reduce energy use and carbon emissions as well as the energy policy adopted in 2007, called Horizon 20-20-20" ([28], pp. 1294; [29], pp. 1493–1502). However, low energy use as a key contemporary demand for better standards of living and as a response to climate change has not yet been extended to the retrofitting of LCBs. The scale of the problem is exacerbated by the fact that churches are difficult to modify to meet up with current energy efficiency standard. Nonetheless, users of rehabilitated church buildings also need to have healthy and thermally comfortable internal environments at an affordable installation and running cost. The problem is that certain restrictions deriving from the specific historic character do not permit major interventions to improve the building's energy performance. Indeed, when dealing with protected buildings of significant architectural merit, altering the building envelope will be prohibited. This difficulty is partly due to the nature of the materials from which they were built as traditional buildings; which affects their thermal performance in terms of heat loss requiring significant updating.

LCBs continue to present a retrofit dilemma all of their own. For instance, the fabric of heritage buildings functions in a certain way due to the way they were built. Thus, makes it challenging to improve their fabric thermal performance. However, to avoid degradation of their fabric they should be preserved because of their breathable elements. Thus, a clearer understanding of their values and needs must be found so that an appropriate intervention can be adopted. Specifically, the challenges of rehabilitating Heritage buildings could be attributed to several factors such as heritage factors, embodied energy, economic factors and building factors (**Figure 2**).

In addition, it is difficult to understand their current energy performance. LCBs traditionally have solid walls, meaning they are 'hard to treat buildings' and hard to

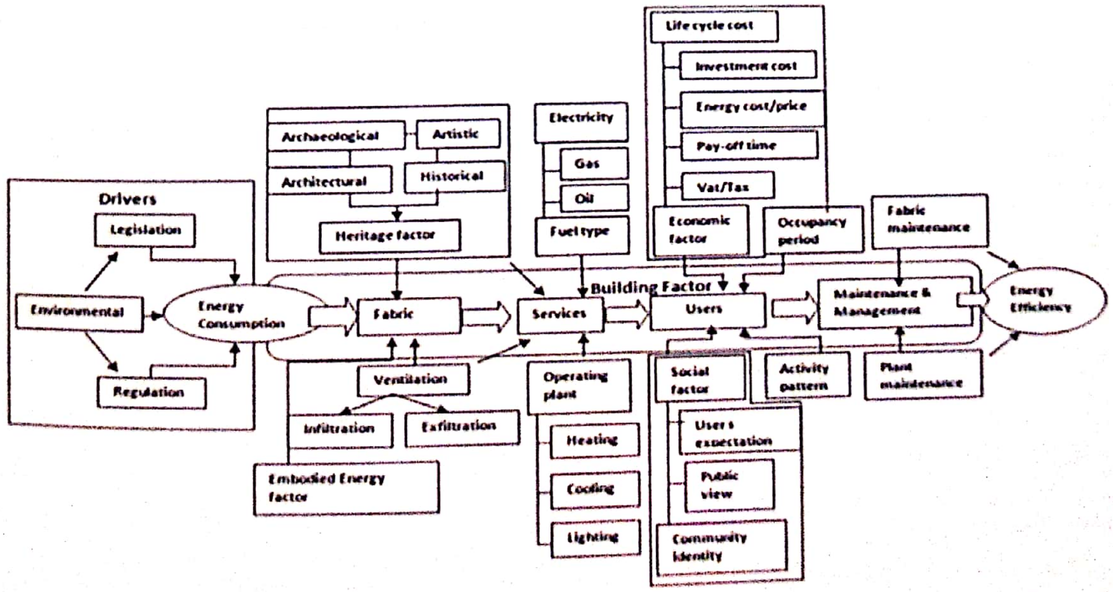

Figure 2.
The drivers and the challenges of retrofitting and environmental sustainability of heritage buildings. Source: Akande [30].

deal with when alterations are locally permitted. If the fabric of the building cannot be readily improved, the question that this study seeks to answer is what options are available to reduce the energy consumption of Heritage buildings with specific reference to investigate operational energy performance involving existing adaptive reuse of LCB projects. Thus, this paper's aim is to investigate current retrofitting strategies and interventions in heritage buildings. The objective is to assess current performance of the existing reuse of heritage buildings through the viewpoint of energy efficiency.

3. Research development and methodology

In developing the research methodology an interview survey was devised, comprising a semi-structured interview. According to [31] there are two types of interviews relevant for subjective surveys. One of them is exploratory or in-depth interviews normally used for surveys. Retrofitting of LCBs was targeted for the survey and adopted for this study. The focus of this study was developed from part of a doctoral study on energy management in the reuse of LCBs. A set of questions was formulated in accordance with the objective of the study and a draft questionnaire was prepared and piloted. Comments were received back from the piloted questionnaire after which a number of redrafts of the questionnaire were undertaken. The final version of the questionnaire contained 85 questions which covered an extensive range of operational issues in retrofitting projects. The questionnaire was designed to address different areas of investigation categorised into six different parts namely: building characteristics, energy using equipment/systems, how the equipment is used, energy used, energy management strategies and user behaviour.

3.1 Sampling and selection process

Due to the qualitative approach of this study, a non-probability sampling technique was used. Specifically, purposive sampling technique was selected for the retrofitting projects. Zikmund ([32], p. 382) defines purposive sampling as "a non-probability sampling technique in which a researcher selects the sample based on his/her judgment about some appropriate characteristics required of the sample members". Thus, through a process of purposive sampling ([33], pp. 381–385) the researcher selected five case study buildings from the categories of retrofitting projects involving LCBs. The selected projects for this study were chosen from LCB retrofitting projects in the East of England. However, unlike statistical sampling, the sample is not a representative of the entire population of LCBs in England. Although the selected projects have various types of ownership, however, they are used for similar purposes.

3.2 Data collection process

The data were collected through phone interviews, site interviews and case study buildings. The researcher conducted some interviews with the building tenants to collect information on how energy is used in the building. Following the phone interview, the researcher conducted six on-site interviews with the building managers/operators to learn more about the management practices being implemented in their building. The purpose was to build on the phone interviews to obtain a more in-depth view of the operational performance of the building and to gain a deeper understanding of the best practices in operating the building. Energy use data collection formed the main focus of the data collection of the selected buildings. According to [34] annual energy use can be estimated either by using top-down approach or a bottom-up approach. The bottom-up approach involves the use of the calculation methods while the top-down approach involves an analysis of measured energy consumption and appropriating it to the elements responsible for energy consumption. The bottom-up approach is mainly founded on theory, the calculated loads, and the rated capacity of energy-using equipment. The limitations of the bottom-up approach lies in the weakness of the calculated results rarely agree with metered data. This leads to overestimating energy consumption and in masking individual elements of energy use. Thus, the top-down approach was preferred for this study because of its advantage of providing a greater degree of accuracy as it is based on factual metered data [35]. In the top-down approach, the actual measured data are obtained from utility companies such as monthly utility bills and meter prints outs and are critically examined. The rational for this is to estimate the annual energy consumption and to determine how energy is being used for the activity within the building. Utility data from the buildings were collected for 12 months and the figures were converted to kg of CO_2 and ranked in order of absolute energy consumption.

3.3 Data analysis method

The data analysis method for this study comprise of two approaches. Firstly, benchmarking was adopted as an energy performance tracking strategy. It is a strategy most often use in normalising energy consumption-based metrics such as weather or square footage to promote realistic comparisons with other similar buildings [36]. Benchmarking as used in the analysis of the data in this study is the most prevalent performance tracking approach found in the literature capable of providing a high level picture of energy use. CIBSE TM46 [37] energy benchmarks were adopted to benchmark the performance of the investigated buildings (**Table 2**).

Secondly, the ranking was adopted to categorise higher performing buildings from the lower performing ones. Although the review of literature indicates that numerous ranking and scoring systems have been developed, however, there is no scientific consensus method [38]. The use of ranking will enable the building owners and the facilities managers to be able to compare their building performance to similar building's size and similar pattern of use in order to be adequately informed on the actions to be taken to boost the performance of their buildings. Energy use of the surveyed buildings was converted into CO_2 emission using DEFRA [35] CO_2 emission conversion factors. It assumes CO_2 emission factors of 0.184 kg of CO_2/kWh for gas and 0.542 kg of CO_2/kWh for electricity. The carbon emissions of the buildings were calculated to determine both 'absolute' and 'relative' terms. The absolute emissions indicate the total footprint while relative emissions refer to the absolute figure indexed to a unit of this per m^2 per performance also referred to as 'intensity indicators'. During the analysis of data, the interpretation and the presentation of results; ethical issues were taken into consideration

	Benchmarks (kWh/ m^2)	**Units (m^2)**	**Benchmarked annual utility consumption (kWh)**
Gas	105	390	40,950
Electricity	20	390	7800

Source: CIBSE TM46:2008 energy benchmarks.

Table 2.
Annual utility benchmarking.

by intentional coding the surveyed buildings using an alphabet (**Table 4**) to keep the building's identities and location hidden. This is in line with the suggestion of ([39], p. 89) that the process of data collection should not put participants at risks and that the vulnerable population should be respected by the researcher.

4. Results and discussions

A benchmark comparison of surveyed buildings was performed; first to provide an indication of how the buildings are performing; second, to identify where energy waste is prominent, and third to identify the areas for improvement. **Figure 3** shows the result of the comparison between the benchmark and annual energy consumption of the buildings surveyed.

It could be observed that the energy use of the buildings was substantially and simultaneously higher and plateaued than the benchmarked utility consumption, apart from buildings 'B1' which had lowest energy consumption (i.e. better than the benchmarked utility consumption). The energy performance indicator (EPI) for the investigated buildings is depicted in **Table 3**. It can be seen that the total annual energy use per heated floor area ranges from 17 to 730 kWh/m^2/year with a mean of 321.6 kWh/m^2/year. Building 'B1' was found to have the lowest EPI of 17 kWh/m^2 while building 'B5' was found to have the largest EPI of 730 kWh/m^2/year. Accordingly, the CO_2 emission from the buildings is shown in kgCO_2/m^2 per floor area in order of their emissions to allow for comparisons. **Table 4** shows the building characteristics and the pattern of use. It was observed that buildings used for catering services (B2, B3 and B5) recorded high energy use when compared to other uses. Meanwhile, building used for online bookshop (B1) recorded low energy usage per floor area. To facilitate comparison of energy use, according to the building pattern of use, total energy use in each category was determined and given

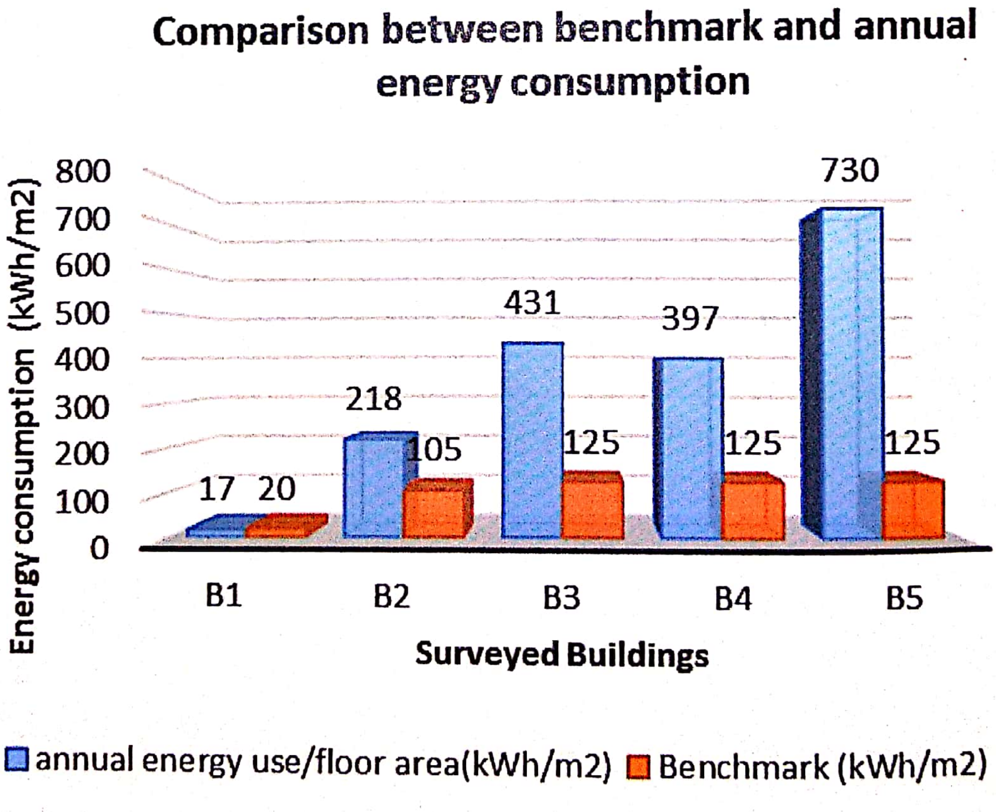

Figure 3.
Comparison between benchmark and annual energy consumption of the surveyed buildings.

	B1	B2	B3	B4	B5
Annual energy use (kWh)	4437	76,170	234,827	111,261	73,712
Annual energy use/floor area (kWh/m^2)	17	218	431	397	730
Annual CO_2 emissions/floor area ($kgCO_2/m^2$)	9	40	128	140	154
Energy performance category	High	Low	Low	Low	Low
Rank	1	2	3	4	5

Table 3.
Energy performance of surveyed buildings by ranking.

	B1	B2	B3	B4	B5
Built	C15	C15	C15	C14	C17
Grade listing	I	I	I	I	II
Main uses	Online bookshop	Community cafe	Community cafe	Bookshop	Community cafe
Secondary uses	Online bookshop	Community cafe	Worship	Community cafe	Community cafe
Floor area (m^2)	269	349	545	280	101
Type of energy use	Electricity	Gas	Electricity & gas	Electricity & gas	Electricity & gas

Table 4.
Building characteristics and pattern of use.

overall rank (**Table 3**) according to their performance range (1 = high performance, 5 = low performance). Building 'B1' ranked 1st and the best performing having the least environmental impact.

Building 'B2' used as community café ranked 2nd with energy use more than twice compared to the benchmark. Energy use became more than tripled with building 'B3' used for dual purpose (i.e. community café and worship) and ranked 3rd. Building 'B4' (397 kWh/m^2) used for dual purpose (i.e. bookshop and community café) ranked 4th. Meanwhile, building 'B5' with a singular use for community café use the largest amount of energy (730 kWh/m^2) ranked 5th as the lowest performing building. The fuel type used by the buildings was investigated; the operational energy performance of the building (B2) using only gas energy was poor compared to the building (B1) using electricity only given the similar construction properties of the buildings. To compare and contrast between the performances of the buildings (B2 and B5), the overriding element that makes building 'B5' less performing to building 'B2' could be attributed to the level of demand, its use requires compared to building 'B2' or put another way, how desirable is its use. Further, the building location factors and the energy efficiency characteristics of the building is a key feature that should not be overlooked but instead needs to be better understood. Meanwhile, the risk posed to a building having such a very poor energy efficiency performance could become undesirable with time and become unfit for purpose. Thus, it can be seen that buildings used as a community cafe either as single use type (B2 & B5) or used in combination with other functions (B3 & B4) appears to consume more energy when compared to other uses. Apart from space heating, the high energy use of these buildings is perceived to be as a result of multiple factors arising from energy end uses. For instance, process plant (e.g. freezers, fridges, etc.) and other equipment (e.g. catering), user's behaviour and attitude, efficiency of heating equipment, etc. It is estimated that around 25% of the energy used for catering operations is expended in the preparation, cooking and serving food. By far the largest proportion of this energy is consumed by cooking apparatus from which much of it is wasted through excessive use, poor utilisation and poor energy management attitude.

Further observation from **Table 4** show that as the building size (i.e. B3, B4 and B5) decreases, energy consumption increases. This finding is quite surprising and contrary to expectation that smaller size building (B5) would consume less energy. The increase in energy consumption in smaller size buildings could perhaps be attributed to the intensity of energy use and more patronage than the larger ones and operational practices of the building operators. In addition, the preference in the use of smaller buildings may have consequently resulted in their over-use, which could have also been responsible for their high energy consumption. Further findings show that among the investigated buildings, only building 'B1' had a form of energy management strategies apart from the fact that the pattern of use contributes to its low energy use. Generally, there are two methods to effectively reduce the energy demand of a building. The first and the most common approach is the physical improvement to the buildings (i.e. fabric and services). The second approach is to improve the way the building is operated (i.e. through facilities management and users behavioural change). However, the peculiarities of Heritage buildings (e.g. listed churches) such as their thick masonry walls, stained glass windows, traditional organic building materials, lime plasters/lime wash and the way they absorb and release moisture; pose challenges and limitation to modern applications of energy efficiency measures. Therefore, the first approach has limited application in several ways. For instance, application of modern type of insulation could create excessive humidity and dampness damaging the fabric irreversibly. Whilst a balance between air tightness and unwanted heat loss through the envelope and controlled ventilation needs to be found; the second approach, which is more passive would be more appropriate.

The most sustainable and available options for heritage buildings is to actively engage users and visitors in an energy saving campaign, introduce energy management systems and making building services such as heating and lighting more efficient. Public building users generally do not have incentives to act in an energy efficient manner. This is the case for all types of users. The result from this study reveals the need for energy management policies and strategies to minimise the energy required to operate rehabilitated Heritage buildings and to ensure their long term sustainability. This is due to their nature as 'hard to treat buildings'. Thus, it is this project's contention that the operational energy efficiency policy should be developed and implemented for sustainable retrofitting of heritage buildings in the world level and not only at EU level.

5. Recommendations and implications for sustainable practices

Existing buildings, particularly those of historical significance, can be transformed with a wide range of interventions, a process which greatly relies on the peculiarities of each case. However, the designer needs to assess what is best for the building and its future users/occupant. A secondary objective of the project should be to investigate and assess proposed functions of the new and upgraded building through the viewpoint of low energy use since energy use of a building is greatly affected by its use and the occupancy patterns that it creates as evidenced by this study. Thus, low energy use as a key contemporary demand for better performance and as a response to climate change should be fully integrated into the retrofitting of heritage buildings. In this way, energy use in rehabilitating heritage building projects can also provide insights for the selection of the appropriate future use, and whether that use can be a viable option for its operation. Further recommendations include considering the potential of integrating building management systems into any proposed retrofitting projects. This allows the monitoring and controlling the heating, cooling and lighting systems as well as ventilation systems where it is introduced in different parts of the building at different times of the day.

Generally, the traditional heritage building technology did not tightly seal buildings neither did they use damp-proof courses in walls nor damp-proof membranes below ground floors. This results in high ventilation rate within the building and consequently high energy consumption. Thus, achieving balance between moisture content, water vapour and ventilation within the building is achieved by high ventilation rates through operable windows, doors and different kind of gaps. By adapting historic buildings, this equilibrium is disrupted, as a rule, providing a building with an insulation envelope is accompanied by an increase in air-tightness, with the aim of reducing the heat losses and making the insulation work. In order to achieve a good energy performance, the available and the most inexpensive and effective option is draught proofing. Nevertheless, this disrupts natural ventilation, making a ventilation system essential to secure the necessary air exchange rate and to maintain the interior air quality. Meanwhile, where internal partitions are used, they can be linked to the function room booking system so that lighting, heating and cooling are only switched on when a function is going to be in use.

Other areas could be fitted with movement or occupancy sensors as part of a wider building management system, so lights come on only when people are present. Similarly, the use of daylight sensors can control artificial lighting according to what is required in different areas of the building, based on natural light entering the building from outside. Building management systems are considered more cost-effective for large Heritage buildings (e.g. churches) used for community and commercial purposes. Further, building owners and corporate building occupiers (i.e. users) and the professionals should be made aware that one of the overriding factors that make a sustainable building is the level of its reduced energy demand when occupied. Therefore, behavioural change of the users should be targeted by making real time information about energy use available. The energy behaviour of employees can also be influenced and changed by providing them with current information about their energy use at their desk, room and/or section within the building. Consumers would also need to be made to understand that lower energy running costs of the buildings means higher operating profits and less impact on the environment.

Additionally, the appointment of personnel trained in energy management as building operators for Heritage buildings retrofitting projects is imperative as this has been known to dramatically reduce energy consumption by 40% and consequently advanced improved operational energy performance of retrofitting projects. More importantly, after all the minimum intervention options have been exhausted for energy saving, consideration for generating on-site energy from renewable (e.g. air-source heat pumps, ground source heat pumps, biomass boilers, etc.) sources could also be sensitively installed on the buildings. Although this option could also be considered earlier where there is already a history of an on-site energy generation, or where boilers are being replaced. The professionals involved in heritage buildings retrofitting projects, such as architects, installation engineers, building surveyors etc., should include services such as analysis of whole life costs and carbon savings in services they provide to support the justification of the investment. Achieving the levels of improved energy performance in the retrofitting of heritage buildings required would not be likely reached if professionals rely on marketing only the economic benefits and payback periods to potential clients. The retrofitting projects should be seen as an opportunity to reduce long term expenditure on energy use by tackling the two simultaneously.

6. Conclusion

The purpose of this paper was to assess the current performance of the existing retrofitting of heritage buildings through the viewpoint of energy efficiency. Findings from the study support motivation for conducting this study as it shows that in terms of energy performance, the majority of retrofitting projects of heritage buildings are currently underperforming. This study has shown that the quantity of energy used in the retrofitting of heritage buildings depends upon how intensity the building is utilised and how the building is operated. Thus, to effectively deal with energy use in retrofitting of heritage buildings, it is necessary to understand the purpose for which the building is to be used, the energy use implications for the new use, the building characteristics and its energy using systems. In addition, adequate knowledge is required of the options available to improve energy utilisation, the techniques for modifying buildings and systems, and the feasibility of replacing portions of them. Thus, it is recommended that lower energy use should be a key consideration in determining the effectiveness of any proposed interventions to the retrofitting of heritage buildings. Energy consumption of the resulting interventions and the possibility of energy generation should be the means for evaluation of actions taken to rehabilitate heritage buildings. The wider benefits of improved energy performance in retrofitting projects apart from improved thermal comfort can become a strong contributor to sustainable retrofitting of heritage buildings. Although the challenging factors impacting sustainable retrofitting of heritage buildings are varied and total elimination of the factors is difficult. However, sustainable management strategies towards the minimisation of their energy use should be aimed at provided such ameliorating strategies would not contravene the conservation policies and the requirements for their protection. New technological approaches with measures for low energy use should be explored not just for their retrofitting and adaptation capability but also for their sustainability.

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