ANGLIA RUSKIN UNIVERSITY

FACTORS INFLUENCING OPERATIONAL ENERGY PERFORMANCE AND REFURBISHMENT OF UK LISTED CHURCH BUILDINGS: TOWARDS A STRATEGIC MANAGEMENT FRAMEWORK

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ANGLIA RUSKIN UNIVERSITY

ABSTRACT

FACULTY OF SCIENCE AND TECHNOLOGY

DOCTOR OF PHILOSOPHY

FACTORS INFLUENCING OPERATIONAL ENERGY PERFORMANCE AND REFURBISHMENT OF UK LISTED CHURCH BUILDINGS: TOWARDS A STRATEGIC MANAGEMENT FRAMEWORK

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MAY 2015

The heritage building sector is recognised as a promising industry capable of reducing environmental impacts of its buildings. However, their current energy performance still remains low with insufficient research into the causes for their poor performance. Current research on heritage building's energy performance is mainly concerned with investigating their thermal performance. Meanwhile, statutory conservation requirements for listed buildings remain a challenging constraint on their sustainable energy refurbishment options. There is, however, a gap in terms of specifically investigating their operational energy performance. Exacerbating this problem is the existence of operational islands between the industry's stakeholders involved in reuse of listed church buildings (LCBs) projects.

This study investigated critical factors perceived to be responsible for this problem from the perspectives of the stakeholders' practices and influence on energy consumption in the reuse of LCBs. A sequential mixed-method research approach was adopted using soft system methodology as the main theoretical perspective.

Findings identified four critical factors perceived to significantly influence energy consumption in the reuse of LCBs. These indicate that human 'subsystem' factors permeate the individual, institutional and system levels as both a trigger and the most critical factor constituting the biggest challenge to achieving sustainable reuse of LCBs. Results from the study highlight the need for a tool redirecting current practice to improve the operational performance of these buildings. The output from this study is the proposal of a strategic energy management framework which could contribute to the development of a body of theory relating to more sustainable heritage building conservation and asset management.

An implication of this study is that a tool, such as this proposed strategic energy management framework could aid designers and facility managers to take informed decisions early in the design and operational practices; supporting them and other stakeholders in achieving environmental sustainability in the reuse of LCB projects. It concludes that if the critical factors are addressed appropriately, environmental impacts of LCBs could be minimised.

Keywords: Energy consumption, energy management, listed church buildings, performance, stakeholders, sustainable reuse.

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ACRONYMS AND ABBREVIATIONS

AABC = Architects Accredited in Building Conservation

ANOVA= Analysis of Variance

ASHP= Air Source Heat Pump

BEMS = Building Energy Management Systems

BMS = Building Management System

BRECSU = Building Research Energy Conservation Support Unit

BREEAM = Building Research establishment Environment Assessment Methodology

BS EN ISO = British, European and an International Standard.

CFL = Compact Fluorescent Lamp

CIBSE = Chartered Institute of Building Service Engineers

CITB = Construction Industry Training Board

CO_2 = Carbon Dioxide

CRC = Carbon Reduction Commitment

CT = Carbon Trading

DCLG = Department for Communities and Local Government

DECC = Department of Energy and Climate Change

DEFRA = Department for Environment Food and Rural Affairs

DETR = Department of the Environment, Transport and the Regions

DoA = Degree of Acceptance

DPC = Damp Proof Course

DTI = Department Of Trade and Industry

EE = East England

EH = English Heritage

EHCS = English House Condition Survey

EIA = Energy Information Administration

EM = East Midlands

EHA = Empty Homes Agency

EPC = Energy Performance Certificate

EPI = Energy Performance Indicator

EPIELEC = Energy Performance Indicator by Electricity Use

EPIGAS = Energy Performance Indicator by Gas Use

EU = European Union

EPBD = Energy Performance of Buildings Directive

FiTs = Feed in Tariffs

GBS = Generic Building Solutions

GHG = Greenhouse Gas

GL = Greater London

GSH=Ground Source Heating

GSHP = Ground Source Heat Pump

HID = High Intensity Discharge

HPP = Heritage Practising Professionals

HSD = Honestly Significant Difference

IEA = International Energy Agency

IES = Integrated Environmental Solutions

IHBC = Institute of Historic Building Conservation

IRR = Infra-Red Radiation

LCCA = Life Cycle Cost Analysis

LED = Light-Emitting Diode

LEDs = Light-Emitting Diodes

LFC = Loaded Factor Code

LCC = Life Cycle Costing

M&E= Mechanical and Electrical Engineers

MVHR = Mechanical Ventilation and Heat Recovery Systems

NE = North East

NHER = National Home Energy Rating

NI = Northern Ireland

NPI = Normalised Performance Indicators

NTHP = National Trust for Historic Preservation

NW = North West

OECD = Organization for Economic Cooperation and Development

PCC = Parish Church Council

LCB = Listed Church Building

LCBs = Listed Church Buildings

PHBs = Public Heritage Buildings

PIU = Performance and Innovation Unit

POS = Planning Officers Society

PPG = Planning Policy Guidance

PPS = Project for Public Spaces

PV = Photovoltaic

RdSAP = Reduced data Standard Assessment Procedure

RH = Relative Humidity

RIBA = Royal Institute of British Architects

RICS = Royal Institute of Chartered Surveyors

RII = Relative Importance Index

RIs = Rank Indices

RPEC = Registered Professional Energy Consultants

RSI = Relative Significance Index

SAP = Standard Assessment Procedure

SBEM = Simplified Building Energy Model

SD = Standard Deviation

SE = South East

SECHURBA = Sustainable Energy Communities in Historic Urban Areas

SL= Scotland

Soft Systems Methodology (SSM)

SPAB = Society for the Protection of Ancient Buildings

SPSS = Statistical Package for the Social Sciences

STBA = Sustainable Traditional Building Alliance

SW = South West

TOE = Tonne Oil Equivalent

UK = United Kingdom

UNEP = United Nations Environment Programme

UNESCO = United Nations Educational Scientific and Cultural Organisation

US/ICOMOS = United States International Council on Monuments and Sites

VAT = Value Added Tax

VOC = Volatile Organic Compound

VOCs = Volatile Organic Compounds

WBCSD = World Business Council for Sustainable Development

WBDG = Whole Building Design Guide

WCED = World Commission on the Environment and Development

WL = Wales

WM = West Midlands

YH = York and Humber

LIST OF PUBLICATIONS RESULTING FROM THIS RESEARCH

Journal Articles

1. **Akande, O.K.,** Odeleye, D., Coday, A. and JimenezBescos, C., 2015. Energy Performance and Improvement Potentials for Selected Heritage Building Adaptation in England. *British Journal of Environment and Climate Change, ISSN: 2231-4784,* Vol.5 Issue 3 DOI: 10.9734/BJECC/2015/19791.

2. **Akande, O.K.,** 2015. Stakeholders' influence on environmental sustainability of reusing religious heritage in the UK: A case of historic churches. *International Journal of Case Studies*. Canada. Vol.4 issue 4 April

3. **Akande, O.K.,** Odeleye, D., Coday, A. and JimenezBescos, C., 2015. Achieving energy efficiency in public heritage buildings: Stakeholders' indicators of sustainable approach. *International Journal of Case Studies*. Canada. Vol.4 issue 3 March

4. **O.K. Akande**, D. Odeleye and A. Coday., 2014. Energy Efficiency for Sustainable Reuse of Public Heritage Buildings: The Case for Research. *International Journal of Sustainable Development and Planning* (UK).WIT Press DOI: 10.2495/SDP-V9-N2- 237-250

Conference Proceedings

5. **Akande, O.K.,** Odeleye, D., Coday, A. and JimenezBescos, C., 2015. Energy use reduction for sustainable reuse of public heritage buildings: The stakeholders' perspectives. In: Amoeda, R., Lira, S. and Pinheiro, C., (Eds.), *Proceedings of the 2nd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structure*. Vol. 2 No1. July Pp. 901-910, Porto, Portugal, Green Lines Institute of Sustainable Development.

6. **Akande, O.K.,** Odeleye, D., Coday, A. and JimenezBescos, C., 2015. Low Energy Use Interventions in Rehabilitation of Built Architectural Cultural Heritage: Challenges and Options for Sustainable Practices. Accepted for *BIO CULTURAL 2015 Proceedings of International conference on Sustainability in Architectural Cultural Heritage*. December 11 – 12, Limassol, Cyprus.

Conference Paper

7. **O.K. Akande**, D. Odeleye and A. Coday and L. Marjanovic, 2011. Energy Efficiency in Public Heritage Buildings: The Efficacy of Options Available for Long Term Sustainability. *Paper presented at the Faculty of Science & Technology's Annual Research and Scholarship Conference, Anglia Ruskin University, Chelmsford.* AirSpace Conference Centre, Imperial War Museum, Duxford UK. 6 May 2011

PART A: INTRODUCTION TO RESEARCH AND THEORETICAL REVIEWS

CHAPTER 1: ENERGY CONSUMPTION AND EMISSIONS CHALLENGES

1.0 INTRODUCTION

Worldwide attention is currently focused on the issues of the rapid increase in energy consumption and its consequential environmental impacts such as greenhouse gas (GHG) emission, global warming and climate change. In 2005, Energy Information Administration (EIA) statistics revealed the global energy use has reached 14.7 Btce (IEA, 2008) resulting in CO_2 emission of approximately 20 billion tons. With the growth in urbanization in developing countries and industrialized in the developed countries, energy usage will continue to rise with its consequences of global warming if is not curtailed. Evidence from Figure 1.1 shows the top contributing nations of the world to global warming in absolute terms.

According to Ravilious (2014) the order of contributions from the nations is US, China, Russia, Brazil, India, Germany and the UK. The chart presented in Figure 1.1 shows that the US leads with 0.15 °C or 22 percent of the 0.7°C warming. China accounts for 9 percent; Russia 8 percent; Brazil and India 7 percent each, while Germany and the UK account for 5 percent apiece between 1906 and 2005. Specifically, the building sector contribution to total energy use in the domestic sector of developing countries and regions such as Africa, Brazil, China, and India is about 20% - 25%; meanwhile their counterpart from other developed countries is about 30%–40% (Zhang *et al.* 2010).

Globally, it is acknowledged that the building sector and existing building stock have a significant contribution to energy consumption (Rowe *et al.*, 2008). In 2007, energy

services delivered to the world's buildings – living, commercial, and public space - required 2 billion tonnes oil equivalent (TOE) fuels for direct combustion and 0.84 billion TOE in the form of electricity and heat (IEA 2010). These represent about 31%, 46%, and 51% of fuels, heat, and electricity available for global final energy use.

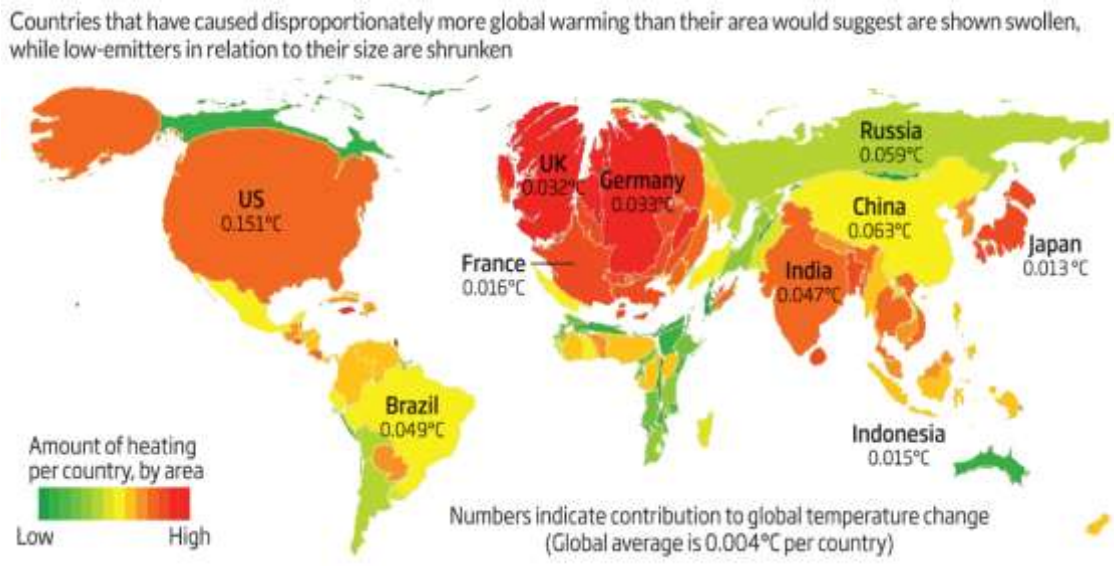


Figure 1.1: Global warming culprits judged by size

Source: Environmental Research Letters adapted from New Scientist Magazine (2014)

1.1 Background to the Study

Due to the significance of the building sector, the key world peer-review assessments such as the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Barker *et al.* 2007); the Global Energy Assessment (Ürge-Vorsatz *et al.* 2011); the Energy Technology Perspectives (IEA 2008) and others have agreed that the building sector is a priority when considering energy security and climate change mitigation. Considering its overall significance, considerable importance is attached to incorporating energy saving measures for new buildings as well as improving the efficiency of the

existing ones. Caleb (2009) indicated that while on that point is considerable recognition given to measures for reducing the emissions from new buildings, the existing building stock has significantly suffered neglect resulting to refurbishment projects missing the opportunities of reduction in emissions and delivery of energy efficient buildings. In reinforcement of this perspective expressed by Caleb (2009) other authors such as Rowe *et al.*, (2008) argued that the retention of existing buildings helps to conserve embodied energy, thus causing a significant contribution to energy saving.

Energy consumption in the built environment is predicted to increase by 34% in the years ahead at an average rate of 1.5% by 2030; while the trend of the increase ascribed to dwellings and non-domestic sectors has been anticipated will be 67% and 33% respectively (Perez-Lombard *et al*. 2008). This rise in energy use and CO_2 emissions from the built environment has further reinforced the urgency for energy saving strategies especially in existing buildings. Chusid (1993) expressed the opinion that existing buildings firstly become obsolete and near demolition. The author reasoned that it is more efficient to allow the building to remain intact and more importantly, give it a new use, which is more preferable to demolition. This approach is called adaptive reuse and described by Douglas (2006) as a notable change to an existing building function when the former function has become obsolete.

Langston and Shen (2007, p.3) noted that adaptive reuse is a particular kind of refurbishment that presents challenges for designers as 'changing the functional classification of a building will introduce new regulatory conditions and perhaps need new planning consent' (Langston and Shen, 2007: p.3). As part of the strategy to promote

sustainability within the built environment, many existing buildings of cultural and historical significance in the UK are being adapted and reused. These buildings are viewed as 'hard to treat' buildings because the larger number of them pre-date 1919 and mainly built of solid wall construction type (Roaf *et al.*, 2008). Thus, they also need to be improved as far as reasonably possible (European University Institute, 2012) if the targets for carbon emission reduction are to be achieved.

A notable potential area for carbon emission reduction in the adaptive reuse of these buildings is the non-domestic sector of public heritage buildings (PHBs). However, of utmost concern is the question of how can energy use of these buildings be curtailed, their efficiency maximised and their carbon footprint reduced without undermining their historical value? Reusing existing buildings are considered to be fundamental to sustainability policy because of its advantages such as the prevention of wasteful process of demolition and reconstruction. Additionally, the environmental, social and economic benefits of reusing existing buildings make it to be recognised as an important component of sustainable development in Australia (McLaren, 1996; Maggs, 1999); Atlanta (Newman, 2001); Hong Kong (Poon, 2001); North Africa (Leone, 2003) and Canada (Brandt, 2006).

A number of scholars (Doak, 1999; Ball, 1999; Gallent *et al.*, 2000; Van Driesche and Lane, 2002; Abbotts *et al.*, 2003; Anon, 2006) have also extensively discussed the importance of reusing existing buildings such as airfields, churches, defence estates, government and industrial buildings as a form of global strategy. Whilst some of the facilities were converted to residential apartments, others were reused for community

purposes such as cinema, restaurants and other functions for public use. This adaptive reuse has become relevant to the current climate change adaptation agenda due to its ability to recycle resources in place (Conejos *et al.*, 2012). In the UK, estimates vary as to the proportion of existing buildings that pre-date 1919 built with different vernacular materials. They are defined as being buildings of traditional construction built of moisture-permeable materials (English Heritage, 2004) and also referred to as 'historic', conservation buildings, older properties or traditional buildings. Table 1.1 presents a breakdown of the estimated number of heritage buildings in the UK. Government data indicate that many of these older properties have a much lower energy performance with over 40% of buildings constructed prior to 1919 (DCLG, 2006). However, according to Moran *et al*. (2012), in spite of government statistics revealing higher CO_2 emissions from the historic building stock, yet there are differences in how the energy efficiency of these buildings is seen.

The energy efficiency of heritage buildings is either regarded as better (English Heritage, 2009; Wood, 2009; Wallsgrove, 2008) or worse (EHCS, 2007; Boardman, 2007; DCLG, 2006). The reasons for these divergent views are centred on the sustainability of these buildings in terms of their energy performance. One major claim from the conservationists supporting the sustainability of historic structures is the perceived value of their embodied energy while the modernist such as Boardman (2007) argued that in spite of their embodied energy, historic structures still need to be upgraded to energy efficiency requirements.

Table 1.1: A breakdown of estimated number of heritage buildings in the UK

	Total number of listed buildings	Listed buildings at risk	Percentage of listed buildings at risk	Percentage of listed buildings at risk owned by local authorities
England	373,892	Estimated to be 8,600 (actual number on register is 1365 i.e. Grade 1 and II* only)	Estimated to be 2.3%	14.6% (refers to those BARs actually recorded on the register)
Wales	29,903	2,849	9.5%	7.5%
Scotland	47,400	1,581	3.3%	7.1%
Northern Ireland	8,500	437	5.1%	4.1%
TOTAL	**459,695**	**Estimated to be 13,467** (actual number of BARs on UK registers is 6,232)	**2.9%** (based on estimated BAR figures for England)	**8.7%** (based on actual number of BARs on the registers)

Source: The Prince's Regeneration Trust, (2010)

1.1.1 Statement of the problem

Currently in the UK, several non-domestic heritage buildings are converted to other uses mostly because of the issue of redundancy. Whilst demolition appears to be the option, however, English Heritage (2004) and Rowe, *et al.* (2008) have expressed concern on the replacement of an existing building for a new one requiring a considerable investment of 'embodied' energy in materials, transport and construction. Hence, according to Forster *et al.* (2011) the alternative of retention and reusing of traditional masonry buildings is not only important from a cultural point of view, but as well as from an economic standpoint.

Although, numerous potential benefits of reusing heritage buildings for other purposes has been highlighted and widely acknowledged, yet there is still need to adapt and retrofit them to optimize energy performance standard in their operation. This is due to the persistence of their common operational energy use problems as noted by Forster *et*

al. (2011, p.659) to include: "*certain aspects of the degradation a building such as gaps in the masonry, with the potential consequence of leading to higher air permeability and associated heat loss*"; saturated masonry resulting in reduced thermal performance as a result of altered conductivity of the material; dampness which may require dehumidification. Hence, contributing to high heating demand (Wilkinson and Reed, 2005), poor internal comfort conditions for users and high operational running cost. Whilst this view is important for the reduction in carbon emissions, exacerbating this situation is the absence of studies specifically targeted at the carbon and energy use reduction associated with adaptive reuse projects required to retain the continual usefulness of PHBs in service condition. Compounding this problem is the perceived lack of consensus among heritage industry stakeholders and scholars and low perception of actual operational energy performance of these buildings.

In addition, current methods adopted for investigating energy use of heritage buildings have concentrated on investigating their U-value either to prove or disprove their energy efficiency or inefficiency thereby leading to perceived tension between the design professionals, the planning and conservation officers and researchers when considering energy efficient retrofit to heritage buildings (Friedman and Cooke, 2012). Meanwhile, non-invasive methods, modernisation and energy reduction strategies compatible with conservation projects such as those involving energy management approaches to improve environmental sustainability of reused heritage buildings are yet to be fully explored.

It is noteworthy that current refurbishment work has a central part to play in meeting the UK's long term emissions reduction goals, reaching beyond the minimum standards of

building regulations, and adopting the best possible practice standards wherever this is technically, functionally and economically feasible can lead to achieving a remarkable improvement in the levels of energy performance. Although, the environmental sustainability and the advocation by several researchers (Snyder, 2005; UNEP, 2009; Langston, 2010; Getty Conservation Institute, 2011) on the importance of focussing on incorporating green and sustainable environmental design and features into adaptive reuse of heritage buildings has raised a lot of concern; to date there is little evidence in the literature focussing on how energy performance of these buildings can be improved. It is clear that the significant gap in knowledge is most pronounced with heritage buildings in public use. This is because 'hard to treat' solid wall construction is more often linked to domestic properties with much literature concentrated on domestic sector (Roaf *et al.*, 2008; Vadodaria *et al.*, 2010; Loveday *et al.*, 2011).

Although, other researchers (Gorgolewski, 1995; Papadopoulos *et al.* 2002; Hong *et al.* 2006) has also emphasized that energy efficient refurbishment of existing buildings is an essential tool for reducing energy use in the building sector. Yet, in many refurbishment and conversion of heritage buildings, this is yet to be fully achieved in practice. Shiel (2009) stated that the general findings of previous studies shows that in the drive to increase the adoption of sustainable practices and approaches within the construction sector, developers and other major influencers often lack a consistent and structured application of decision making processes and the necessary criteria that will guide them in making the most sustainable choices. There is therefore an urgent need to develop robust, low energy strategies for refurbishment schemes of LCB projects. Following the gaps identified, this study addressed the research problem with two key research questions.

1.2 Key Research Questions

The problem addressed in this research is guided by the following key questions:

(i) What are the critical factors influencing energy use in the reuse of listed church buildings? How can they be identified and addressed to more

(ii) effectively manage energy usage and improve performance for long term sustainability?

(iii) How can these influence built asset management (BAM) framework for refurbishment decision making?

1.3 Research Aim

The research aims to investigate factors influencing the operational energy performance in the reuse of LCBs; and establish their relative importance in order to propose an energy management framework.

The specific objectives to achieve the aim are to:

(i) Review existing literature and research relating to reuse of LCBs' contribution to energy use and carbon emission reduction.

(ii) Investigate the perceptions, priorities and values of heritage building stakeholders' influence on energy use reduction in the reuse of LCBs

(iii) Determine the relative importance of strategies perceived as most sustainable and implemented in practice by the stakeholders to improve energy efficiency in the reuse of LCBs.

(iv) Identify the critical actors responsible for energy use in LCBs arising from stakeholders' perceptions that needs to be addressed to improve energy performance.

(v) Assess the energy performance and operational practices of existing reuse of LCB projects and to determine the critical factors responsible for their current energy performance.

(vi) Identify the factors preventing energy use reduction for the delivery of sustainable reuse of LCB projects in practice.

(vii) Propose a strategic energy management framework to serve as an achievable guideline for design professionals and operators of LCBs.

1.4 Significance of the Study

Energy use reduction in buildings would not only benefit the environment, but would also yield benefits in reducing the cost of operating the building. Meanwhile, users of public buildings have inadequate motivation to act in an energy efficient manner and this is common to all types of public building users. Whilst significant progress has been noticed in the development and implementation of policy and regulations to enhance energy efficiency, however, to reduce energy use and its impact on the environment the strategies could be categorised into two methods, namely: (i) physical improvement to the buildings (insulation of fabric, efficiency of services, etc.); And (ii) improvement of the operation of the building (facilities management and the pattern of building use by the staff and other users). These improvements can further be divided into two, namely: (a) activities that can be done by a facility manager (e.g. Changing the set point temperature); and (b) activities that can be performed by those who interacts with energy consuming devices in the building and other building users.

Ideally, energy efficiency improvement that could be more appropriate for 'hard to treat' buildings should be predicated on transforming the building users' behaviour and improvement to the day to day operational performance of the facilities. Meanwhile, the continuous use of buildings that consume energy inefficiently becomes a sustainability problem. Current evidence suggests that by the year 2050, 80% reduction in carbon emissions will be required by developed countries in order to avoid the damaging levels of climate change (AEA Technology Report, 2010). It has been noted that the refurbishment of old buildings could contribute up to 60% cut in carbon emissions of UK by the year 2050 (Power, 2010).

According to estimates by Carbon Trust, non-domestic buildings in UK account for approximately 20% of all carbon emissions (Kelly, 2010). Essentially, it is apparent that significant savings could be made through the improvement of energy efficiency in non-domestic heritage stock if long-term emissions are to be reduced. Thus, reduction in CO_2 emissions and the national dependency on finite fossil fuel resources can be achieved via major conversion/refurbishment of PHBs. This underscores a need to investigate and explore critical factors influencing energy use in buildings at both local and global levels to identify practical solutions at each level.

The use of energy inefficient buildings locally will lead to greater energy consumption and wasteful utilization of resources with global effects. Meanwhile, if local problems are not sufficiently addressed, they become global most especially when they are allowed to happen on an everyday basis all over the world. It is therefore important to seek other possible approaches to curtail energy use in heritage buildings and to seek sustainable solutions to make them more effectively lessen their energy use. The significance of this

study is its focus on method (ii)(b) and the need for direction in current practice for developing and implementing more focussed policy on operational energy performance of 'hard to treat' buildings in order to minimise the energy required to operate them.

1.4.1 Contributions of the study

The paucity of research investigating the critical factors influencing energy use in the reuse of LCB projects drives this present study. Critical factors influencing energy use in the reuse of these projects were explored from quantitative and qualitative perspectives. Adopting a mixed-methods approach provided additional perspective on the factors investigated. Quantitative aspects of the research focused on the factors associated with influence of heritage stakeholders' perception of energy use reduction, and field investigation of operational practices of existing reuse of LCBs. In addition, a qualitative perspective captured a more complete picture of the critical factors perceived by heritage building professionals. Hence, this relatively balanced methodological approach allowed for the exposure of critical factors investigated; a less explored area of research on sustainable reuse of LCBs specifically listed churches.

Current literature on energy performance of heritage buildings only provided insight into main generic factors that influence their energy consumption, namely: (i) thermal envelope performance and improvements related influences; (ii) fabric heat loss influences; and (iii) socio-cultural value influences. Meanwhile, most studies in these areas are mostly concerned with domestic heritage buildings providing numerous and conflicting explanations on their energy efficiency. To date, no study has specifically

investigated in detail the critical factors that need to be addressed to effectively manage energy use for sustainable reuse of LCBs. This investigation added to the literature regarding how energy use can be effectively managed in LCB projects, particularly for the low energy performing ones. More importantly, this research study proposed an energy management framework for reuse of listed churches to enable designers and facility managers identify and address the critical factors. It is hoped that the proposed framework if considered early in the design project's objectives and applied during building operational phase could lead to the improvement in the operational energy performance of LCBs.

1.5 Research Methodology Approach

A two-phase sequential mixed method approach was employed in the collection of quantitative and qualitative data for this current research study. Although, the research design gives equal priority to both quantitative and qualitative aspects of the research study; however, the methodology for this research study was more qualitatively dominated. In the research design, the researcher used qualitative perspective to assist in elucidating and interpreting findings from the quantitative phase. Figure 1.2 shows the research roadmap indicating the theoretical underpinning for the research methodological approach. Following the data collection, findings from the two phases were integrated for a complete interpretation (Tashakkori and Teddlie, 2003). The strategies used for data collection include:

1.5.1 Quantitative method

(i) Online stakeholders' perception survey using survey monkey platform.

(ii) Field building energy use and technical survey involving exploration of existing reuse of heritage building projects operational practices and building structure for subjective evaluation.

1.5.2 Qualitative method

(i) Review of relevant literature relating to energy consumption in buildings and more specifically relating to heritage buildings.

(ii) Information gathering through interviews from heritage building practising professionals, namely: architects, engineers, facilities managers and sustainability consultants

(iii) Development of heritage building strategic energy management framework.

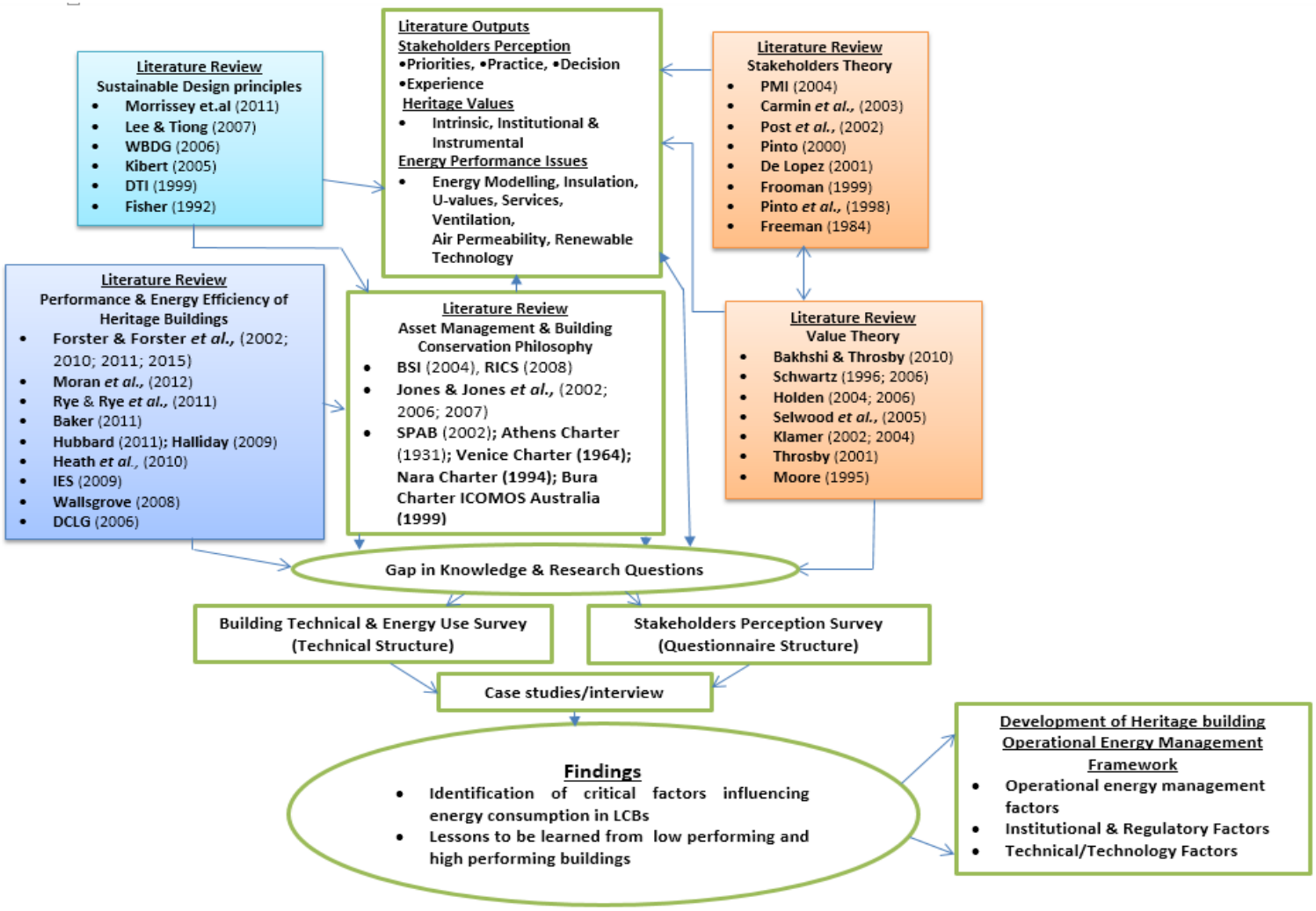


Figure 1.2: Research roadmap
Source: Author's Survey (2012)

1.6 Research Assumptions

The major assumption underlying this research is based on the premise that heritage buildings could be made more sustainable if informed measures are taken to improve their operational energy performance. This greatly depends on heritage stakeholders' perception of energy use reduction measures, design professional's strategies and facility managers' operational energy management practices. Identifying the critical factors underlying energy consumed in the operation of LCBs could aid designers and help facility managers focus on areas to address in order to more effectively manage energy use in these buildings. Thus, by using a combination of methods that consider values, subjectivity, management and behaviour relating to both heritage buildings and the stakeholders perceptions and practices enabled an in-depth investigation into critical factors to be addressed.

1.7 Scope of the Study

It is acknowledged that all PHBs cannot be considered due to available time and resources within the confines of this research study. Hence, as suggested by heritage groups and professionals, heritage buildings should be investigated on a case by case basis (English Heritage, 2011). Therefore, the scope of this research is limited to a long-overlooked area of adaptive reuse of listed churches (Figure 1.3) for community purposes. Churches are exemplar public buildings for community uses and have been estimated to have carbon emissions tens of times those of a typical family home (Eco Congregation, 2006). The data gathered in 2007, indicated that churches and halls account for about 65% (212,000 tonnes) of total emissions (330,000 tonnes) by cathedrals, churches, houses and offices in UK (Church of England, 2008).

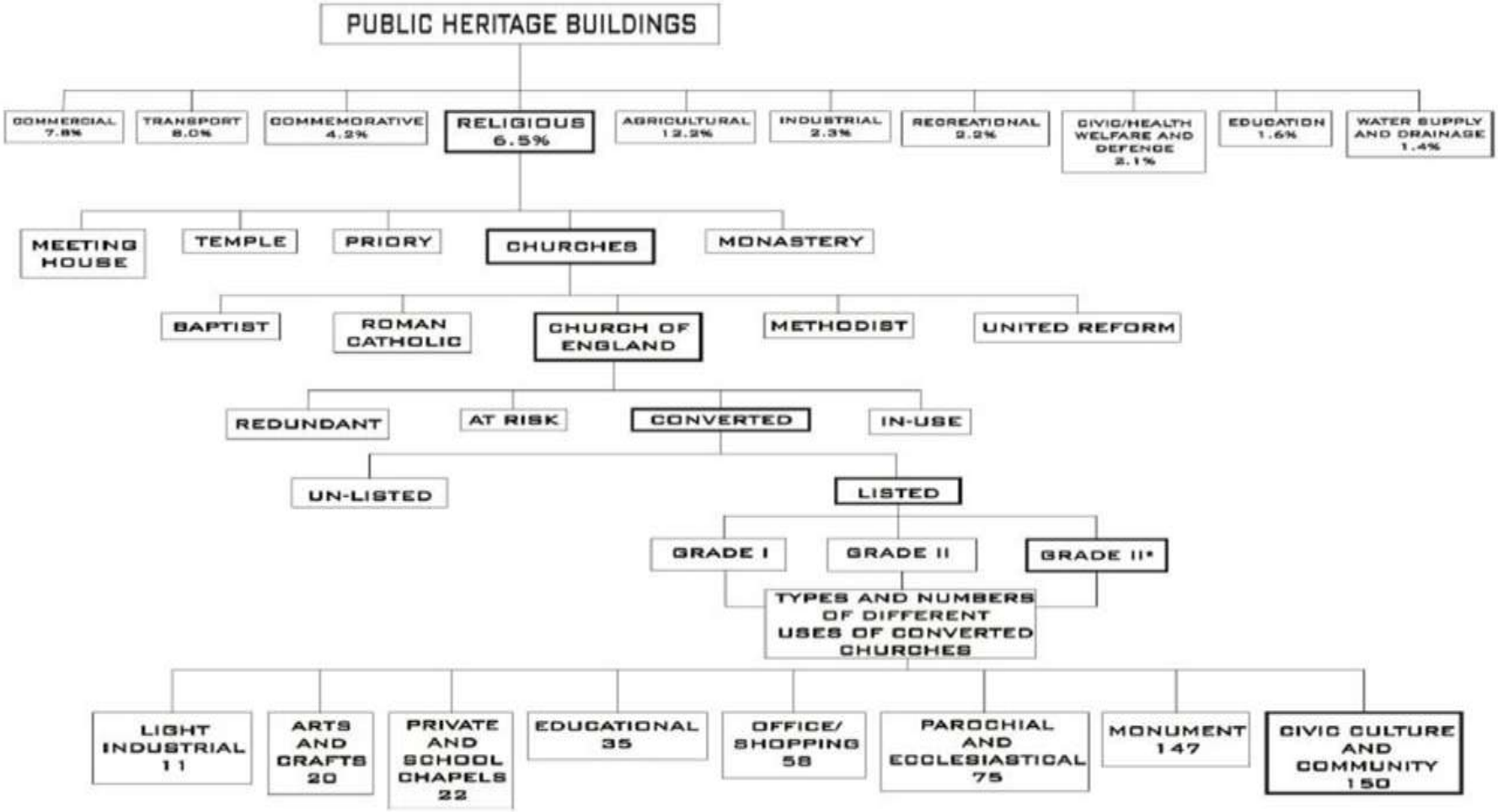


Figure 1.3: Rationale and justification for selection of Church of England (CofE)
Source: Authors Survey (2012)

1.8 Organization of the Dissertation

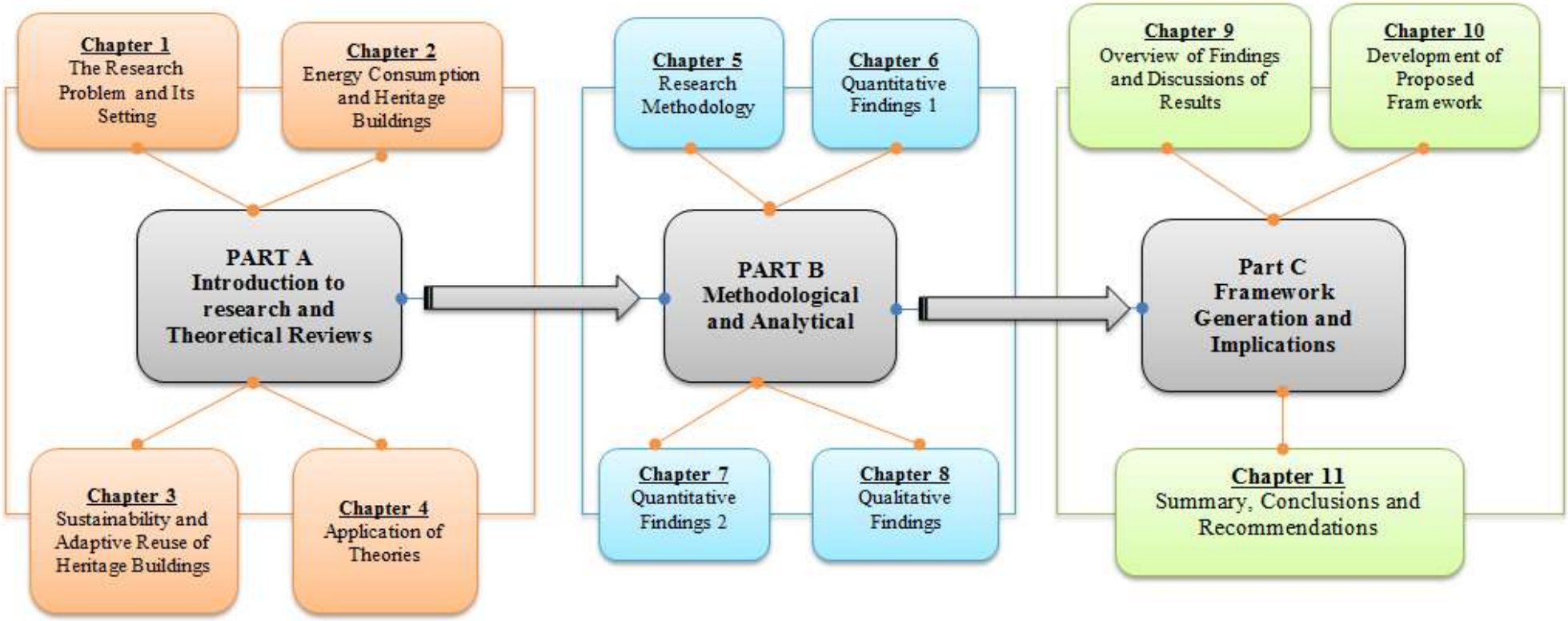


Figure 1.4: Thesis structure and roadmap
Source: Author's Survey (2012)

Chapter 2 reviewed the current literature on asset management, building conservation philosophy, energy use in listed buildings and factors influencing them. It reviewed various researches on energy efficiency measures in heritage buildings.

Chapter 3 presented the drivers for adaptive reuse of public heritage buildings focussing on listed churches and constraints to their energy efficiency.

Chapter 4 reviewed a distinct theoretical perspective and developed conceptual framework that provided the basis for the research methodology approach, interpretation of findings and development of the proposed framework.

Chapter 5 described the research methodology by providing an overview of philosophical paradigms in scientific inquiry (i.e. Positivism and interpretivism) and research methods underpinning the collection of data for the study. The rationale and justification for adopting a mixed methods research strategy was provided while details of the data collection procedure were fully elaborated.

Chapter 6 presented the analysis and findings from the online stakeholders' questionnaire survey and developed illustrative diagram of the outcome the findings.

Chapter 7 presented the analysis and findings from field survey on building energy use and technical survey and developed illustrative diagram of the outcome the findings.

Chapter 8 presented the analysis and findings from interviews with heritage building professionals and developed illustrative diagram of the outcome the findings.

Chapter 9 presented the overview of the findings of this study and extensively discussed and developed illustrative diagram of the outcome; integrated the findings and its implications for the development of the proposed framework.

Chapter 10 presented the background, methodology and the description of the development of the proposed strategic energy management framework; the proposed framework and the recommendations for the users.

Chapter 11 presented the summary, conclusion and recommendations for further study

CHAPTER 2: ASSET MANAGEMENT AND BUILDING CONSERVATION PHILOSOPHY

2.0 CHAPTER OBJECTIVES

- To review literature on asset management and building conservation philosophy.
- To explore the nature of heritage buildings and the peculiar problems associated in improving their energy performance.
- To assess attempts made to improve energy efficiency of heritage buildings.

2.1 Energy Consumption, Emissions and Drivers in the Building Sector

Globally, the building sector accounts for 30-40% of energy consumption, this is equivalent to 8,978 Mtoe every year (International Energy Agency, 2014); while buildings in Europe account for 40-45% of energy use (UNEP, 2007). Meanwhile, in the United Kingdom, existing buildings are responsible for nearly half of present CO_2 emissions: 27% from domestic and 22% of public and commercial buildings (over 100million tons of CO_2 per annum). Approximately 40% of homes – about 8 Million – were built before 1939; half of those were constructed prior to1919 (English Heritage, 2011a). The concern for the environmental impact of buildings has given rise to varieties of drivers and increasing energy policies and reviews for environmental sustainability of buildings in the form of policies, directives, regulations, guides and incentives for energy efficiency and carbon reduction targets.

The global and national policies and legislation introduced include: The Kyoto Protocol 1997; Energy Performance of Buildings Directive (European Union, 2010); Energy White Paper (DTI, 2007); Climate Change Act 2008 (DECC, 2008); Building Regulations Part L: Conservation of Fuel and Power of the building regulations for

England (HM Government, 2010); introduction of Energy Performance Certificates (EPC) and Display Energy Certificates in England and Wales; the Carbon Reduction Commitment (CRC); Carbon Trading (CT) and Climate Change Levies. The Energy Review of 2002 noted the essentials for improving energy efficiency in buildings with recommendations for strategy or action to deliver a phased transition to low energy buildings through the development of the Building Regulations (PIU, 2002).

The question regarding the creation of an Energy White Paper on "*What possible ways are there for encouraging (or requiring) the owners of the existing stock of dwellings and other types of buildings to improve energy performance?"* (DTI, 2003, paragraph 2.8) was not addressed in the Energy White Paper itself. In response to the UK Energy Review, Royal Institute of Chartered Surveyors (RICS, 2006) is of the opinion that energy review is a failed opportunity to challenge the broader and more critical issues that concerns sustainability in buildings. Notably, most recent advances and significant development towards environmental sustainability in construction and operation of buildings on energy use assessment and carbon emissions reductions to meet the government's carbon targets are, to date, concentrated on domestic sector (English Heritage, 2008; ASC, 2011). Meanwhile, little attention and effort have been directed to public buildings and most notably those in the heritage sector has been somewhat neglected.

2.2 The Built Environment Assets

The built environment is predominantly comprised of assets such as buildings (e.g. Historic and modern) and infrastructures (e.g. Utilities, energy and transportation) not limited to physically build assets. As indicated by McClure and Bartuska (2007) it encompasses other areas like facilities, commodities, comfort, health and safety, energy,

products, materials and services. A growing body of knowledge demonstrates the increasing documentation on the impacts that climate change could have on built assets (Camilleri *et al.*, 2001; Liso *et al.*, 2003; Sanders and Phillipson, 2003; Levermoore *et al.*, 2004). Viewed through this lens, is the importance of appropriateness of alternative adaptation strategies to address the impacts to built assets, leading to considerable attention from numerous researchers (Gavin *et al.*, 2005; Hacker *et al*., 2005; DCLG, 2010; Tillsona *et al.*, 2013). Meanwhile, Desai and Jones (2010) have expressed concern at the lack of clarity in integrating adaptation strategies for long term built asset planning.

The authors identified the following association that exists with climate change: the uncertainty, the nature of future climate change projections in the long term and the operational demands on buildings in the short term. Thus, posing challenges to facilities managers in prioritising climate change adaptations above other interventions having other direct advantage. Jones *et al.* (2014) argued that if climate change is not addressed appropriately the aftermath could lead to several buildings becoming obsolete too early. Desai and Jones (2010) observed that current forecasting tools used by facilities managers to set built asset management plans could exacerbate the problem by restricting the scope of possible long term 'futures' to an extrapolation of current experiences and performance trajectories. Such an approach will limit the inclusion of step change scenarios that may be required to address the impacts that future climate change could have on many buildings.

2.2.1 Asset obsolescence

Butt *et al.* (2011) defined obsolescence as depreciation in value and usefulness due to an impairment of desirability and function caused by new inventions, current changes in

design, and improved processes of production, or external factors that make a property or infrastructure less desirable and valuable for a continued use. There are a host of factors which could either play a single or collective role leading to asset obsolescence and depreciation. This could be conventional such as physical, functional and economic depreciation acting together or separately. On the other hand, they could also be contemporary factors such as energy consumption, energy efficiency, environmental issues (e.g. Carbon emissions reduction, legislation and regulations, change of use, change in tenants and end user demands, climate change etc.). According to Butt *et al.* (2010) obsolescence could be considered as climate change induced if it's due to the impacts of climate change.

Similarly, Adair (1996, p. 210) and Anthony and Michael (2004) noted that physical depreciation of asset implies the depreciation suffered by the structure due to its function, the quality of materials utilised in its construction and the absence of adequate maintenance or ineffective management. Depending on the maintenance of the assets, physical depreciation could occur slowly but also could occur faster than the asset's normal life span. Assets usability is also considered as a physical asset depreciation source and as indicated by Anthony and Michael (2006), usage that exceeds an asset's normal use will cause faster depreciation. Functional depreciation depends on physical obsolescence, but often the case rests in aesthetics, social change and the advent of new production processes. Connected with the functional depreciation is the useful life of the building meaning the period from the beginning till the end of the property's operational usefulness. Meanwhile, economic depreciation concerns the real or probable profitability of the property, either let or in owner-occupation. The major outcome of obsolescence in

a building is the reduction in performance of the building and, consequently, not being able to meet the end user's expectations.

Arguably, refurbishment and maintenance are possible options to halt obsolescence and to improve the sustainability of an existing building. Thus, the means of closing obsolescence gap lies in maintenance and refurbishment. Nonetheless, if climate change impacts become intensified and frequent, Butt *et al.,* (2011) asserted that the obsolescence induced by climate change will gradually result to considerable expenses on maintenance and refurbishment. Thus, leading to a reduction in their length of cycles with a corresponding increase in occurrence and expenses which could eventually put financial and economic stress on an organisation. Hence, Butt *et al.,* (2011) stressed the importance of relating obsolescence induced by climate change with in-time asset management so as to sustain the performance of the built environment.

2.3 Asset Management Concepts

Recently, the concept of asset management has gained growing attention with diverse definitions put forward by a number of researchers (Hoskins *et al.* 1999; Grigg, 2003; Cagle, 2003; BSI, 2004a; Davis, 2007; RICS, 2008; Hastings 2010; Valencia *et al.,* 2011) in different ways and employing the concept to describe different types of management, such as property management, facility management, asset management, real estate management, real estate asset management and others. Although the concept is globally recognised (Kaganova and McKellar, 2006), however, there is no universally accepted single definition of asset management. Meanwhile the review of literature has increasingly featured the definition of asset management as presented in Table 1.

Common to asset management definitions (Table 1) is the observation of several themes illustrating what constitutes the real meaning of asset management. This implies the set of process management, which takes a holistic approach to a full life cycle management (i.e. Acquiring, maintaining, upgrading, operating/utilization and disposal) capable of providing the tools and techniques required to address assets issues in order to reduce cost and associated risks effectively. Additionally, the above definitions recognised the duty of asset managers as including the minimization of cost for stakeholders, not limited to fiscal constraints on operating budgets but rather inclusive of the entire lifecycle cost of the assets.

Table 2.1: Definitions of asset management

Author	Year	Definition
Hoskins et al.	1999	*"...activities for the upkeep of a given infrastructure system such as inspection, maintenance, repair, and replacement of parts of the system network all at minimum cost"*
OECD	2001	*"...a systematic process of maintaining, upgrading, and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organized and flexible approach to making the decisions necessary to achieve the public's expectations"*
Peterson	2004	*"...a global management process through which organisations consistently make and execute the highest value decisions about the use and care of assets"*
British Standard Institution	2004a	*"...the optimum way of managing assets to achieve a desired and sustainable outcome "*
British Standard Institution	2004b .	*" ..Systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organisational strategic plan"*
Davis	2007	*"...a continuous process improvement strategy for improving the availability, safety, reliability, and longevity of assets, that is systems, facilities, equipment, and processes"*
RICS Public Sector Asset Management Guidelines	2008	*"...an activity that ensures that the land and buildings asset base of an organisation is optimally owned and managed in the best corporate interest of the organisation objectives and aims"*
Hastings	2010	*"...Information based process used for life-cycle facility management across organizations"*
Asset Management Council Inc. and The Institute of Asset Management	2010	*"...the optimal lifecycle management of physical assets to sustainably achieve the stated business objectives"*
Valencia et al.,	2011	*"...the holistic assessment of a given infrastructure system using a life-cycle approach based on quality data for the purpose of optimally managing physical assets at least cost to stakeholders"*

Source: Author's Study (2015)

Although there are diverse ways by which the concept of asset management can be viewed, Gibson (1999) argues that relationships exist between the term asset management, property management, facility management and/or estate management,

especially in instances where asset management is perceived to embrace property management and other related activities and identified as a decision of property management. Meanwhile, Burns (2002) argues that the concept of asset management is yet to be well defined nor understood because of the different definitions of the concept interpreted to have different meanings by different authors. However, Consilian (2007) advanced an argument expressing that the difference between the asset management and other terms such as property management or facilities management is directly a result of how the concepts are derived from different views based on the roles and nature of asset management itself.

In order to develop and recommend an asset management concept that is accepted globally, the Institute of Asset Management in the UK and the Asset Management Council in Australia has been developing an integrated framework of various concepts of asset management. In addition, researchers (Rebecca and Richard, 2006; Walter and Sisli, 2007; Frank, 2007; Asset Management Council Inc, and The Institute of Asset Management, 2010) has noted the increase in international effort to align the concept and guidance on the asset management framework and practices aimed at avoiding the development, duplication and possibly conflicting guidance by countries around the world. Meanwhile, to develop internationally accepted standards, the Institute of Asset Management has been in support of the BSI proposal to the International Standards Organisation (ISO) in developing an ISO standard on asset management practice using PAS55 as a key input document. This effort is quite commendable and laudable as International asset management practitioners' quest for guidelines to improve their asset management capabilities could be achieved. Furthermore, this would also help to meet

the requirement of PAS55 and the ISO conformance requirements, thereby helping to balance the increasing challenges from customers and regulators.

In 2004, the Institute of Asset Management in the UK put in place systems to effectively manage public property assets for the Local Government and Housing Act. This led to the development of the PAS 55 which serve as British Standard Institution (BSI) publicly available specification to optimise management of physical assets covering the whole asset management. The system provides guidance on achieving and sustaining good practices in all facets of acquiring, owning and ultimately disposing of physical assets. Based on the guidelines, the key dimensions of asset management, which are consistent with other literature are proposed by Hanis (2012) as a good summary of the general approach required for effective asset management as:

• Holistic – taking a larger view and avoiding a 'silo' approach;

• Systematic – a methodological, consistent, justifiable and adaptable approach;

• Systemic – optimising the system as a whole rather than individual assets;

• Risk based – identifying risks and associated costs/benefits and prioritising accordingly;

• Optimal – establishing the optimum balance between performance, cost and risk; and

• Sustainable – taking a long term and life cycle approach.

Following this, in 2008 the Royal Institute of Chartered Surveyors (RICS) produced a guide to best practice of public sector assets management encompassing the whole subject of public sector operational asset management for land and building. This ranged from strategy development (Figure 2.1) to implementation inculcating financial management tools, information and performance monitoring and the use and management of the workplace.

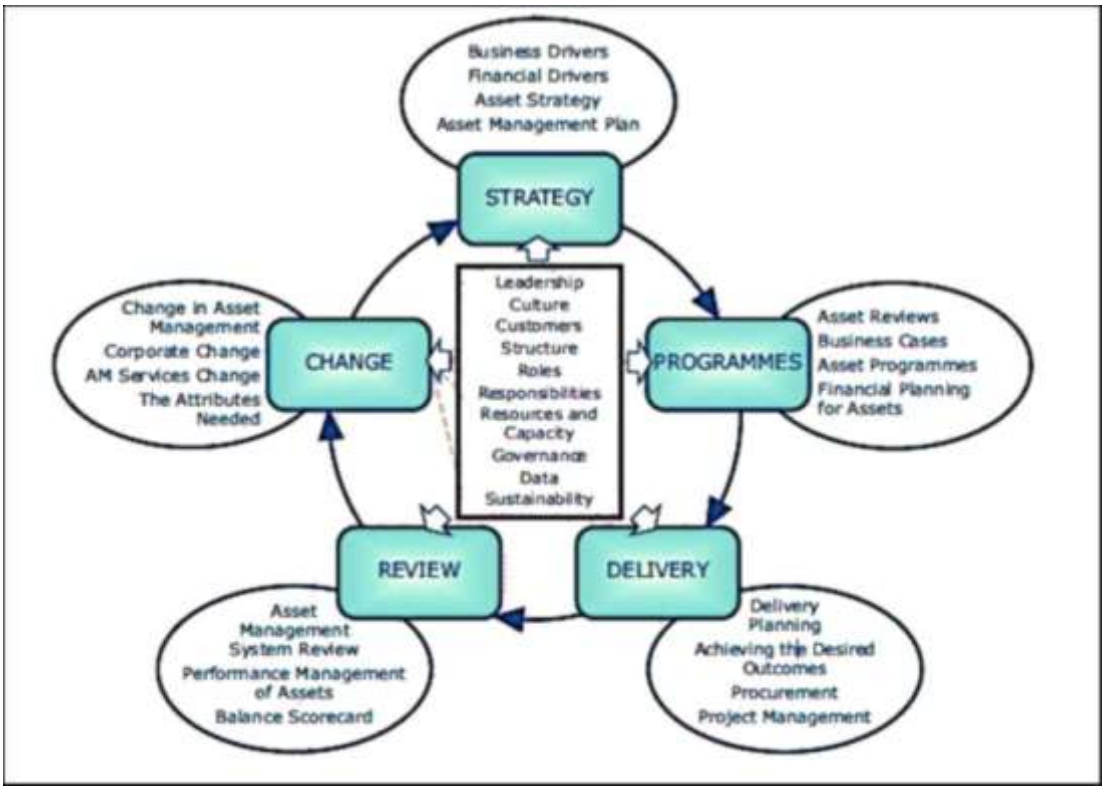


Figure 2.1: Business Process for Assets and Supporting Activities
Source: RICS Guidelines (Royal Institution of Chartered Surveyors, 2008)

PAS55 and the proposed ISO define a set of requirements for a good asset management framework which provide guidance for asset management practitioners to develop their asset management capabilities. According to Asset Management Council, Inc. And The

Institute of Asset Management (2010), the challenge for the practitioners now is to align their practices with the proposed standards and improve their management capabilities beyond the conformance of the standards to achieve higher levels of asset management maturity. Thus, for the purpose of this study, asset management would be viewed from the perspective of the British Standard Institute (2004a) as *'the optimum way of managing assets to achieve a desired and sustainable outcome'.* This would be applied specifically to build assets (i.e. Buildings). The rationale for adopting this definition is based on the premise of its reference to optimising the management of assets, which implies a holistic, systematic and structured approach.

2.4 Asset Management Approaches and Practices

2.4.1 Stakeholder involvement approach

The most prominent approach in any given asset management has been to initially determine stakeholder involvement. The reason for this is that asset management has an extensive scope of stakeholders with varied agendas, making their intangible impacts significant to asset managers. Therefore, according to Maunsell project Management Team (2006) given that the assets are already built, the objective would first be to define stakeholder involvement which centres on establishing levels of service. This process involves segmenting the stakeholders into identifiable groups and then understanding what they value. This is significant because the differing values, agendas, needs, and interests of the diverse stakeholders are used to evaluate the efficacy of the organization which in turn is adjudicated by the level of service offered.

Rogers and Louis (2008) investigated and considered the desirable level of service with regards to water service. They identify inefficiencies in asset to have been occasioned by the fault of the decision-makers to appropriately account for stakeholder involvement. The authors argued that although the typical decision approaches result in short-term positive impacts for the immediate community (i.e. Increased economic activity through capital improvements) nevertheless, the potential outcome of the long-term impacts (i.e. System deterioration because of deferred maintenance) is negative.

2.4.2 Decision management approach

The descriptions of asset management are linked to the process that involves selecting the optimal decision among a number of alternatives. Therefore, a key process for asset management is the decision management process and according to Blanchard and Fabrycky (2011) the process include utilization of classical decision-making approaches such as risk-based and multi-criteria decision-making along with the use and development of decision-making models. While the risk-based approach quantifies the alternatives and, combined with the likelihood of an outcome, leads to the basis of a decision; on the other hand, the multi-criteria decision method seems to be able to address intangible impacts. Numerous researchers have used multi-criteria decision methods in different fields such as energy (Mills *et al.,* 1996), waste management (Vego *et al.,* 2008) facility management (Montmain *et al.,* 2009) and transportation (Rybarczyk and Wu, 2010).

Given the decision-making approaches, decision making models and simulations have become an essential component of the process and have become useful tools in the

process as they enable the study of the system at far less cost and with far less time compared to direct observation of the system (Blanchard and Fabrycky, 2011). The use of decision models has also been used extensively in asset management. For instance, in wastewater sector by Fenner (2000) and Hoskins *et al.* (1999) who suggests changes to asset management decision models are essential and presented a decision approach that recognises the constraints of limited budgets. The authors developed a six-step approach generalisable to other infrastructure. They indicated that their approach is contingent on the ability of managers to quantify and model the condition of a component. While their approach relates to the component and the overall system, it also modelled the component's deteriorating over time with potentials to lead asset managers to more informed decisions. However, Hoskins *et al.,* (1999) observed that the availability of data could restrict the quality of decisions.

2.4.3 Risk management approach

The risk management approach is a well-developed concept in asset management with numerous studies (Piyatrapoomi *et al.,* 2004; Rogers and Louis, 2008; Taillandier *et al.,* 2009; Mansouri *et al.,* 2010; Nordgard and Sand 2010) offering insights into specific applications of risk management principles from different sectors such as facility management, water infrastructure, transportation and energy. An innovative metric for systems engineers was proposed by Austin and Samadzaeh (2008) to measure the effectiveness of a risk management system. The authors found that a large body of literature exists which evaluate different risk management systems, however no literature was found to offer a "risk management effectiveness" metric. They proposed a measure

of effective metric with the goal to improve the overall system engineering and risk management system with potential application to asset management systems.

In relation to climate change, Jones (2001) and Willows and Connell (2003) highlighted the application of a risk assessment framework and methods to climate change. In an attempt to describe environmental risk management, Jones (2001) identifies it as the process of identifying, evaluating, selecting, and implementing actions to reduce the risk to human health and ecosystems. Based on the approach of intergovernmental panel on climate change (IPCC) impact assessment, the author present seven stages of risk assessment. Noteworthy among the stages specified by Jones (2001) is the importance of the stakeholder participation at stage 4 identifying their impact thresholds. The key climatic variables are placed in successive steps. Although, Jones (2001) approach is a stakeholder-focussed, however, Desai (2012) argued that it is still a scenario-oriented approach, reflecting the difficulty associated with uncertainty in scenario selection and modelling common in other approaches.

The UK climate impacts programme (UKCIP) produced a technical report on climate adaptation, which particularly focussed on risk, uncertainty and decision making containing a framework to confront the challenge of climate change. As the framework presented in Figure 2.2 indicates the use of scenarios and projections in in agreement with decision makers' and stakeholders' knowledge and the level of decision making (i.e. Policy, programme and project). Although the framework includes the assessment of risk, however, it is rather more generalised in approach with suggestive limitations on the use

of climate change scenario for organizational use adaptation options and decision making. Meanwhile, Willows and Connell (2003) argued that the UKCIP proposed framework and related guidance is to support good decision making and intended to help decision makers to consider climate change adaptation and climate-influenced decisions by recognising risk factors and uncertainty (Figure 2.2).

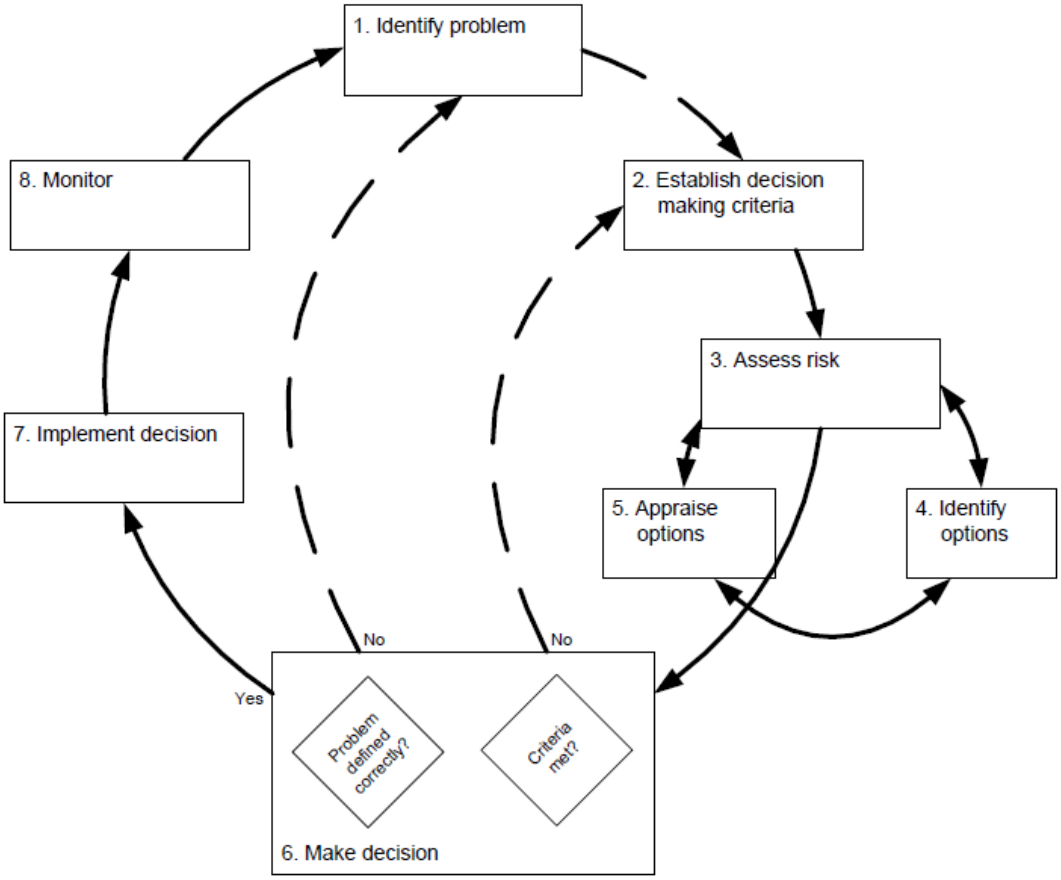


Figure 2.2: Decision making framework for risk of climate change
Source: Willows and Connell (2003)

2.4.4 Life-cycle model approach

According to INCOSE (2010) life-cycle model approach is an organisational process that creates life-cycle models as a groundwork for common reference to a project's life-cycle.

In this approach, feedback mechanisms are generated to determine if the organization is following its own management process and adjustments are made accordingly. Two perspectives; a global systems perspective or component level perspective can be taken of the asset life-cycle. A global system perspective can be taken of the entire system usually to understand the overall system life-cycle costs (LCC) or life-cycle value (LCV). Review of published case studies shows the successful implementation of LCC in the facility construction, energy and transportation sectors (Kim *et al.,* 2010). The authors demonstrate its applicability by developing an LCC estimate for light rail transit.

The objective for conducting these analyses is to achieve the lowest long term costs in system operation and maintenance rather than choosing alternatives that result in short-term savings (Maunsell Project Management Team, 2006). Unfortunately, policy makers typically gravitate towards the latter approach which results in increased future risk due to deferred maintenance and repairs. Somewhat different from LCC is the idea of measuring and quantifying value in LCV, which places emphasis on stakeholder involvement, both present and future. However, other authors (Browning and Honour, 2008) have argued that as perceived value change with stakeholders over time, analyses of LCV would lead to better designed systems. Therefore, developing a system that can support these changes could contribute to a more valuable organization.

While this approach is generic to asset management approach, Jones and Desai (2006) expressed that it is a traditional approach use in built asset management. According to the authors, the approach calls for taking inventory of the condition of an organisation's built

assets and using the combination of some form of life cycle analysis along with operational asset management policy to plan asset maintenance, refurbishment, acquisition and disposal. Meanwhile, Jones (2002) and Sharp and Jones (2012) stated that the stock condition survey is effectively a snapshot of the physical condition of an asset at any given time. Whilst this approach continues to be used by many organisations in practice; a number of documented problems associated with this approach have been identified.

Jones (2002) and Jones and Desai (2006) have criticised the effectiveness and efficiency of this approach by pointing out its limitations as far as long-term operational asset management is concerned. They argue that the weaknesses stem from the theoretical basis on which the life cycle modelling is based. According to Jones and Desai (2006) the life cycle approach involves modelling and an incremental process which commence from a given point along the time-performance line and project maintenance and refurbishment actions forward to return the built asset to a pre-defined level of performance (Figure 2.3). They argued that it is rare that future demands are built into the modelling process.

In the situation where they are, their projection is limited to no more than 3-5 years. Consequently, the refurbishment cycles consistently play catch-up to the changing building demands resulting to gradual obsolescence which ultimately contribute to the building becoming a liability to the organisation. Moreover, Jones and Desai (2006, p. 340) posit that on the basis of the development of mitigation and adaptation strategies, what is required by the model is a more effective assessment of the changing demands

placed on a building over a normal refurbishment cycle. Hence, the limitation of this model needs to be overcome in the proposed framework for heritage buildings.

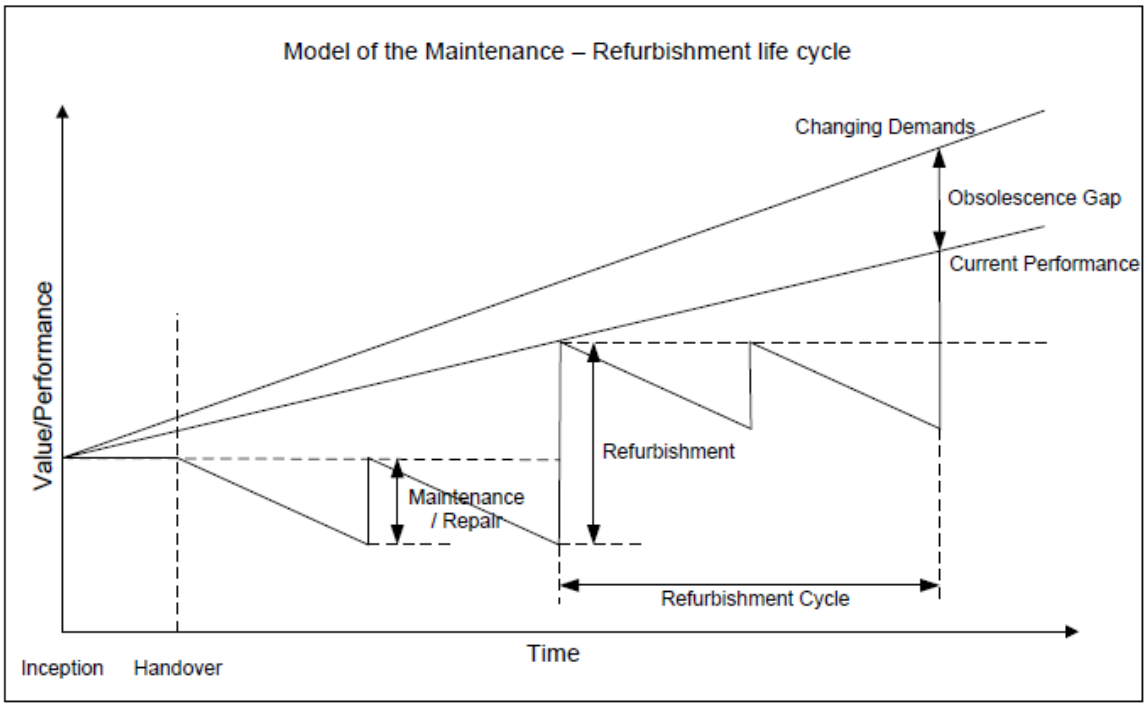


Figure 2.3: The building maintenance/refurbishment lifecycle.
Source: Finch (1997)

2.4.5 Performance based approach

To address the shortcomings in the existing maintenance and refurbishment process, different approaches were developed and used in other service based industry. However, there is an emerging approach that viewed asset management as a combined action within the life cycle's product where a component or system reliability is perceived to be critical to its performance (Sharp and Jones, 2012). The emerging approach includes the development of a range of tools which link asset management to the performance of the product in use. Whilst Sharp and Jones (2012) suggested a similar approaches for the built environment, much earlier suggestion was made by Vanier *et al.* (1996) that if the

building performance could be defined in terms of its users' functional requirements, it could produce standards (benchmarks) against which performance indicators could be compared and maintenance interventions considered.

Hassanain *et al.* (2003) adopted the performance based approach and proposed a model for infrastructure asset maintenance management process. The process model was developed to recognise maintenance interventions by way of considering the degree at which the asset was meeting predetermined performance criteria. The authors assigned multiple performance standards to asset components and set upper and lower limit levels to define an acceptable performance range. Evaluation of the maintenance need was carried out and action were prioritised using a cost-risk model which sought to minimise the risk of failure whilst maximizing system performance. Similarly, El-Haram and Horner (2003) applied the principles of combined logistic support to identify and select built asset maintenance actions. They argued that given the consideration of collective physical and functional models of a building with the application of failure analysis; coupled with reliability centred maintenance principles, an additional approach to cost-effective building maintenance may possibly be realised.

In an attempt to address the limitations in other existing built asset maintenance approach, other scholars such as Sharp and Jones (2012) proposed a new and innovative performance based maintenance process model. Their model underscored and incorporated decisions on built asset's performance within a framework that reflects owners' critical success factors. While it is acknowledged that the framework indicates key performance benchmarks and targets, so as to identify maintenance need and

prioritise the required actions; however, the model is still conceptual and yet to be implemented in real life application. Furthermore the model applicability is limited to social housing maintenance management. Therefore, in the light of the above approaches, it could be concluded that there is a gap between the traditional and the performance based approach to built asset management.

More importantly, further limitations and the shortcomings observed in the current approaches is that there is no existing framework that take into consideration the critical factors influencing energy use and operational performance of built heritage asset maintenance management. According to Sharp and Jones (2012, p.418) the observed gap lies in the philosophical change from maintenance need being assessed on a prediction of the remaining life (the condition model) to one in which maintenance need is based on the ability of the built asset to meet user expectations (the performance model).

2.5 The Case for Improved Performance in Heritage Assets Management

Heritage asset is a combination of word used in planning policy statement (PPS5) for '*a building, monument, site, place, area or landscape positively identified as having a degree of significance meriting consideration in planning decisions*' (cited in Drury, 2012: p.4). They are recognized as valued parts of the historic environment comprising of designated heritage assets; either identified by the local planning authority in the decision-making process or in the plan-making process. In the UK, the built asset maintenance and refurbishment accounted for approximately 45% of the total UK construction output (DTI, 2006) representing approximately 6.2% of the UK's Gross Added Value (Dye and Sosimi, 2006). More significantly, the estimates from the built

heritage construction sector directly accounts for a sum of £10.6bn of construction output, £4.1bn of GDP, £14bn of indirect economic output and a total contribution of £10bn of GDP (Ecorys, 2012).

Recent reviews of literature by Jones and Sharp (2007) and Acclimatise (2009) indicates the lack of knowledge, models, and holistic approach towards integrating refurbishment cycles with performance and life-cycle of a given built asset or infrastructure. Like others, heritage assets could deteriorate through any of the combination of causes of obsolescence. The most extreme examples and more vulnerable in this respect are seen with large and complex buildings such as listed churches, abandoned warehouses and other building types facing the challenge of approaching obsolescence. Meanwhile, due to the increasing mitigation initiatives and legislation, much attention is concentrated on addressing CO_2 reduction of existing built assets. Nevertheless, due to legislative drives, the mitigation agenda has found an increasing operational importance in heritage industry's built asset management and operations. Consequently, an increasing concern for emission reduction for the built heritage have become the agenda within many organisation's corporate responsibility and sustainability strategies as an extension to energy efficiency and cost saving initiatives.

Given the existence of gaps in asset management of the built environment, a suitable strategy is required to ensure that the available resources are effectively and efficiently deployed in a systematic manner to deliver outputs on the operational performance of the built heritage assets. Meanwhile, adequate understanding of building conservation philosophy and principles is paramount as an essential precursor to any proposed

interventions. This is to ensure that the most appropriate intervention is carried out based on a well-defined and understanding of building conservation philosophy. In conservation terms intervention is defined in BS 7913 (2013, Section 6.11) as the "*action that has a physical or spatial impact on a historic building or its setting*." Intervention is used as a combined noun to describe all works relating to change, alteration, repair or maintain the historic environment in good condition and in so doing preserve its historical and cultural value or significance.

2.6 Heritage Building and Statutory Designation

Heritage as defined by Koboldt (1997, p.68), is *'...an expression or representation of the cultural identity of a society in a particular period'*. A wider definition of heritage is given by Throsby (1997, p.15) as *'...the capital value that can be ascribed to a building, a collection of buildings, a monument, or more general place, which is additional to the value of the land and buildings purely as physical entities or structures, and which embodies the community's valuation of the asset in terms of its social, historical or cultural dimension'*. From these definitions, it is clear that heritage comprise sets of 'assets' grouped into a number of interrelated categories such as built environment, including historic buildings, monuments, townscapes, archaeological sites and landscapes (Ecorys, 2012).

Traditionally constructed buildings in the UK is defined by English Heritage as mostly all buildings constructed before 1919, in addition to a substantial proportion of those constructed prior to 1945 with solid walls made of moisture-permeable materials (English Heritage, 2005; 2010). Sometimes these buildings are denoted as 'historic', 'conservation

buildings', 'older properties' or 'heritage buildings'. Feilden (2003) referred to them as buildings of archaeological, architectural, historical, documentary, aesthetic, economic, political, societal and spiritual symbolic values. Harrison and Oades (1997) described them as buildings of all periods containing information about cultural priorities of people influencing how they lived, worked and built. In the UK, several designations are applicable to historic buildings such as:

- Listing of buildings
- Conservation areas
- Schedule of ancient monuments
- Locally listed buildings.

2.6.1 Listed buildings

A listed building is a structure having special architectural or historic interest recorded in a statutory list. In England, listed buildings are classified in grades to indicate their relative importance as follows:

Grade I - buildings of exceptional interest, sometimes considered to be internationally important; constitute 2.5% of all listed buildings

Grade II* - buildings of particular importance and more than special interest; constitute 5.5% of all listed buildings

Grade II - buildings of national importance and of special interest; constitute 92% of all listed buildings. Figure 2.4 shows the age range of listed buildings in the UK.

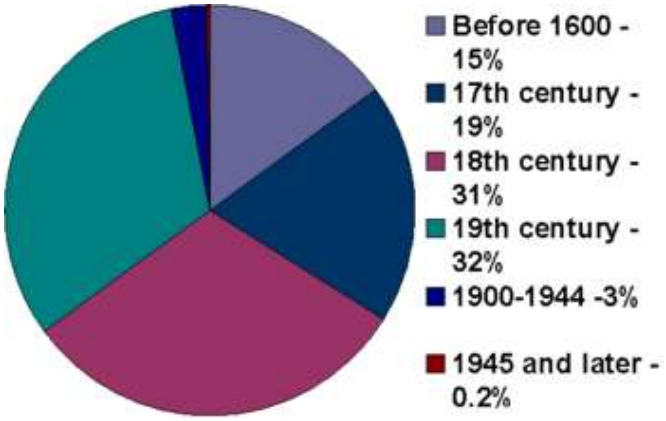


Figure 2.4: Age range of listed buildings in the UK
Source: English Heritage (2011)

The climate change agenda is an important driver for changing the way in which the built environment is created and managed. It leads to increasing pressure for the existing building stock including heritage buildings to incorporate measures which directly or indirectly reduce CO_2 emissions. However, it becomes more challenging with heritage buildings where compromises may be needed between maintaining the integrity of the original structure and adapting them to climate change (Connelly, 2011). An instance is the part L of the building regulations which excludes listed buildings and those in conservation areas. Essentially, achieving holistic, sustainable management of heritage buildings requires all aspects of sustainable development to be considered from the perspective that aims to meet the present needs without compromising the opportunities for meeting the needs of the future generations. This fundamental tenet of sustainability has its origin in the philosophy of Ruskin (1849) on architecture expressing that older building belongs partially to those who built them and partially to all the generations of people who are to follow. As such Ruskin criticises restoration practices that contributed to the substitution of the word ‘restoration’ with ‘conservation’ and

associated the marks of age on a building as part of its beauty and acquired character thus became an advocate of honesty in any intervention on heritage buildings.

2.7 Historic Context of Conservation Philosophy and International Charters

According to BS 7913 (1998, Section 4.3) conservation is defined as the "action *to secure the survival or preservation for the future of buildings, cultural artefacts, natural resources, energy or any other thing of acknowledged value for the future*." While conservation philosophy could be referred to the way conservation is carried out with the thought process behind every conservation related decision. Conservation philosophy was developed over centuries and has been adapted constantly to satisfy the needs of different generations and societies. Charters were formulated and became an excellent reference point for any conservation related decision for conservation professionals. The motivations behind conserving buildings are equitable to those behind the general heritage protection which advocates values-based approach; established on integrity and authenticity. Consequently, conservation is guided and achieved through philosophy, legislation, policy and principles of good practice including international charters such as

- SPAB manifest 1877, William Morris.
- Athens Charter 1931 brought to wider attention by Le Corbusier 's book La charter d ' Athens
- Venice Charter 1964, reflecting post-war Consensus.
- Nara Charter on Authenticity 1994.
- Bura Charter, ICOMOS Australia 1999

2.7.1 The Society for the Protection of Ancient Buildings (SPAB) Manifesto

Generally, most modern conservation characteristics dates back to the publication of William Morris' conservation manifesto in 1877 to the Society for the Protection of Ancient Buildings (SPAB). The Manifesto was conveyed at a period where damaged monuments were regarded as an architect's canvas upon which to impress his vision of how the building should have been built. Morris and SPAB campaigned was for the protection of historic monuments as against what at the time was termed restoration. Essentially, the Manifesto focused on 'ancient monuments of art' whose qualities may include historical and picturesque which criticises 'restoration' and encourages 'protection' (Rodwell, 2007: p.12). It expressively states:

> *'to stave off decay by daily care, to prop a perilous wall or mend a leaky roof by such means as are obviously meant for support or covering, and show no pretence of other art, and otherwise to resist all tampering with either the fabric or ornament of the building as it stands'* (SPAB, 1877).

According to Rodwell (2007, p.12) two basic principles of conservation are reflected in the manifesto. Firstly, the principle of minimum intervention which was expressed as '*to stave off decay by daily care*'. Secondly, is the principle of preservation of the monument where it's no longer considered suitable for use; should be preserved as it stands without being altered or enlarged. Since the founding of SPAB, Earl (2003, p.28-33) argued that the approach to building conservation and the appreciation of the historic built environment has changed and become wider. It now builds on the broader public interest and support and as well become more inclusive in acknowledging a great diversity of building types beyond what is considered as national monuments. Whilst Morris's venerated proposals called for a complete stop of contemporary additions or changes to historic structures; on the other hand, modern conservation is much more engaged with

the management of change (English Heritage, 2008; Jokilehto, 1998; Nasser, 2003; Rodwell, 2008).

New uses and the inclusion of contemporary design are nowadays believed to be 'Modern'. In this context, modernity refers to the concept of post-medieval and post-traditional society characterised by the rise of industrialisation and mechanisation. Whilst Cramer and Breitling (2007) expressed that modernity should be appreciated and encouraged provided they are of high quality and executed in a manner sympathetic to the character of the building; on the other hand the SPAB's concern is about interfering and imposing modern art on ancient building in a manner that it could destroy the building. Arguably, contemporary building conservation needs to stay true to its historic origin and should constantly promote maintenance, minimal intervention, and authentic materials and repair techniques for historic buildings.

2.7.2 The Athens Charter

Internationally, the preservation and restoration of historic monuments' scientific principles was first determined by the Athens Charter of 1931. Following this was the Charte d'Athens of 1933 giving recognition to protecting individual monuments and urban ensembles. Although the Charte d'Athens 1993 condemns the attempt to imbibe the idea of aesthetic in historic areas for newly built structures by using the historical style (Rodwell, 2007). However, both 1931 and 1933 Charter embraced the design ideas that originate from architecture, planning and construction techniques of the modern movement. Whilst the Charters' focus is on historic sites with strict custodian protection, nonetheless, it gave support to using modern materials and techniques for restoration

projects. More importantly, the Athens Charter embraces continue use of historic monument in appropriate manner and gave regard for the monuments' surroundings and as well as the design of new buildings.

2.7.4 The Venice Charter

The Venice Charter, generally known as the International Charter for Conservation and Restoration of Monuments and Sites originates from numerous aspects of the SPAB Manifesto. It was adopted in 1964 by the International Council of Monuments (ICOMOS) as a representation and revision of the 1931 Athens Charter, which establish a document that regulates the handling of historic edifices. The Venice Charter forms a strong consensual view of twentieth-century conservation experts and provides a logical set of rules and guidance for those engaged in conservation work. It was introduced with the following words: "*imbued with a message from the past, the historic monuments of generations of people remain to the present day as living witnesses of their age-old traditions*". The concern for specific ethics of conservation is evident in the fifteen articles of the Venice Charter, according to which, the treatment of a monument excludes any initiative reconstruction based on an historical style. This preclusion is a product of the idea that the form of a monument documents the past. Therefore, conservators cannot alter its appearance without debilitating its value as an historical source.

The Venice Charter reflects more consciousness for values through its respect for ancient monuments as a common heritage. Therefore, the common responsibility to safeguard them for future generations is recognised. The singular interest in the appearance of the

monument is most evident in Article 9, which states that "*restorations must be based on incontestable evidence and not on conjectures about their previous state*". However, if additions are essential, it states that modern design "*must bear a contemporary stamp so that it is distinguished from the original work and it is our duty to hand them on in the full richness of their authenticity*". A similar statement is mentioned in article 15 of the Charter, which deals with ruins and damaged monuments and recommends that new materials used in the reconstruction or reconstitution of buildings should be distinguished from the old fragments.

2.7.5 The Nara Charter on Authenticity

According to UNESCO (1994) the Nara Document was conceived and established upon the spirit of Venice Charter 1964. However, it extended to an increasing scope of concern for cultural heritage and interests in the contemporary world. The Document was the first international heritage preservation document, which gave major attention to the social and cultural values of all societies; giving attention to the need for a broader understanding of cultural diversity and cultural heritage in relation to conservation. It gave full recognition to cultural heritage conservation indicating the establishment of historical periods and values attributed to heritage. One of the main advocate of the Nara Document is the dynamic promotion of diversity, protection and enhancement of culture and heritage around the world as an indispensable facet of human development. The Nara Document while upholding the importance of value and authenticity of heritage states that:

> *"It is not possible to base judgments of value and authenticity on fixed criteria. On the contrary, the respect due to all cultures requires that heritage*

properties must be considered and judged within the cultural contexts to which they belong".

Authenticity according to Stovel (1994a) as originally presented in the Venice Charter (1964) lacks clarity; giving rise to general assumptions about the nature of an appropriate response to conservation problems. However, authenticity as a word became more recognised when it was included as the "test of authenticity" in the operational guidelines of the World Heritage Committee to determine the vital truth about the established values when observing cultural criteria (Stovel, 1994a). Meanwhile, Lemaire (1994) maintained that the question of what constitute authenticity criteria for effective decision making in conservation still remained unanswered? Basically, such question is also vital for historic areas, particularly with the increasing number of organisations and groups (e.g. ICOMOS, ICCROM, UNESCO, English Heritage and Europa Nostra) working on historic buildings and conservation areas (Feilden and Jokilehto, 1993; Nara, 1994; Cohen, 1999).

Although, one of the objectives of Nara document is to recognise different associations and cultures that people experience with the cultural heritage and the concept of authenticity; however, Rhyne (1995) observed and criticised its lack of provision for indigenous peoples and their values. He indicated that the diversity of culture is globally valued and as such preservation practices should consider the varying traditions, monuments and environments belonging to all. Rhyne (1995) philosophical position is founded based on the premise that the universal significance of the most important sites of historic and artistic achievement exists everywhere in the world. This view is reflected in most international charter and guidelines in one form or another. For instance, The

Operational Guidelines for the World Heritage Convention (UNESCO, 2012, p.12) declared that:

> *"The cultural heritage and the natural heritage are among the priceless and irreplaceable possessions, not only of each nation, but of mankind as a whole. The loss, through deterioration or disappearance, of any of these most prized possessions constitutes an impoverishment of the heritage of all the people in the world. Parts of that heritage, because of their exceptional qualities, can be considered to be of outstanding universal value"* (UNESCO, 2012 p.12).

Whilst this view forms the bases of the Nara Document, it could summed up that the document, advocate for allegiance to the principles and responsibilities imposed by international charters.

2.7.6 The Burra Charter

The Burra Charter was first drafted and produced in 1979 by Australia ICOMOS (International Council on Monuments and Sites) and successively modified in 1981, 1988 and 1999 (ICOMOS 1988). The Charter conveyed the notion of 'cultural significance' by bringing forward the debate on heritage conservation while advocating a cautious approach to change by stating: *"do as much as necessary to care for the place to make it usable, but otherwise change it as little as possible so that its cultural significance is retained"* (Australia ICOMOS, 1999). It provides guidance not only for the conservation of historic buildings or urban areas; but also covered the conservation and management of places and landscapes of cultural significance. According Rodwell (2007, p.14) the focus on the Charter's guiding principles is centred about the importance of understanding and safeguarding significance, unravelling of historic layers in a manner that encapsulate

a place's aesthetic, historic, scientific and spiritual values from the past, in the present, and for the future.

Although developed based on the expertise of Australia ICOMOS member, Earl (2003) cautioned that the significance of the charter should not be limited only to Australia as it has received a wider international reputation in defining and conserving cultural heritage and has been adopted as a practical guide beyond Australia due to its clarity of expression and common sense approach. Whilst the Burra Charter could be viewed as a operational tool for devising conservation management plans for culturally significant places, it also adopts a curatorial and scientific approach (Rodwell, 2007). In the Charter, provision is made to differentiate between the old and new fabric in any conservation and allowance given to make the required alterations provided they are temporary and reversible. Its advocate for continual usage of historic assets makes it to play an important part in the national and international levels in guiding conservation practice and procedures and to influence national and governmental public policy. Rodwell (2007) remarked that the conclusion of the charter contains a crucial message for any conservation project: 'the best conservation often involves the least work and can be inexpensive'.

2.8 The Principle of Conservation of Historic Buildings

Broadly, the building conservation's philosophy and practice are based on principles and processes with the purpose of establishing consistent conservation projects. Specifically, Bell (1997, p.27-33) stated that conservation projects should be based on specific criteria derived from conservation principles. Several principal building conservation tenets were drawn up in the Appleton Charter (1983), to help guide conservation professionals in

carrying out high quality repair work. Likewise, the British Standard 7913 (1998) offered guidance on conservation principles of historic buildings and the need for balance between them and their energy conservation. Meanwhile, Forster (2010) observed some conflicts in the conservation principles which produce tensions and possibly affect technical decisions and intervention. Nevertheless, the principles are acknowledged and recognized by international and national heritage organizations with global efforts through legislations to safeguard the built heritage.

Notably, the lessons arising from the various charters (i.e. The Athens Charter, 1937; Venice Charter, 1964; European Charter of Architectural Heritage, 1975; the Nara Document on Authenticity, 1994; Charter for the Built Vernacular Heritage, 1999) encompasses set of principles that should characterize any proposed interventions (e.g. Adaptation and alteration) to buildings and sites of historic, artistic or cultural value. The principles are summarised and discussed in the following sections.

2.8.1 Proactive maintenance

Proactive maintenance in conservation principle refers to the principle of protecting and preserving a building's historic fabric from deterioration so as to avoid or minimise the need for repair or replacement. BS 7913 (1998) defines maintenance as a necessary routine works to keep the building fabric in good order which is "fundamental to good conservation". The importance given to maintenance was mentioned before in the mid-nineteenth century by John Ruskin and William Morris who identified it as a means of retaining the embodied values in historically sensitive fabrics by referring to it as to "stave off decay by daily care" (SPAB, 2008, p.1). Internationally, the importance of

maintenance has also been given adequate recognition and is being refered to as "essential to the conservation of monuments" (Venice Charter, 1964, p.1). According to Burra Charter (1999, p.6) maintenance is "fundamental to conservation and should be undertaken where the fabric is of cultural significance and its maintenance is necessary to retain its cultural significance." Other international organisations such as the UN member states of the 'World Heritage Convention' in their aim to promote the preservation of buildings of international importance have also recognised and linked conservation of historic buildings and sites to building maintenance by adopting and extolling its virtues (UNESCO, 1972).

2.8.2 Minimum intervention

The principle of minimum intervention relates to the principle of restricting conservation operations to the minimum necessary for preservation of the fabric. Brereton (1995, p.7) referred to it as 'minimal or least intervention' and the principle of 'as much as is necessary' while Feilden (2003, p.235) described it to be 'as little as possible'. Whilst the first premise of responsible conservation seem to centre on sensitivity and respect towards the original building or artefact; however, British Standard document (BS 7913:1998, p.12) states clearly that the conservation principles on which historic buildings are based is minimum intervention. This is fundamental to good conservation as the stock of historic building is finite, and each loss is significant. The principle of minimum intervention also reflect and support historic building conservation guidelines produced by the RICS (2009, p.11) which emphasise that "*it is rarely wrong to leave undone that which does not actually unarguably need to be done to maintain structural and architectural integrity*." Therefore, the concept of least intervention is established upon the concept that if the principle of minimum intervention is applied, maximum historic fabric and the

significance it embodies could be preserved. Thus, this principle of cautious approach is emphasised and exemplified by the international charters (Australia ICOMOS, 1999), organisations (British Standard Institution, 1998) and professional bodies (RICS, 2009).

2.8.3 Conservation repair

This is the principle of determining the quality of repair to accord with the quality of the original fabric of the building. The avoidance of distortion of the original evidence is emphasised and the use of 'like for like' material is usually recommended in replacement. It is stated in the Venice Charter (1964, Section 12) that when dealing with repair in conservation project, the missing parts to be replaced must incorporate with the whole and at the same time be distinguishable from the original. This is to avoid the restoration falsifying the artistic or historic evidence. Meanwhile, the Burra Charter (2013, Section 22.2) buttressed this principle by stating that 'new work should be readily identifiable, must respect and as well have minimum impact on the cultural significance of the place. Similarly, the Athens Charter (1931, Section IV) added that the 'new materials used for conservation purpose should be recognisable in all cases'. SPAB (1877) referred to this as 'honest repairs' while English Heritage (2008, Section 5) principles recommended that 'the decision about change must be reasonable, transparent and consistent'.

2.8.4 Explicitness of alteration or addition

This is a principle of clear differentiation between the genuine fabric and any necessary modifications sometimes expressed as an injunction to avoid pastiche. According to Venice Charter (1964, Article 5) *'the conservation of monuments is always facilitated by making use of them for some socially useful purpose'.* Thus, it's clear that alterations and

additions to historic fabric could be necessary to enable sensible change to occur. However, according to Forster (2010, p.168) the necessary interventions must be well designed, readable, reversible and not detract from the integrity of the building.

2.8.5 Reversibility of alteration and extensions

Reversibility is the principle of conceiving any necessary modification in such a way as to enable the original design to be reinstated at a future date. The BS 7913 (1998, p.3) referred to this principle as the "concept of work to a building, part of a building or artefact being carried out in such a way that it can be reversed at some future time, without any significant damage been done". The principle of reversibility which also reflected in the Burra Charter (2013, Section 15.2) states that "changes which reduce the cultural significance should be reversible, and be reversed when circumstances permit".

Although, in the Burra Charter, provision is made for some flexibility in special cases as cited by Earl (2006, p.172) which implies that "non-reversible change should be permitted as a last resort in some cases and should not inhibit future conservation action". However, implicit in this principle is the need to record the details of any genuine fabric before it is covered or removed. The BS 7913 (1998, p.10) recommended that "any work carried out on the fabric either before, during and after should be recorded, maintained, properly deposited and stored". According to the Sterling Charter, the recording of work done should include "the description, depiction and analysis of any feature or area using drawings, survey, photographs and any other suitable means as well as the preservation

of documents, photographs and other material relating to the feature or area in any earlier condition or use" (Historic Scotland, 2000, p.7).

2.8.6 Compatibility of use

The Burra Charter defines 'compatible use' as that which 'involves no change to the culturally significant fabric, changes which are substantially reversible, or changes which require a minimum impact.' Thus, the principle of compatibility of use is about maintaining or introducing a use for the building that includes least or no change to the culturally significant fabric. According to the Venice Charter (1964, Section 5) 'the conservation of monuments is always facilitated by making use of them for some socially useful purpose'. It further stated that while such use is inevitable, nevertheless, it must not change the layout or the decoration of the building. It is within this limit only that modifications demanded by a change of function should be envisaged and may be permitted. Therefore, both national and international charters specializing in the care of heritage buildings promote the idea of an adaptive reuse as a good strategy for preserving them (ICOMOS, 1964, English Heritage, 2011).

2.8.7 Sustainability

The BS 7913 (1998) encourages minimum intervention and a cautious approach in conservation as well as encouraged energy efficiency improvement by not only putting the historic buildings into consideration but also into the larger environment. This is evident in the BS 7913 (1998, p.7) which states that "in global environmental terms, the balance of advantage strongly favours the retention of existing building stock, particularly

when performance in terms of energy consumption in use can be improved". Accordingly, English Heritage (2004, p.3-4) gave consent to this by stating that "retaining existing elements of construction in old buildings and seeking to enhance their thermal performance in benign ways rather than replacing them is a heritage conservation principle in line with the concept of sustainability." Thus, conservation principles support changes that could be made to historic buildings which would fulfil both energy and building conservation principle.

The concept of sustainability has also been discussed by Forster (2010, p186) who indicated that there are two meanings of sustainability within the context of building conservation philosophy namely a 'green' agenda and perpetuation of a building's utility. The author asserted that 'the ability of a building to be in continuous use is essential for its survival' in which case 'change must be sensitively managed'. Similarly, this aspect is discussed in the Venice Charter (1964, Article 5) stating that *'the conservation of monuments is always facilitated by making use of them for some socially useful purpose'.*The above critique of literature indicates that conservation principles provide an essential framework for the implementation of conservation projects, whether they are small-scale interventions linked to historic building maintenance or large-scale projects involving adaptive reuse of a historic building. Thus, they are formulated to ensure consistent and comprehensive approach to sustainable management of the historic environment. The importance of conservation philosophies is thus becoming apparent when any work is to be carried out to historic buildings to ensure that every technical decision made is assessed against these principles. Although each conservation project will be different, however, the project is to be evaluated on its own merits against the

identified values, demonstrating a sound and ethical approach guided by internationally accepted principles. This must be embodied within a built asset management framework.

2.9 Energy Performance of Heritage Buildings

Energy performance of a building was defined by Poel *et al.* (2007, p.395) as '…*the amount of energy actually consumed or estimated to meet the different needs associated with a standardised use of the building'*. According to the authors, this amount is reflected in one or more numeric indicator calculated while considering parameters, namely: insulation, technical and installation characteristics, design and positioning in relation to climatic aspects, solar exposure and influence of neighbouring structures; building's own energy production; and other factors such as indoor climate that affect the energy demand. Due to various drivers for improved energy performance in buildings to meet carbon reduction targets new buildings are constructed to be more energy efficient than older ones (DCLG, 2006).

Basically, in the UK, building energy performance is determined from Standard Assessment Procedure (SAP). SAP measures the fuel efficiency of the heating systems and the thermal efficiency of the building fabric on a scale from 1-100 (Friedman and Cooke, 2012). Using SAP, it was concluded from the government data presented in 2006 that older properties have a much lower energy performance with more than 40% of properties built prior to 1919 having SAP ratings of less than 41 when compared with 60% of those built since 1990 with SAP ratings over 70 (DCLG, 2006). However, the use of SAP has been vigorously challenged by several authors (Rye 2010; 2011; Baker, 2011; CITB, 2012) arguing that SAP among other methodologies

such as Reduced data Standard Assessment Procedure (RdSAP); Energy Performance Certificates (EPCs) and National Home Energy Rating (NHER) all generates widely varying results with faulty underlining assumptions for the predictions of older buildings.

The authors (Rye 2010; 2011; Baker, 2011; CITB, 2012) argued that these software and the accompanying methodologies are characterised by inbuilt inflexibility and their generic treatments predisposes older buildings to less accurate energy efficiency ratings. Meanwhile, Moran *et al.* (2012) stated that in spite of government statistics showing higher CO_2 emissions from the historic buildings, yet there are differences in how the energy efficiency of these buildings is viewed. These differences emanate from more research that has been geared towards investigating and modelling the thermal and energy use performance of heritage buildings. The difference in the perception of energy performance of heritage buildings has rather led to more conflicting claims on energy efficiency of heritage buildings been regarded as either good (Wallsgrove, 2008; English Heritage, 2009; Wood, 2009) or poor (DCLG, 2006; EHCS, 2007; Boardman, 2007; DCLG, 2006).

2.9.1 Embodied energy and sustainability of heritage buildings

The various divergent views on energy performance of heritage buildings could be attributed to the perception of their environmental sustainability. A major claim from the conservationists supporting the sustainability of heritage buildings is the perceived value of their embodied energy. Meanwhile, the argument in favour of modern buildings is that in spite of their embodied energy, heritage buildings could still be upgraded to energy efficiency requirements. For the conservationists, heritage buildings are ahead of modern buildings in their consideration for the environment. According to Jackson (2005) the

embodied energy of heritage buildings has already been expended as part of their construction. The author, along with others defined embodied energy as *"the sum of all the energy required for extracting, processing, delivering, and installing the materials needed to construct a building*" (Whiddon, 1981; Jackson, 2005). Their argument was further reinforced that since embodied energy does not contribute to an existing building's present-day energy performance and cost of operation; reusing an existing building implies there is no generation or wastage of additional energy compare to building afresh.

Further argument was also based on the fact that many older buildings were constructed using traditional materials (e.g. Stone, brick and lime) that will have been subjected to little or no processing or manufacturing, particularly before the Industrial Revolution (Oxley, 2003). Arguably, the processing that took place will have been achieved without the use of fossil fuel, but the use of other sources such as timber (bio-mass). Furthermore, the local and the vernacular origins of most of the materials will have minimised the distance for the transportation of the materials and many materials used for construction would have been close to their natural state. Accordingly, the embodied energy of the fabric used to construct many older buildings is very low in comparison with modern buildings (Oxley, 2003). Therefore, from the conservation point of view, the environmental cost of using energy to demolish or construct a new building is higher. Essentially, in sustainable terms, it is more environmentally sensible to preserve and reuse existing buildings because of their embodied energy. In this way, natural resources are conserved with fewer costs because of long-term energy savings.

2.9.2 Investigations on improvement into thermal performance of heritage buildings

In spite of the argument for the embodied energy of heritage buildings, English heritage (2004) accepts that measures to increase energy efficiency of heritage buildings can be incorporated without significant damage to the buildings. This acceptance has led to the development of various guidelines for the interpretation of the regulations in order to 'balance the needs of energy conservation with those of building conservation' as the regulations require. The regulations seek to improve the energy performance of all buildings, new and old, when they are altered, extended or subjected to change of use (English Heritage, 2004) making provision for the improvement of energy efficiency in heritage buildings provided that their character is not jeopardised.

In line with the view of English Heritage (2004); Foresight (2008), MacKay (2009), DECC (2010a), Cambridge Centre for Sustainable Development (2011) survey of UK-based future developments and pathways indicates that improvement of the thermal performance of the existing building stock is crucial to achieving the required reductions (DTI, 2003; Friedman and Cooke, 2012). This has led to numerous studies regarding measures undertaken to reduce carbon emissions from heritage buildings. A Study on older buildings by the Department for Communities and Local Government (DCLG, 2006) has demonstrated that a significant decrease in carbon emissions can be realized by introducing cost effective technology which can make substantial savings on fuel bills for consumers. However, the study did not go beyond determining a correlation between building age and poor energy performance. The findings show pre-1919 buildings to be the worst performing age category of all the building stock.

Furthermore, on that point is no clarification whatsoever from the determination of other possible factors that might have impacted on energy consumption of these buildings. Hence, this result has been criticized by a number of authors (Heath *et al.*, 2010; Rye 2011; Moran *et al.*, 2012) that the method of using the Standard Assessment Procedure (SAP) model to derive these findings has been shown to provide inaccurate assessment of the energy performance of traditional buildings. Wallsgrove (2008) considers energy efficiency of law courts in the UK, and reported conflicting results to the findings of DCLG (2006). He identifies pre-1900 buildings to be the most energy efficient with 1940-1960 buildings being 35-45 percent less efficient. While these findings are really instructive and revealing, even then, they may not be applicable to all buildings of these periods. Furthermore, Wallsgrove (2008) did not address the whole spectrum of factors and other variations that may be found in other types of buildings. Therefore, a new study focusing on other public buildings is required to validate the applicability of his findings to other buildings.

2.9.2.1 Modelling software and approaches

Other researchers (Barnham *et al.*, 2008; Jenkins, 2008; Integrated Environmental Solutions (IES), 2009; Heath *et al.*, 2010) have used energy modelling software for assessing energy performance and internal comfort conditions of traditional buildings. However, the results obtained show that modelling software generates different results depending on the nature and amount of the data sets inputted into it. Thus, making the results obtained from it more likely to be inaccurate when modelling the energy efficiency of traditional buildings. This is because historic properties are diverse due to a wide range

of building types and other relevant factors such as age, localized building patterns and material of construction (STBA, 2012).

The modelling method for energy performance assessment has a number of limitations and therefore has been strongly challenged by a number of researchers arguing that energy models do not provide robust information about the performance of traditional buildings (Barnham, 2008; Wood, 2009; Heath, 2010b; Gupta, 2010; Gentry *et al.*, 2010; Moran, 2012). Apart from the diversity of historic building types, one of the criticisms of using modelling methods to determine the energy performance of heritage buildings is the argument about the absence of typological analysis to distinguish traditional buildings in stock modelling and lack of base-case performance data on which to calibrate and inform the assessment of traditional buildings in models.

Another problem associated with modelling approaches is that their outputs depend on the operator skill and interpretation; this is coupled with the operator's limited understanding of the heterogeneous nature of traditional building construction and the resultant effect that it may have for determining its performance. Additionally, Kavgic *et al.*, (2010) observed the inability of modelling assessment to consider the human and physical rebound effects relating to internal temperature rise. Furthermore, modelling performance assessment has also been criticized by Powter and Ross (2005) for their narrow focus in scope as they are being majorly conceived around immediate, short term localized energy reduction goals rather than a wider based value system which could put into consideration other factors like heritage values, durability, life cycle costs and effects on human health.

It can be concluded that there is a lot of uncertainties regarding the performance of traditional buildings as modelled by building energy performance software. The uncertainty results in limitations emphasised by Rye (2010); Baker (2011); and Moran (2012) who support the presence of gaps identified between modelled assessments and monitored realities of traditional building performance especially in the absence of real-life case studies. This underscores the need for an alternative methodological approach to obtain new and valuable insights of energy performance of heritage buildings by collection of real and hard data such as a physical measurement, monitoring, questionnaires and surveys.

The challenge of determining the energy performance of traditional buildings is not limited to the method of finding accurate modelling software, but extends to other areas of building energy performance such as heat loss and moisture behaviour of different elements of historic buildings. Various researchers (Kavgic *et al.*, 2010; Rye, 2010; 2011; Rye *et al.*, 2011; Baker, 2011; Little, 2012) have focused on the subject of heat loss in traditional buildings, investigating the subject of thermal performance in traditional buildings through a study of heat loss and U-values of traditionally built walls.

2.9.2.2 Numerical assessments

The review of literature indicates that different approaches based on numerically based simulation have also been adopted ranging from simple heat loss computations through to dynamic three-dimensional whole building model. These methods rely mostly on high-quality data input, which placed much emphasis on accurate material properties and users' operation. However, Kavgic *et al*. (2010, p.1683) have identified the inherent weaknesses in these approaches, pointing to *'lack of publicly available detailed data relating to inputs*

and assumptions' for building physics-based stock models. This view is shared by other prominent researchers such as Rye (2010), Baker (2011) and Little (2012) noting that there are almost no well-defined data on traditional material properties available for application in modelling and calculation programmes.

Furthermore, findings from research undertaken by the Society for the Protection of Ancient Buildings (Rye, 2010), Historic Scotland (Baker, 2011) and English Heritage (Baker and Rhee-Duverne, 2012) demonstrates a level of consistency in results that continuously indicates discrepancies between the measured U-value with the conventional standard calculated U-value. These authors' results have been found to be in variance with the outcome of method of calculations adopted by the Energy Saving Trust (2004; 2005) which was found to have underestimated the thermal performance of traditionally built walls in 75% of cases.

The calculated estimates used by the Energy Saving Trust (2004; 2005) has been criticized to have been based on typical or default values determined using BS EN ISO 6946 (1997) which is grossly limited in many ways. Firstly, the stock age bands follows either change in construction patterns when relevant changes in building regulations assume that building in certain periods will have to comply with the threshold limits set for the time. Secondly, BS EN ISO 6946 (1997) standards used is structured around the modern conception of building forms made up of discretely layered materials comprising of known thermal properties such as modern cavity walls. This creates problems for traditional buildings which consist of a more inhomogeneous form or properties difficult to define. Thirdly, the assumption that all buildings constructed prior to 1919 share

approximately similar U-value for a specific element is hardly reliable. The discrepancies observed in these studies further demonstrates the presence of gaps in the methods of determining and understanding heat loss in solid wall buildings; revealing the difference between the theoretical assumption and the measured reality.

2.9.2.3 Humidity and hygrothermal performance

In addition to research on energy performance of traditional building walls, hygrothermal performance with particular reference to moisture behaviour is an aspect of research attempted by many authors such as Sedlbauer (2001); Altamirano-Medina *et al.* (2009); Viitanen *et al.* (2010); Selves *et al.* (2011) and Little (2012). It is acknowledged in several studies that historic or traditional buildings deal with moisture in a totally different way from modern construction and insulating them alters their moisture balances. Moisture performance in building physics is very much influenced by temperature, relative humidity, and vapour pressure and air movements. This in turn affects the energy performance by influencing the U-value of the component of the materials and by transfer of heat through the process of evaporation and condensation. According to Baker (2007) and Wood (2010), from the perspective of building physics, traditional buildings' moisture behaviour is not yet thoroughly understood coupled with the fact that there are many associated technical problems inherent in monitoring and modelling their behaviour especially liquid water within solid walls.

Little (2012) critiqued the Glaser method obtained from BS EN ISO 13788 (2002) used in assessing the hygrothermal performance of traditional buildings. The author argued that the method of computation and the determination of surface interstitial condensation risks does not cover other aspects of moisture such as built-in moisture and its convection. Thus, when this method is applied to traditional solid walls constructed without a damp-proof course (dpc) to address phenomena like driving rain and groundwater, it will undoubtedly have a major influence on the moisture behaviour of the building envelope.

It is noteworthy to mention that although BS 5250 (2011) is currently in common use as the test of the moisture performance of buildings and building components. However, according to BS 5250 (2011), 'the calculation methodology given in BS EN ISO 13788 (2002) does not make provision for an accurate prediction of moisture conditions within the structure under service conditions'. This statement is principally applicable to pre-1919 moisture permeable solid wall buildings. Other researchers (Sedlbauer, 2001; Viitanen *et al.*, 2010) have shared this view by noting the difference between modelled predictions of mould growth and *in situ* observations. Thus, with different researchers and studies placing different emphasis on either the necessity for or the counter-effectiveness of these approaches, a gap is left to be filled when employing the calculation methodology for traditional buildings.

In traditional buildings, the issue of thermal bridges is another aspect that relates to heat loss and consequently leads to increased energy use. According to Oxley (2006) most traditional buildings are built with stone, soft bricks, earth, and timber, employing earth or lime based mortars and renders. In essence, these materials, especially lime mortars

and renders permits moisture, which has been absorbed by the fabric to readily evaporate from the surface causing the building to 'breathe' (Hughes, 1986; Banfill and Forster, 1999). The levels of dampness are 'controlled' by the ready evaporation of moisture. Traditional buildings create particular challenges when considering them for energy efficiency measures. It is widely described in the literature, that the nature of moisture behaviour within traditional buildings probably differs from what is obtainable within a modern construction, and that the insulation of these buildings changes moisture balances (STBA, 2012).

It is clear that there is greater risk of condensation occurring in heritage buildings as a consequence of air leakage which transports water vapour through gaps, joints and cracks in the building fabric. In worst cases, when the walls become cold and wet it can cause a rise in U-values and a reduction in thermal performance. English Heritage (2012) guidelines on adding insulation into existing permeable construction states that insulation, which has hygroscopic properties should be employed as this produces a beneficial 'buffering' effect in the course of temperature fluctuations and vapour pressure, therefore decreasing the risk of surface and interstitial condensation occurring.

2.9.2.4 Insulation

English Heritage (2012) states that insulation materials with low permeability are not entirely incompatible with older buildings, however, caution is required in reducing levels of water vapour moving through such building or construction either by means of ventilated cavities or through vapour control layers. A crucial issue when considering thermal upgrading of older or heritage buildings is the movement of water vapour through

parts of the construction. Several other factors are required to be put into consideration in order to reach an optimum solution such as heating regimes, the orientation and the exposure of the specific building.

With regard to internal insulation in decreasing heat loss due to thermal bridging around windows, doors, floors, party and partition walls, roof-wall junctions and lintels, Andersson (1980) and Schnieder (2005) identify limitations to the effectiveness of internal insulation. Schnieder (2005) observations showed that there is decreasing marginal returns on the thickness of insulation to walls because of unavoidable thermal bridges. Andersson (1980) however, found that where little or no insulation is possible on certain thermal bridges, such as window reveal, the possible insulation values of the whole wall became reduced considerably. In a study relating to the challenge of dealing with thermal bridging when employing external wall insulation, Hooper *et al.* (2012) have also indicated the possibilities of thermal bridging in buildings fitted with external wall insulation.

2.9.2.5 Ventilation

Mechanical ventilation and heat recovery systems (MVHR) are sometimes specified as part of energy-efficient refurbishments; however, such systems depend on buildings being properly-sealed to function effectively. This could pose a serious danger of creating long-term health problems for heritage buildings and the occupants. Based on the nature of their construction, historic and traditional buildings require adequate ventilation to preserve their fabric, maximise the evaporation of their moisture and maintain an acceptable equilibrium. However, STBA (2012) has argued that suitable levels of

ventilation for traditional buildings constructed of moisture-active (i.e. 'Breathable') materials are yet unknown. Oxley conservation (2006) stated that the provision of excessive or poorly thought out draught proofing to attain an arbitrary level of air tightness may result in mould growth, associated health problems for the occupants and the conditions for fungal decay and insect attack for traditional buildings. Meanwhile, Bone *et al.* (2010) has emphasised a genuine need for large-scale longitudinal studies to examine the relationships between energy efficiency, ventilation, indoor air quality and health.

Another area of challenge to improving the thermal performance of heritage buildings is the improvement to single-glazed windows in masonry structures without distorting their character. The study, commissioned by Historic Scotland, comparing the thermal values of various adaptive options conducted by Baker (2008) for single-glazed windows found secondary glazing and timber shutters to be the most effective overall options compared to internally use curtains and roller blinds which were found to be less effective. While the study also discovered that a combination of measures produced the greatest reductions of heat loss, however, the caveat is that design options in one solution may impinge on the other issues.

Baker (2008) illustrated a typical scenario where it would not often be possible to close window blinds all through the day as this may reduce daylight from getting into the building. According to Connelly (2011) good maintenance of historic structures and its building services could be the key to climate change adaptation.

Meanwhile, Connelly (2011) advised that owners of listed buildings would have to make sure that the cost and benefits of adaptation weighed up against irreversible interventions and possible climate risks.

2.9.3 Energy efficiency improvement of heritage buildings: conflicts and constraints

The difficulty of refurbishing and upgrading the existing stock is enormous. Particularly, the refurbishment of heritage building projects apparently requires the structure to be upgraded. This implies the structure, the fabric and the building services would need some interventions in order to comply with standards and legislation. Among other factors that also need to be addressed is the potential effects of climate change, minimising their environmental impact, conserving their values, providing safe, secure and comfortable internal environments and providing spaces that are adaptable to change of use. Nonetheless, interventions involving upgrading their energy efficiency require a comprehensive study in order to deal with potential risks such as: moisture and condensation occurrence, incompatibility of old with new construction materials, failures due to limited construction knowledge on restoration applications using sustainable technologies (Kikira and Gigliarelli, 2010).

2.9.4 Modification of existing heritage building structure for reuse

Alteration for reuse is part of the conservation process of managing change to culturally significant buildings which could sustain their heritage values while engaging in opportunities to enhance, develop and improve their energy performance. However,

according to Oxley (2006) alteration can interfere with a building's breathing performance. It can lead to a loss of character, distortion of appearance and loss of historic fabric. Therefore, it is important to remember first to identify the significance of the building, which requires an understanding of the nature of the structure, who values it and why, how do the values relate to the fabric and what is the importance of these values relevant to the reuse advantages. The understanding of heritage values and the historic significance of heritage building is paramount to making appropriate decisions about the energy efficiency improvements to be carried out. This is line with the BS 7913 (2013, Section 4) which state that "*understanding the significance of a historic building enables effective decision making about its future"*.

In clear terms, the significance of the historic building is connected to the value of the building to the people; established as an outcome of its present continuity and as an asset to them. This value is a combination of its historical, emotional, cultural and spiritual significance. Thus, without these considerations, all the good intentions of reuse initiative will eventually compromise the building significance for the future generation. It is, therefore, paramount to understand the history of construction, modification and use, cultural significance and the protected status. Additionally, it is also important to get grips with the performance, intended performance and changes in intended performance along with performance in use (Hay, 2010).

2.10 Chapter Summary and Conclusion

A large body of existing literature on asset management and building conservation philosophy has been reviewed in this chapter. Whilst several definitions of asset management were presented, the definition by the British Standard Institute was found to encompass the key themes required in any asset management. The themes include holistic, systematic and optimal way of managing assets to achieve desired outcomes in a sustainable way. However, little attention is focused on the practical application of these themes to built heritage asset management, particularly in relation to operational performance in the reuse of LCBs; where the nexus of ideas and practices that underpin the operational performance of the built heritage asset are poorly understood. While the review of literature found various asset management approaches and models that has been applied to other sectors, however, none was found that specifically integrate critical factors influencing energy performance in the reuse of UK listed churches.

The broader context from which building conservation philosophy was shaped and how the key conservation policies developed was examined. This provided the platform from which the relevant legislation, technical guidance notes and key professional publications were reviewed. In addition, it was clear from the review of literature that the energy performance of heritage buildings involves several aspects of the 'hard-to-treat' structures. A critical problem or challenge in upgrading them is that they have to be assessed individually to maximise their potential. In addition to the technical challenges of upgrading these buildings, their statutory protection and their values complicate the issue of considering them for other interventions such as the possibilities of insulating them like modern buildings. Meanwhile, a common shortfall from the previous studies is

the lack of coherent view and agreement on energy performance of the 'hard to treat' buildings.

Arguably, all the previously mentioned methods, approaches and results have several shortcomings and limitations in their application. This clearly demonstrates that existing studies have not fully addressed the critical factors necessary for sustainability in improving energy performance of heritage buildings. The literature review has also revealed the limitations that have resulted in gaps to be filled which underlie the rationale for this study. While it is acknowledged from the literature reviewed that numerous studies have examined the energy performance of heritage buildings; however, very little is known about LCBs and specifically the author has not found any literature on investigating energy performance in the refurbishment of LCBs.

To investigate the energy performance of LCBs, a different approach would be required to identify the critical factors influencing their energy use. Furthermore, it could be concluded from the above review that the current standard methods and data used to determine the energy performance of traditional buildings may not be the optimal solutions to determine how their energy performance could be assessed in reality. The resultant effects of the aforementioned performance gaps have been widely discussed with regards to the limitations of the conventional methods of energy assessments used. Additionally, the need for better energy performance data measurements from actual buildings was established to inform debate and practices in relation to energy use reduction strategies in heritage buildings. This study attempted to fill this existing gap in

knowledge by extending the existing asset management performance based model and developing a framework that integrates the critical factors influencing energy performance in the reuse of LCBs within the existing model. Other built heritage assets could benefit from the framework which could aid effective and efficient operational performance of their assets.

CHAPTER 3: SUSTAINABILITY AND ADAPTIVE REUSE OF LISTED CHURCHES

3.0 CHAPTER OBJECTIVES

- To review literature pertaining to sustainability and adaptive reuse
- To present the rationale for adaptive reuse of public heritage buildings
- To explore the rationale for adaptive reuse of listed church buildings

3.1 Climate Change and Adaptation of Existing Buildings

Meeting the current needs of existing buildings to guarantee its sustainable adaptability in the future supports worldwide climate protection and emissions reduction. Energy consumption as a result of recent developments requires it to be checked through greater efforts and concentration on existing buildings with increasing their life expectancy and using less energy. UNEP (2007) has argued that building professionals need to provide more energy-efficient refurbishment of existing buildings to bring them to modern sustainability standard. Meanwhile, the possibility of this lies in adapting and retrofitting of existing buildings to the optimum energy efficiency standard (UNEP 2009).

Yudelson (2010) advanced this further by arguing that nearly 75 percent of all buildings expected to be functioning in the year 2040 by now have been constructed. Urban Land Institute (Cited in Tobias and Vavaroutsos, 2009) reported that green building practices have not given sufficient emphasis on the significance of sustainable retrofits of existing building stock worldwide. The Institute argued that environmentally sensitive and energy efficient, sustainable new construction by itself cannot significantly change the environmental impact of the built environment unless green design and construction

technologies are used in the existing building stock. This argument supports the view that adaptive reuse and retrofitting existing buildings could play a prominent role in reducing emissions from the built environment. This view is supported by Gorse and Highfield (2009) who opined that the recycling of buildings is the best example of the environmental benefits of effective sustainability in practice. Several scholars (Ball, 1999; Bon and Hutchinson, 2000; de Valence, 2004; Gallant and Blickle, 2005; Kohler, 2006; van Beuren and deJong, 2007; Bradley and Kohler, 2007) have acknowledged the growing in trend in the move to building re-use and adaptation in the built environment and suggested that some form of adaptation might be able to reduce the impacts of climate change on the built environment.

Other authors (Douglas, 2002; Gregory, 2004; Remoy and Van der Voordt, 2007; Velthuis and Spennemann, 2007) 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, fewer materials, lower transport cost and lesser pollution 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 both facilities and regeneration of the built environment (Kurul, 2007; Langston *et al.*, 2007). In the past, existing buildings that were structurally sound were adapted to fit changing needs or new functions. For instance, religious buildings were transformed into industrial functions or military uses after they had been confiscated and sold (Cunnington, 1988; Dubois, 1998; Linters, 2006). Whilst these interventions were done in a pragmatic way, Powell (1999) noted that the driving

force behind them was only functional and financial with less attention given to energy use reduction as an operational issue. In recent times, working with existing buildings is common, and as expressed by Powell (1999) and Schittich (2003), repairing and restoring them for continued use is a challenge within the architectural discipline. Meanwhile Brooker and Stone (2004) described the process as adaptive reuse.

3.2 Adaptive Reuse of Redundant Built Heritage

In the UK, redundant heritage buildings have been converted to other functions either for private or for public use. Therefore, reuse of historic buildings has become a sustainable practice of utilising an already existing resource. However, their heating and cooling to current-day comfort standards has been a real source of energy consumption and their conservation are faced with many difficulties in meeting the global challenge of coping with climate change without affecting their special character. According to Langston *et al.* (2007) adaptive reuse has become an essential strategy to improve the environmental, financial and social performance of buildings. The incorporation of historic conservation with environmental issues has become an inherent feature of an agenda to support sustainability (Stubbs, 2004; Bullen and Love, 2010).

Environmental concern in adaptive reuse of buildings is acknowledged by other researchers in historic preservation such as Diamonstein (1978), Robert (1991), Murtagh (1997), Latham (2000), Fitch (2001) and Rodwell (2007). Adaptive reuse of historic buildings is seen as vital to sustainable development (Langston *et al.*, 2008). Thus, it is considered applicable to the present climate change adaptation agenda because of its

ability to recycle resources in place. While it is acknowledged that reuse of existing facilities are very important for sustainable development, the level, scope, and boundaries of research into maximizing their energy efficiency, is not yet found in the literature. As part of the strategy to promote sustainability within the built environment, many buildings of cultural and historical significance are being adapted and reused.

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 (2000, p.8) noted that reuse is usually cheaper than new development as it is a way of banking the built environment. Further, he argues that "transforming 'uneconomic' buildings using 'green materials' has the potential to enhance efficiency, comfort and life span of the building". Meanwhile, van't Hof (cited in Velthuis and Spennemann, 2007) opined that economic considerations have been the major driver behind adaptive reuse although other motives are increasingly considered. However, Stevens (1986), posits that appreciation for sustainability of built heritage is a factor in support for adaptive reuse.

Koster (1989) supported this view by stating that adaptive reuse of listed heritage buildings, specifically, seems to be more about their heritage values than about their functional value when reused. This view is based on the premise that heritage buildings can be architecturally significant, aesthetically pleasing. Further, heritage buildings are recognised and attached to the continuity of a place which is of benefit to the psychological well-being of a community as older buildings have a past firmly rooted in the community (Latham, 2000, p.6). Thus, the reasons and factors for adaptive reuse are many and varied, although, it has been argued and mostly accepted that re-use often

would not occur except with a strong desire from the society to conserve and re-use a building.

3.3 The Drivers of Adaptive Reuse of Listed Churches

A factor driving the adaptive reuse of buildings is redundancy. According to English Heritage (2001), 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. In the UK, many buildings with heritage laden values such as churches, textile mills, railway stations, hospitals, farm buildings, schools and ministry of defence sites have become redundant. Hancock (2009) attributed the cause of redundancy to numerous reasons such as changes in technology, demographic patterns, declining congregational sizes, intensifying financial constraints etc. Majority of heritage buildings affected by redundancy are places of worship converted to alternative use or demolished. Rauti (1989) expressed that generally, all denominations have been affected by the increase of the rate of redundancy.

In the UK, there are approximately 45,000 churches and chapels representing both urban and rural churches (English Heritage, 2003). In England, there are approximately 16, 200 Church of England churches (Table 3.1) of which more than 12,200 are heritage listed with some 52% being listed as either Grade I or Grade II* (Church Heritage Forum, 2004). Whilst most the churches remain in use for worship, however, some 1,626 have been made redundant between 1969 and 2004; a trend predicted to continue at a rate of 30 buildings per year (Cooper, 2004: p.20). The adaptive reuse of church buildings becomes significant in conservation fostered by the economic benefits associated with

tourism they could generate (Diamonstein, 1978: p.21; Cantacuzino, 1989: p.10; Murtagh, 1997: p.116; Stipe, 2003: p.12; Worthing and Bond, 2008: p.52; Bowitz and Ibenholt, 2009: p.2). Velthuis and Spennemann (2007) observed that demolition affects about one fifth of the redundant churches and predicted that about 60% of all redundant churches will at last be demolished.

Table 3.1: Estimated number of Church of England buildings of each grade of listing

Grade	Estimated number of church buildings at given grade	% of total church buildings	% which these churches represent of all listed buildings (both secular and religious)
I or A	4,200	26%	45% of 9,300
II* or B	4,200	26%	20% of 21,400
II or C	3,800	24%	
Not listed	4,000	24%	
Total	16,200		

Source: Church Heritage Forum for the Church of England (2004, p.10)

The rate of church closure since the late 20th century has been a cause for concern; Binney and Burman (1977) argued that if positive actions are not taken, there is jeopardy that the second half of the twentieth century will be remembered as an age of destruction of religious art and architecture. Thus, for church redundancy to be curtailed to an acceptable level, adaptive reuse became one of the strategies to safeguard heritage values of churches and at the same time satisfy the needs of the community and the environment in which it exists (Pantus, 1993). Therefore, reuse of historic places of worship has become a sustainable practice of utilising an already existing resource.

Currently, closed churches are converted to community uses, however; observation shows that their heating to current day comfort standard is a real source of energy consumption.

Furthermore, reusing and conserving these buildings is faced with many challenges of meeting the global challenge of coping with climate change without affecting their heritage significance. The scale of the problem is exacerbated by the fact that churches are difficult to modify to meet up with current energy efficiency standard. 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.

Some authors (Latham, 2000; Douglas, 2002; Jaeger, 2005) expressed the view that conservation architects seem to recognize the significance of listed churches as community cultural identity; nevertheless, their design decisions are observed to be limited with reference to the environmental sustainability of the buildings. Whilst, it is acknowledged that good design is essential for optimum performance for which they are designed for, it could be argued that if planning, construction and management are performed by energy conscious designers, the outcome could be low energy use buildings.

3.4 The Drivers of Energy Use Reduction in Adaptive Reuse of Historic Churches

Rising energy costs with its associated environmental impact has become a driver for the development of new ideas and solutions to achieve sustainable reuse of heritage buildings. According to Ellison *et al.* (2007) the rising trend in energy prices will drive property investors to improve the energy efficiency of buildings so as to sustain market demand and rental growth. Kohler and Yang (2007) described the trend as a factor which

has greatly affected the cost of new construction and has consequently influenced clients' decision for re-using existing buildings (Kohler and Yang, 2007).

More attention is directed to updating existing buildings to improve their environmental sustainability standard and potentially making them more economical to operate, thus giving them longer life span. This view is supported by Brown (2006) and Bruhns *et al.*, (2006) stating that operational energy in non-domestic buildings has risen drastically within the last four decades and such necessitated energy improvements in re-use existing buildings which has the potential to provide substantial cost savings for owners and occupiers. According to Church of England (2008) the Church of England (CoE) emits about 330,656 tonnes of CO_2 in its operations yearly. Figure 3.1 identified the major sources of energy consumption to be; heating (36%) and lighting (31%). Although the limited scope of refurbishment exists in relation to cathedrals due of their historic value, savings of up to 25% are achievable through routine energy saving strategies and utilising energy efficient equipment (Church of England, 2008).

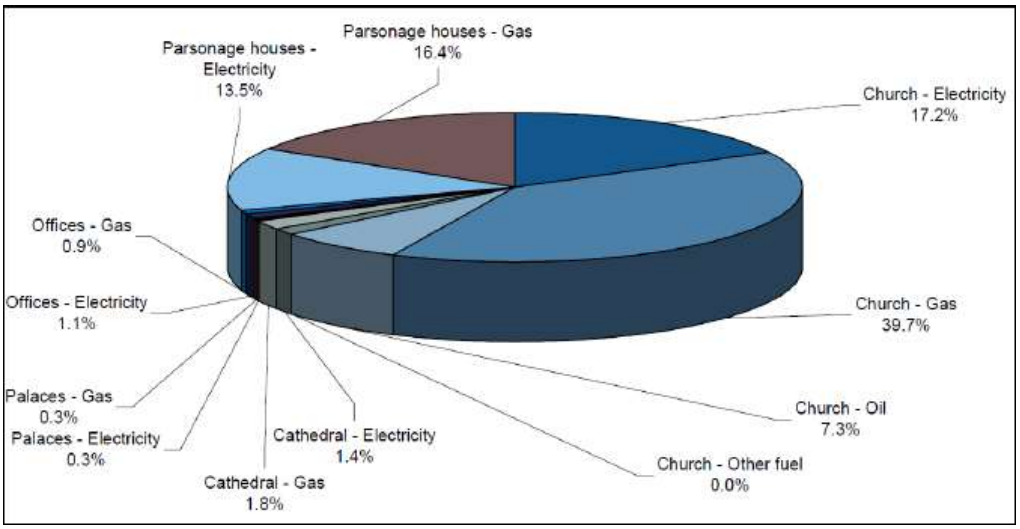


Figure 3.1: CoE's CO2 Emissions by Source
Source: Church of England, 2008

3.5 Historic Churches as Systems and its Relation to Energy Consumption

The characteristics of historic churches differentiates them from other historic buildings and their modern counterparts and their composition as a system establishes what modifications are possible for their sustainable reuse and the energy behaviour of their stocks (i.e. Energy uses, operation, maintenance and problems associated with their reuse and refurbishment).

3.5.1 Bioclimatic (sustainable) design principles

Historic churches are characterised by their geometry and constructional methods which take into account local climatic conditions as well as utilise a number of passive solar technologies. According to Cantin *et al.* (2010) they were constructed with traditional techniques using historical professional practice expertise which were non-industrialised but acquired through some specialised craftsmanship. Benjamin, (2004) and sustainable energy communities in historic urban areas (SECHURBA) (2010) described the characteristics of these buildings as corresponding to bioclimatic (or sustainable) principles and highlighted them as follows:

- Notably high ceilings and large volumes
- Risen thermal mass through wall thickness and solid walls with no insulation
- Large and some instances recessed windows
- Natural lighting and ventilation
- Materials chosen for the nearness of the resource to the construction site or the location of fabrication
- Materials and components linked by organic or non-hybrid substances such as; stone, wood and iron.

- Construction concepts based on the principles of breathability, permeability, thermal mass, and sometimes a sacrificial skin.
- Design concepts usually on the basis of the local climate, the flexibility of component removal or alteration and a generals of the overall design concept to accommodate different users at various times.

According to sustainable energy communities in historic urban areas (SECHURBA) (2010, p.19) these bioclimatic principles have several advantages such as efficient cooling performance; control of internal temperatures; smooth temperature fluctuation; control of solar gain and light; environmental and climatic adaptation. The bioclimatic principle advantages are what could be referred to as the building passive solar technologies. It involves how the buildings passively absorb the energy of the sun without mechanical components as their heating and cooling techniques. While these advantages are significant to the thermal behaviour of these buildings, however, they also have significant influence on their energy use and performance.

3.5.2 Complex geometrical and spatial uniqueness

One of the characteristics of historic churches is their complex geometrical shapes such as vaulted ceilings, varying wall thickness from the ground to the top, rounded towers or apses and sloping floors (Widstrom, 2012). This makes them completely different from other historic buildings and other modern buildings which are generally regular in geometry. The geometrical shapes though provided them with unique characteristics, are nonetheless a form of barrier in many ways when the improvement in their energy efficiency is considered. The barrier becomes more evident when the sustainability

standard is proposed and the need arises to change and adapt them. The significant changes that may be required and the slightest alterations, particularly externally can result to damaging the building to the extent that restoration may not be viable. Other factors that contribute to the complexity of the building include:

- Decorative features such as decorative façade and plaster surfaces
- Presence of monumental sculptures and painting
- Repetitive geometry of the interior spaces and their unique internal layout
- Inventive windows along with tracery and stained (coloured) glass with carved detail
- Thicker and heavier walls with repeated mouldings, stucco work on the edges of interior arches.

3.5.3 Heterogeneity of the building envelope

English Heritage (2003) described historic churches to be predominantly pre-1919 buildings made of massive solid wall construction made of natural and environmentally friendly materials such as large traditional stone and lime mortar with no damp proof course. According to Widstrom (2012) the compositions of the natural materials have large variations and different properties which range in performance from one sample to the other within the building (Figure 3.2). Generally, traditional buildings are built with soft, weak or permeable materials such as lime mortars, plasters, renders and paints; thus making the building fabric permeable to the` passage of moisture and water vapour (Urquhart *et al.,* 2007). As the locally made materials of historic churches are prepared with limited regulation; the thermal heterogeneities of the envelope and their hygrothermal properties are variable in nature thus adding to the uncertainty of the

building component. In addition to their heterogeneity, deterioration and damages to them over time might have also affected the properties of the materials at different times and locations within the structure (Widstrom, 2012).

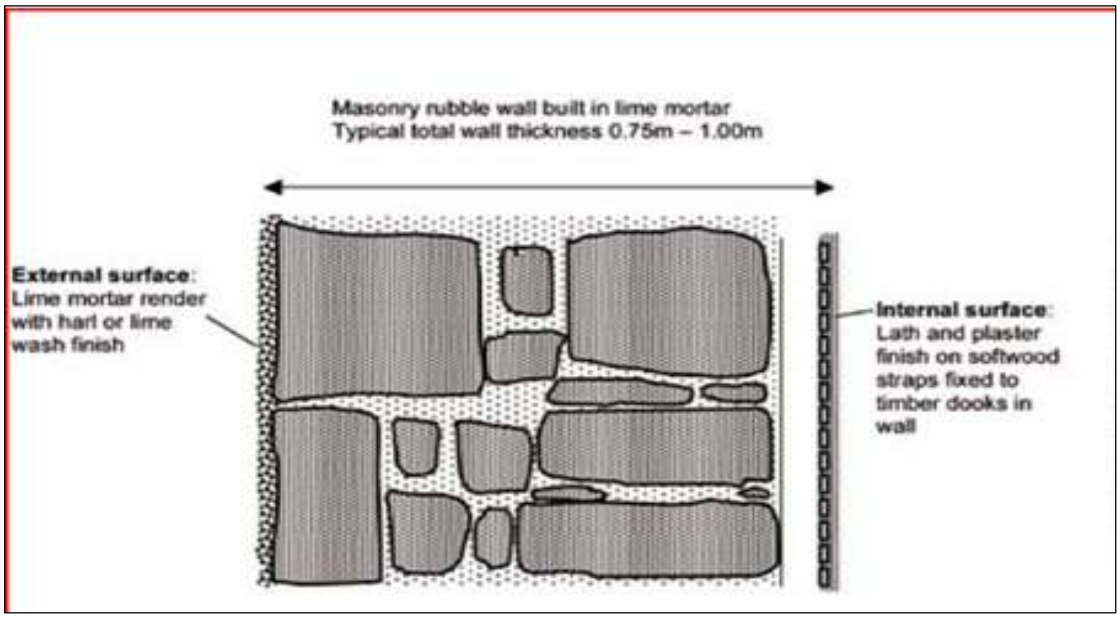


Figure 3.2: Section of a typical traditional masonry wall
Source: Urquhart *et al.*, (2007)

3.5.4 Breathability and air infiltrations in historic walls

Generally, pre-1919 buildings are designed and built with materials that prevents liquid moisture ingress from the external environment, but creates a structure which can be deemed to 'breathe' (Banfill and Forster, 1999; Holes and Wingate, 2002; Forster, 2002). The breathing properties of the historic church fabric allow more abundant air exchange resulting in their natural ventilation strategies (Widstrom, 2012). A number of organisations in building conservation industry (i.e. English Heritage, SPAB and Historic Scotland) have drawn attention to the importance of 'breathing' of traditional buildings. This is due to the comparison of traditional buildings with modern buildings which make use of impervious cementitious materials. Breathing is defined by Hughes (cited in

Banfill and Forster, 1999, p.174) as 'the ability to allow moisture, which has been absorbed by the fabric to evaporate from the surface'.

Whilst the breathability nature of materials used in historic building permits unrestrained natural balance of internal and external environments, it has also been related to the permeability of the material. Although, this material's properties according to Boxall and Trotman (1997) has the advantage of allowing the historic building fabrics to 'breathe' in absorbing moisture which minimise damage due to water entrapment; on the other hand, these properties could also be attributed to them loosing heat and consequently consume more energy than modern buildings. Arguably, though the nature of construction, the materials and technologies used for their fabric from conservation perspectives makes them sustainable buildings; however, their unique characteristics affect their energy consumption and from environmental sustainability perspectives they could be regarded as non-energy efficient buildings.

3.5.5 Insulating properties and moisture barriers

Historic churches are more or less uninsulated and likewise lacking in efficient moisture barriers when compared to modern buildings. This lack of moisture barriers and insulation poses more challenges for these buildings, especially when they are converted to other uses which require modern expectation for their performance. As the pattern of their use changes and the building becomes more frequently operated, internally generated moisture activity may be increased, thus resulting in the building performing in less optimal ways in terms of energy consumption. English Heritage (2008a, p.2) argued that very little possibility exists for considerable interventions in applying wall

insulation to the fabric of traditional buildings to reduce their rate of heat loss. Such interventions similar to those applicable to modern buildings could result in serious consequences, namely: (1) the risk of moisture being trapped in the materials (2) inadequate thermal insulation (3) inadequate ventilations to remove moisture and (4) possibilities of condensation around unheated areas and thermal bridges (English Heritage 2008a, p.2). Based on the above understanding, from heritage and architectural perspectives, any energy retrofitting project involving adaptive reuse of historic churches poses several challenges in terms of sustainable development and their conservation (Wood 2005; Naaranoja and Uden, 2007; Balaras *et al.*,2007).

3.5.6 Socio-cultural values

The Church of England (2004) recognised that churches are inherently a social public good with cultural and educational value. Arguably, the presence of their landmark serves as a physical expression of the poetic longings within the human soul and to embody the nation's history and collective memory (Church of England, 2004). Historic church buildings form a pillar of changelessness and continuity; connected to the realm of community rather than association. Meanwhile, Clark (2007) expressed that a church is a place imbued with meaning as opposed to being a rational asset. Clark (2007) reiterating the social value assigned to historic church buildings as more than just another building; rather it symbolizes the spiritual hope of generations known and unknown.

Furthermore, the author described a church as carrying in its form religious purpose; in its daily history; personal stories; in its very existence, communal tacit knowledge; in its disrepair and renovation the faded, the selected and reconstructed past that might be called

heritage. Arguably, as historic churches cannot be confined solely to their architectural significance, therefore, sensitive consideration is also required for their social and cultural character when they are considered for adaptive reuse. In most cases, the values attached to these buildings also dictate the limit of any retrofit strategies that might require adding insulation and any form of moisture transfer preventing measures (Widstrom, 2012). This poses greater demand and need for creative strategies on the part of designers involved in adapting these buildings for their sustainable reuse.

3.5.7 Specialised window design

A prominent characteristic feature of historic churches is the rich tapestry of large stained glass window designs made of single glazing. The windows serve as a memorial and because of their associative and artistic value they form an important part of the character of the buildings and must be retained during conversion projects. While the stained glass windows are an avenue for both natural light and natural ventilation in historic churches, however, when thermally considered, they are major source of heat loss. Air infiltration from the windows creates uncomfortable indoor draughts this becomes exacerbated with additional air infiltration coming from damaged or partly broken glass windows causing more heat losses and consequently higher energy consumption.

Notably, the situation arises when the building has been left for a long time and had suffered vandalism due to redundancy or lack of frequent maintenance before the building is converted. Meanwhile, the special historic significance of the windows makes it unacceptable to replace them with certain energy efficiency measures applicable to modern buildings such as double glazing etc. This could result to serious visual impact

on the building and consequently the loss of its historic significance as the measure will require the replacing the stained glass with plain glass and the lead cames with modern glass frames.

3.5.8 Roofs and ceiling structure

Stone (slate) and tile roofs are the most common roof materials of historic churches. These materials have a very poor insulating quality. Further, high vaulted ceiling is also a common characteristic of historic churches. The high vaulted ceiling plays a significant role in cooling the interior of churches in summer by allowing stratification of air through buoyancy. According to Zhai and Previtali (2010) The buoyancy effect in historic churches allows hot air to be collected together around the high ceiling area above the users of the building and allows cool air to rest close to the floor area (Zhai and Previtali, 2010).

The buoyancy effect is a common phenomenon of historic churches and it poses a serious challenge to heating these buildings to comfort standard during the winter. Figure 3.3 shows how the buoyancy effects of warm air (in red colour) results to stratification of warm air at high level and a deficiency at low level which is responsible for high energy consumption in historic churches. This effect has led to remedial measures such as the use of ‘punkah’ fans at ceiling height to break-up the warm air layer so as to increase the air movement within the space. While this gas has been observed to be acceptable in an industrial application, it is argued that it is inappropriate for church aesthetics appearance (GBS, 2011).

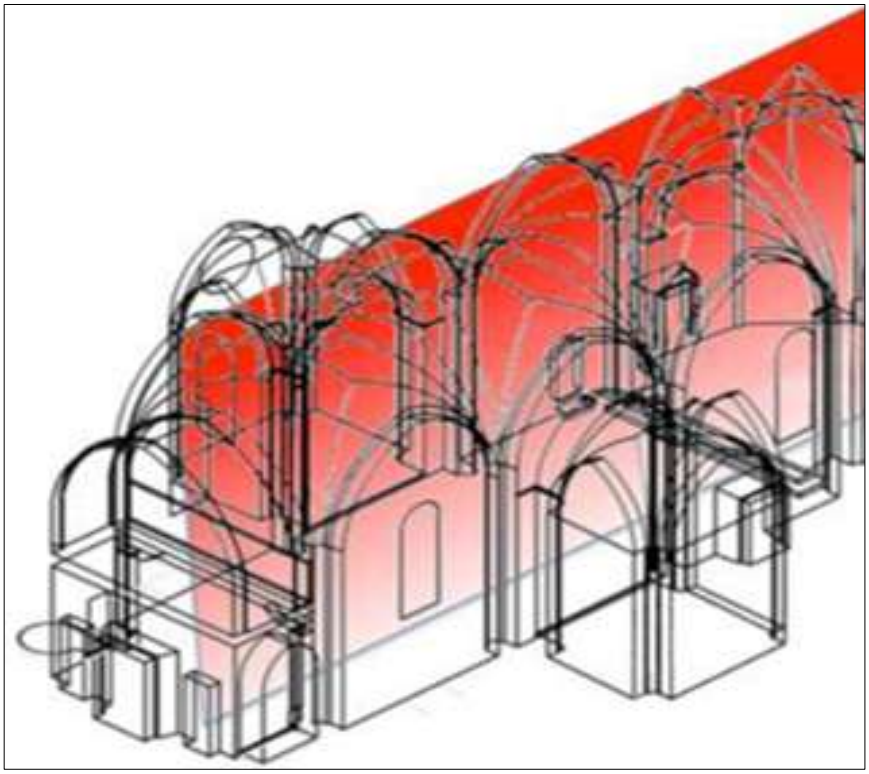


Figure 3.3: Buoyancy effects of warm air leading to stratification
Source: Camuffo (2010)

3.5.9 Heritage related characteristics

Generally, the internal environment of historic churches is made up the precious or valuable religious furnishings and artefacts in relation to historically-valued building elements. To a greater extent than in many other building types the fixtures and fittings such as the pews, screens, internal decoration, wall monuments, frescoes, marble statues, reredoses and liturgical features in historic churches constitute a large part of its historic character. In conversion projects, English Heritage (2003) recommended the retention of heritage furnishings and artefacts wherever appropriate. Although, the guidance from English Heritage allows some degree of compromise for the retention of these artefacts; however, the presence and the retention of these elements poses challenges for the building to accommodate energy efficiency measures that may require the modifications of their fabric.

3.5.10 Indoor environmental factor

Historically, churches have different indoor climate compared to other modern buildings. Neuhaus and Schellen (2004) observation showed that in winter periods a rise in indoor temperature of historic churches to certain level often leads to low indoor relative humidity (RH) leading to the damaging effects within the interior of the building and the objects in the building. A similar observation was made by Erhardt and Mecklenburg (1994) which show that a rise in RH to a higher percentage also poses risk of damage to both the interior and the objects within the building. However, Michalski (1998) argued that controlling indoor RH of historic churches is more essential to control the indoor temperature. More importantly is the need to ensure high indoor environmental quality with minimal energy consumption. Meanwhile, strategies to achieve the balance between the effect of raising the indoor temperature and RH; and their possible influence on energy consumption and user comfort are needed to be integrated at the design stage most especially when the building is converted to another use.

3.5.11 Archaeological remains

Many historic churches have open spaces and churchyards cherished by the people who built and used them as a great historic and aesthetic importance and considered as an intrinsic part of the many churches. More often, part of the open space may have been used for burials before the church is closed, thus, forming part of the archaeological remains within the churchyards (Figure 3.4). In the conversion of historic churches, intervention to improve energy efficiency may require installation of ground source heat pump, or replacement of floor, new service lines and pipes etc. Therefore, a reuse project

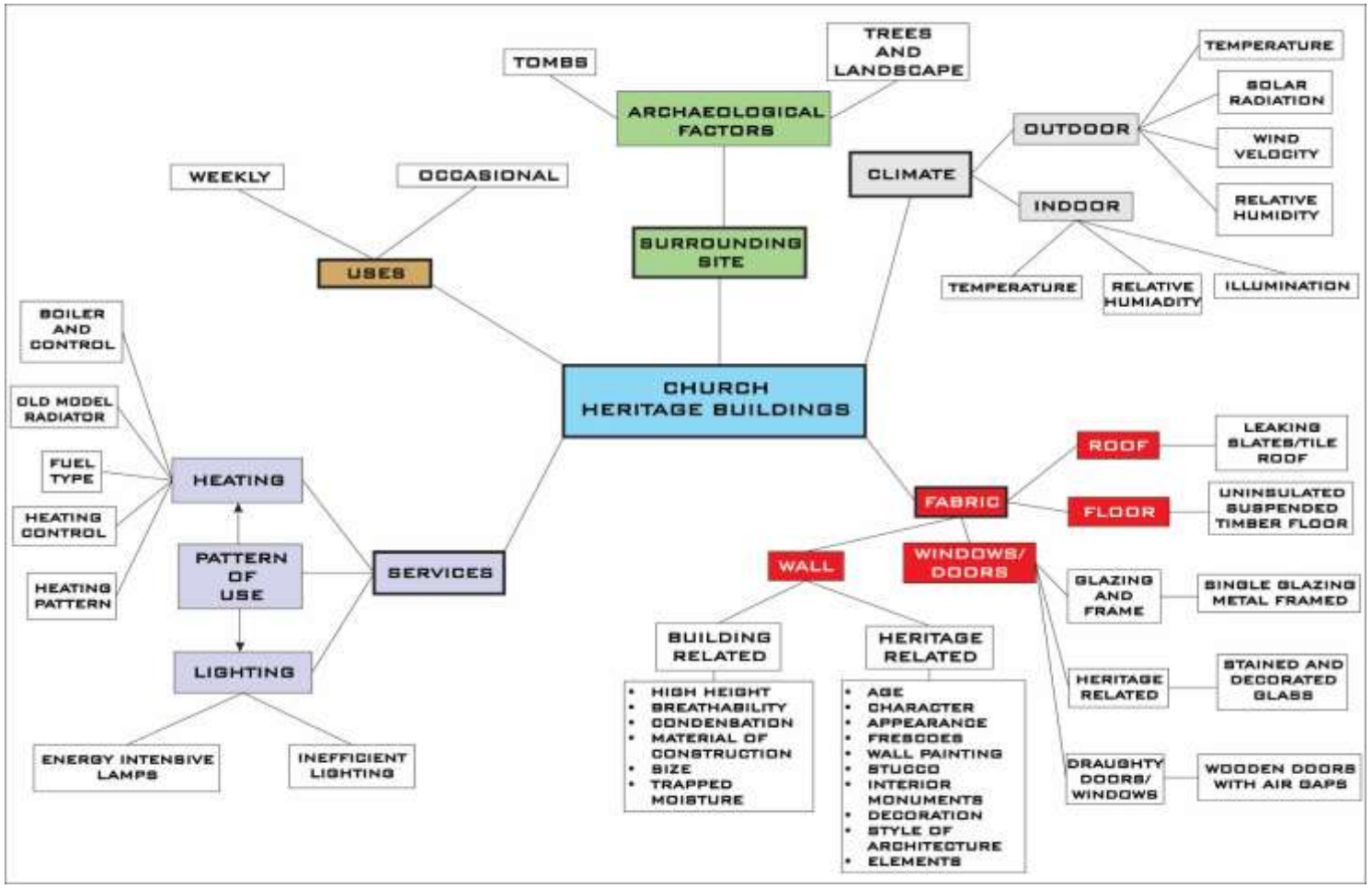


Figure 3.4: Characteristics of historic churches influencing energy use
Source: Study Author (2012)

would need to take account of possible disturbance of burials, something of archaeological significance below the ground, and other possible ecological significance of the churchyard. Permission would be required to carry out any such interventions with minimum permissible disturbance to any human remains in situ as relatives and other interested parties may object. This limits intervention to the improve energy efficiency of these buildings.

3.5.12 Heating systems

Mostly, historic churches were generally unheated prior to the 19th century. Stoves, braziers, chafers and hot-air systems are primarily the most commonly used heating systems. The early heating systems are of two types: localised systems (i.e. fireplaces) and central heating systems. Central heating systems is most common used in historic churches because of its large volume; to provide homogeneous heat distribution within the building; to heat the building envelope; to reach the desired comfort level of the occupants; and to provide some background heating to the building in order to avoid exceedingly low temperature and frost (Camuffo, 2010). The use of central heating is one of the common reasons for huge amount of energy consumption as a large fraction of energy are wasted due to thermal bridges, leakages, storage into the building envelope and severe stratification (Figure 3.5a).

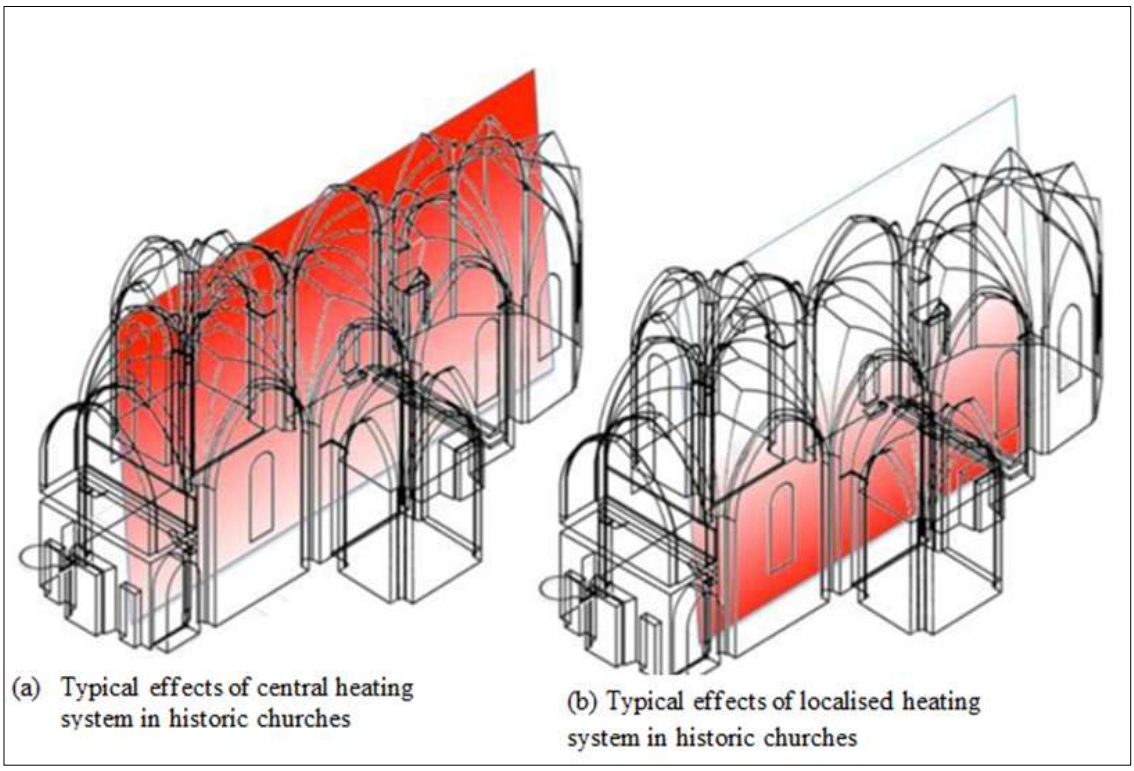


Figure 3.5: Types of heating systems in historic churches
Source: Camuffo (2010)

Another type of heating system commonly found in historic churches is the localised heating system aimed at providing radiant temperature to a limited area with some local increase in air temperature and a minimum of draughts (Fig. 3.5b). This leaves the remaining part of the volume of the church virtually unaffected. The localised heating only disperses a small amount of heat and leaves the rest of the church cold as opposed to central heating. This strategy uses less energy and the RH remains almost unaffected outside the moderately warmed area this makes it suitable for historic churches. When historic churches are being converted to another use, the indoor requirement and level of comfort required for the use of the building would change. This would require some degree of caution and care by the design professionals as ill-designed interior space and systems can result in adverse effects on the users and the fabric of the building (Makrodimitri, *et al.* 2012). This could lead to draughts, thermal stratification,

condensation, and deterioration of historic artefacts and possible elevated energy consumption. (Bordass and Bemrose, 1996).

3.5.13 Lighting

Historic churches were designed with an orientation from west to east with windows to accommodate natural daylight supplemented by candles to provide some artificial illumination at night. However, numerous developments over time brought about series of improvement to historic church lighting, especially with the advent of electric carbon and the tungsten filament lamp making artificial illumination of the interiors possible. The development of the tungsten halogen lamp in the 1960s further made the aesthetically pleasing and architecturally sensitive lighting of ecclesiastical interiors become possible. However, the lighting system is not designed to be energy efficient; thereby they contribute to energy consumption of the building. With the need to save energy when historic churches are converted to other uses, energy-efficient lighting could pose a lot of challenges due to the historic character of the building.

3.6 Conversion of Historic Churches to Community Uses

Most heritage building conservation professional architects have acknowledged the challenges associated with historic churches' conversion more than other building types. This acknowledgement is based on the observation of Murtagh (1997: p.120) and Latham (2000, p.82) on the complex geometry and spatial uniqueness of these buildings attached to their symbolic meanings as earlier discussed. The authors concern was especially focussed on the challenge converting in an economical way the large volume and window

characteristics of the interior. According to the authors, these could result in detrimental changes in conservation of their architectural integrity.

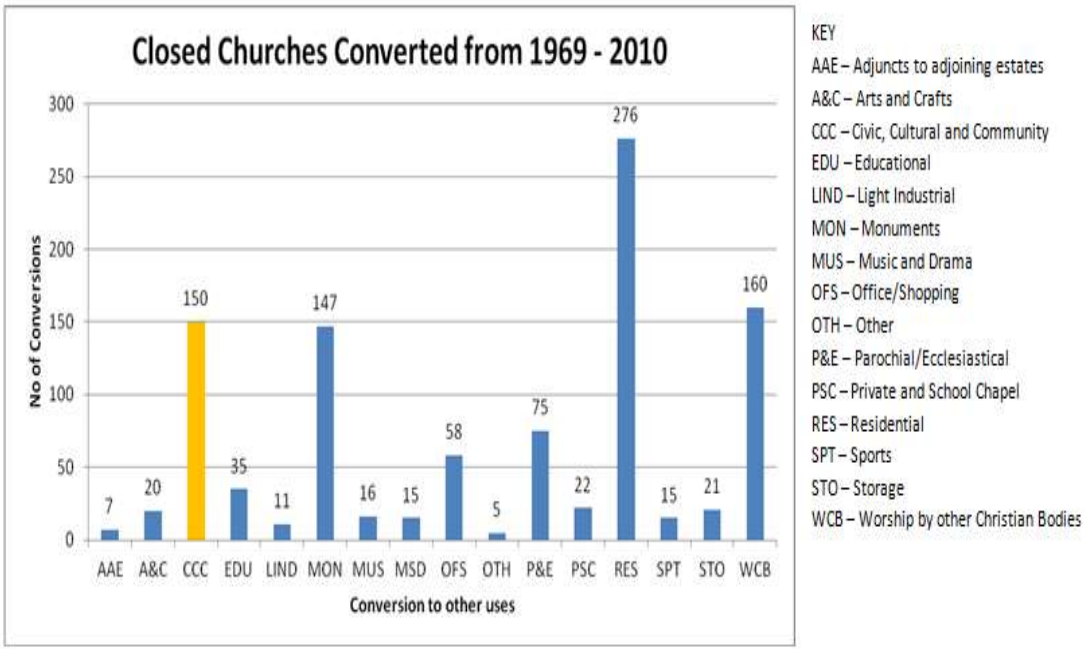
Latham (2000, p.85-86) based on physical and psychological characteristics of historic churches recommended conversion of these buildings to secular buildings appropriate to their physical changes and public use, such as "community centre, charitable uses, civic roles, recreational uses, commercial uses, and residential use". This recommendation mirrors the author's perception of historic churches as cultural heritage valued by the community as it responds to the church's original critical characteristics (Latham 2000, p.85-86). Douglas (2002) made similar suggestions, however, he cautioned on insensitive reuses that could be detrimental to the church's critical characteristics asserting the preference of the public to community reuse over other types. When compared to the focus of emphasis on the reuse of historic churches by Latham, it could be observed that Douglas (2002, p.159-160) emphasis was more towards economic benefits resulting from the conversion projects. Thus, it could be observed that when considering the adaptive reuse projects involving listed historic churches, conservation professionals focus is mostly directed towards the retention of the original architectural integrity of the building; as they give more recognition to the significance of these buildings as community cultural identity (Coryel, 2005; Jaeger, 2005).

Arguably, conservation professionals' design focus and decisions appear to be principally based on their perception of conserving the features and the identity of the buildings. Meanwhile, no mention is made with regard to the implications of energy use in adaptive reuse of these buildings. However, English Heritage (2008) while responding to the challenges of climate change recommends that sustainability appraisal of historic building

stock should put into consideration the whole-life energy costs allowing for strategies to increase its sustainability in terms of energy and materials in mitigating climate change effects. Presently, observation (Figure 3.6) shows that conversion of listed churches to community uses constitute the second largest reuse of these buildings following conversion to residential uses. Meanwhile, from 1969-2010 East England has the highest adaptive reuse of listed church projects.

3.7 Community Uses and Operational energy Use of Historic Churches

Historic churches converted for community use varies according to the pattern of use; some requiring intermittent and variable hours of use. For instance, converted churches use as a food sales service is more likely to be energy demanding due to the use of process plant (such as freezers and other catering equipment) compared to non-food sales service uses such as theatre and entertainment which would probably use more energy for lighting. Thus, the operational phase of these community uses could involve significant energy consumption with both financial and environmental consequences.



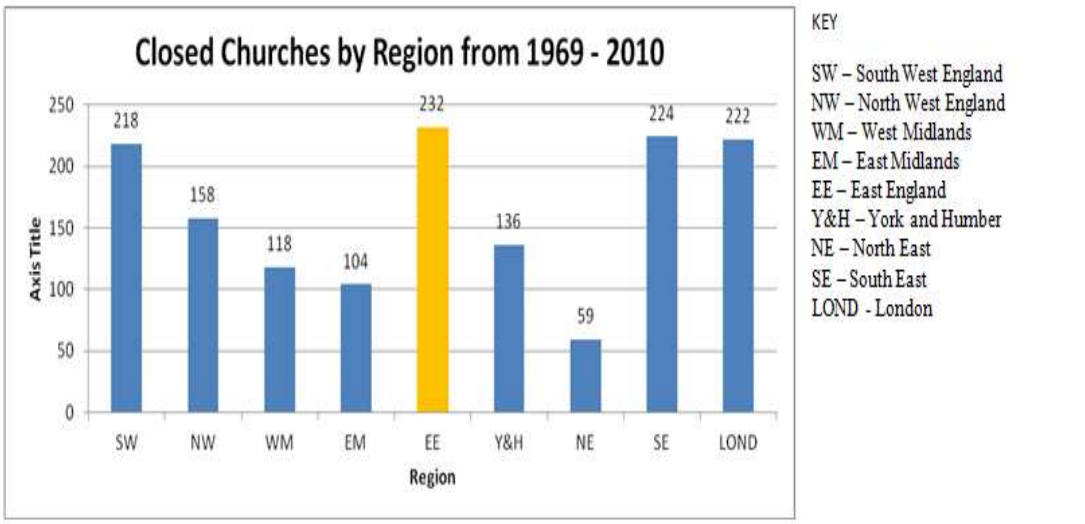
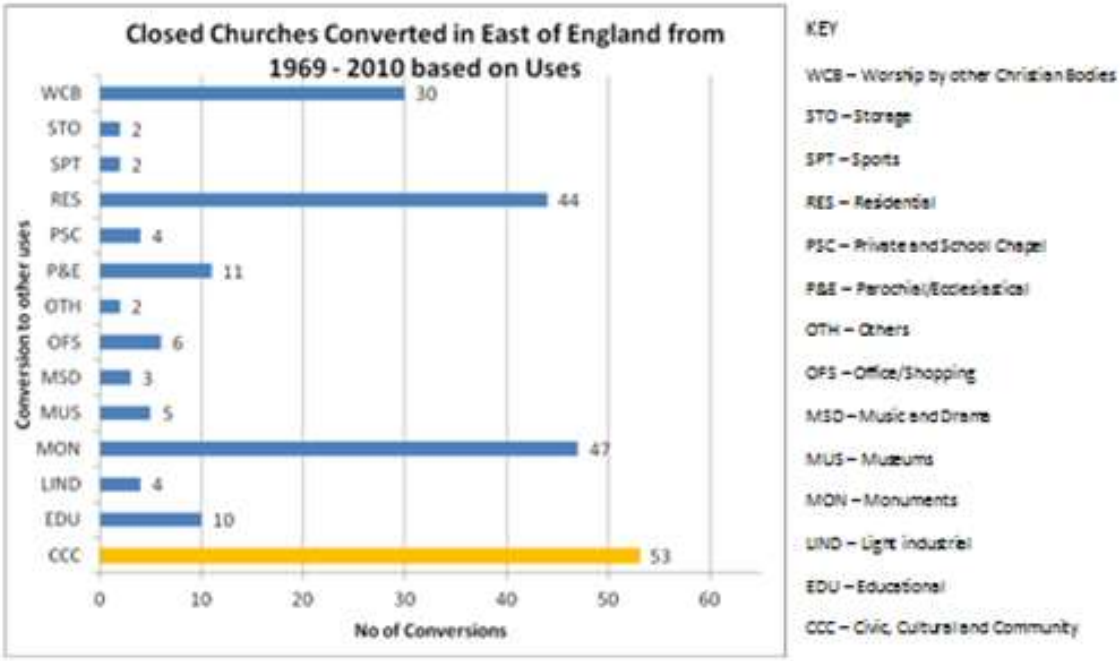


Figure 3.6: Number of converted churches by use type and regions
Source: Author's Survey (2011)

Figure 3.7 shows that in East of England church conversion projects to community uses are more in number compared to the other use pattern.



Source: Author's survey, 2011

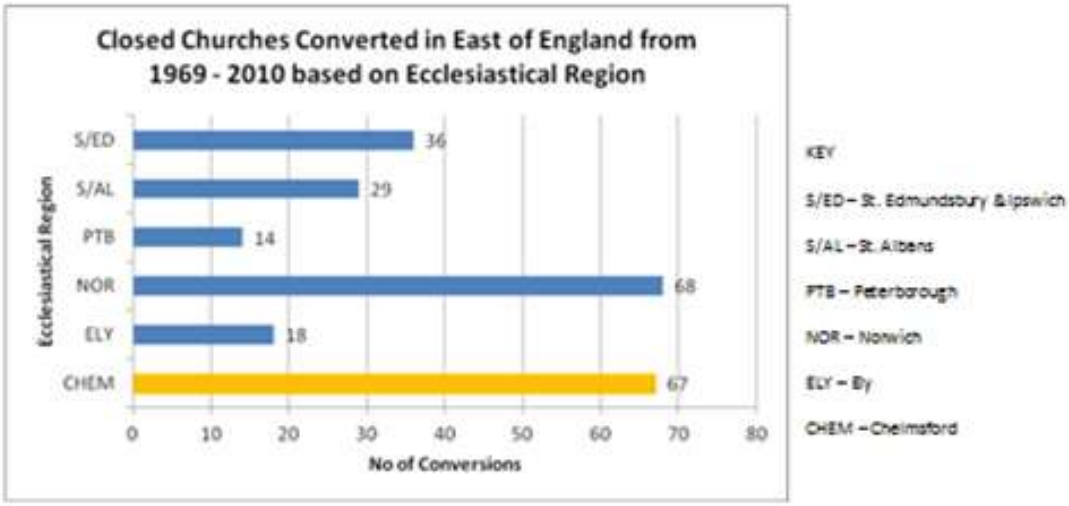


Figure 3.7: Converted churches to other uses in East of England
Source: Author's Survey (2011)

NTHP (2011) categorized building-related energy consumption into three, namely: embodied energy, operating energy, and building transportation energy. Operating energy constitutes about 84% (Figure 3.8) of building energy use in the of a building's life WBCSD (2008). While Raymond and Kernan (1996) argued that operating energy varies significantly with building use pattern, climate and season, and the efficiency of the

building and its systems. However, NTHP (2011) further extended what constitutes operating energy as the energy required to heat, cool, and provide electrical services to a building over its life span constituting the major factor in appraising building-related energy impacts. This varies from building to buildings and usually dependent on building envelope, system performance, building management and maintenance, occupant behaviour and building life span.

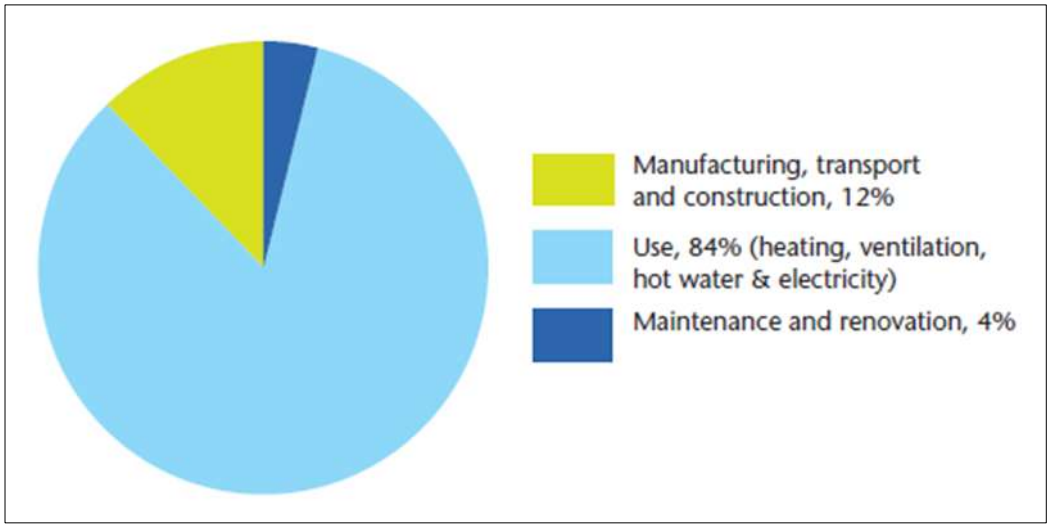


Figure 3.8: Lifecycle energy use
Source: WBCSD (2008)

Raymond and Kernan (1996) differentiated operational energy from those directly affected by the building and systems designs (i.e. Insulation standards, efficiency of lighting and other systems); those depending on how the building is used and managed (i.e. The control strategies, policies, scheduling, etc.) and variation in prevailing climate. Raymond and Kernan (1996) argued that in the former, additional material resources and embodied energy may be needed to reduce operating energy (e.g. increased insulation standards, thermal mass, etc.). Meanwhile, in the latter, significant energy reduction are not dependent on the physical characteristics of the

building. Jackson (2005) found that a building annual operating energy ratio of its total embodied energy can substantially diverge between 5:1 and 30:1. Further studies by Brown (2006) and Bruhns *et al.* (2006) agrees with the finding of Jackson (2005) indicating that operational energy in non-domestic buildings has risen dramatically within the last four decades. Building operational energy has become the main field of influence for designers (the architect and the engineer) therefore, it is widely understood that there is a complex interplay between various design strategies that can be applied to buildings and the opportunities for improving their energy efficiency.

Lehmann (2010) expressed that energy efficiency in buildings means employing strategies (in the design, construction and operation of buildings) that minimize the use of energy imported from utility companies. Arguably, a building could perform at a high level when all major design objectives and goals are considered from early project development phase reflects an operational energy use reduction, rather than focusing on one design objective while others are neglected. Thus, addressing the design objectives to reduce energy demand and environmental impact in early design decisions should be paramount in any building projects.

The review of literature has shown that operational energy use reduction for sustainable performance of buildings is often less prioritised. Further, as earlier revealed from the literature, the focus of conservation professional architects is mainly on performance for intended converted reuse of historic churches. Hence, once performance for the intended use is achieved at the design stage and the building project is delivered, there is a discontinuity leading to operational management gap of isolation, ineffective coordination and poor communication between the stakeholders (the designers and the

facility managers). Mattar (1983) described the gap of isolation, ineffective coordination and poor communication among the stakeholders as operational islands (i.e. Performance gap). This is a situation where end-users or facility managers responsible for the operational phase of the building have normally very little opportunity to provide feedback to developers and/or designers in the design phase (Mattar, 1983). These operational islands (performance gap) have led to difficulties for the end-users or facility managers in taking decisions that can optimize sustainable performance of the building (Figure 3.9).

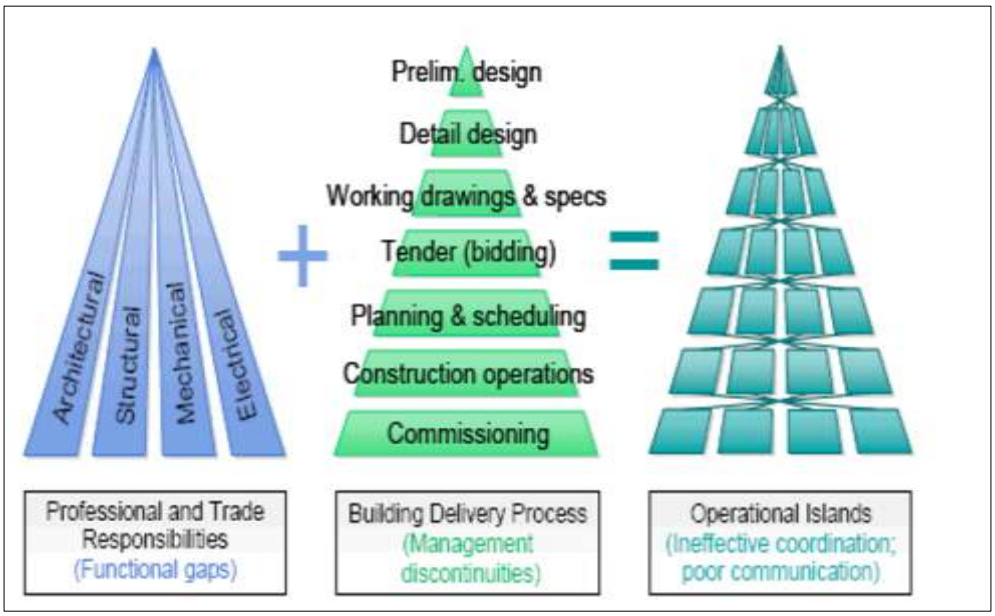


Figure 3.9: Operational islands
Source: Adapted from WBCSD (2008)

3.8 Multiple Approaches to Investigating Operational Energy Use of Heritage Buildings

In order to gain more perspective on what heritage building stakeholders might be saying on energy use reduction and what strategies might be developed to effectively address the problem of high energy consumption in reuse of LCBs; literature on environmental

behaviour was examined to provide insights into the value, priorities and perceptions of the stakeholders involved in LCB projects. Referring to the relationship between behaviour and energy use, Burgess and Nye (2008) characterised energy consumption as 'doubly invisible' implying that most people are ignorant and unmindful of the quantity and influence of a given amount of energy use and how their practices contribute to it. This is specifically applicable to operational energy use.

Ajzen (1991) suggests that behaviour is governed by a person's intention to perform an action influenced by three factors, namely: attitude, perceived control and the subjective norm reflects an individual's perception of social behaviour. This view is supported by Abrahamse and Steg (2009) and Davis *et al.* (2009) who noted attitude-behaviour gap in studies examining the contrast between people's actions and attitudes towards environmental issues. The authors argued that planned behaviour theory posits that a person's attitude and perception is part of the components that dictate the person's action. Meanwhile, human behaviour is seen from a systems perspective as the aftermath of shared connections of individuals working within interconnected social systems. With its interdisciplinary backgrounds from engineering, cultural anthropology, economics, and sociology, it observes occurrences as the aftermath of connections within and among systems.

Within the scope of this study, understanding the underlying factors such as perception and attitudes towards energy use reduction is very crucial. This could help in understanding how perception is connected to actions or decision relevant to target energy reduction measures. Based on the application of these theories in different studies such as Tonglet *et al.* (2004a); and Davis *et al.* (2009) it could be argued that perception and

attitudes might partly be contributing factor of pro-environmental behaviours and intentions (Abrahamse and Steg 2009).

In the context of multiple influences on energy consumption in listed churches (Figure 3.10), it could be inferred from the review of literature that adopting energy saving measures is primarily determined by an individual's attitude, the perceptions and values. Therefore, to implement holistic measures of energy saving strategies for heritage buildings; there is a need for the integration of the social, economic and environmental dimensions of sustainable development using value-based theory, sustainable design principles linked to the understanding of historic buildings as systems for a robust understanding of the approach to address the problem under investigation.

Following the extensive review of relevant literature, it was observed that a great deal of research efforts has been concentrated on energy consumption of heritage buildings from those directly affected by the building (e.g. Increasing insulation properties) in an attempts to make them energy efficient while the researcher is unaware and has not found literature directed to energy use as a result of the way the building is used and managed (i.e. The control strategies, policies, scheduling, etc.) Yet, it could be argued that in spite of numerous research efforts along with reports, guidelines, policies and legislation to address energy use problems in heritage buildings, to date, the desired energy use reduction has not been achieved.

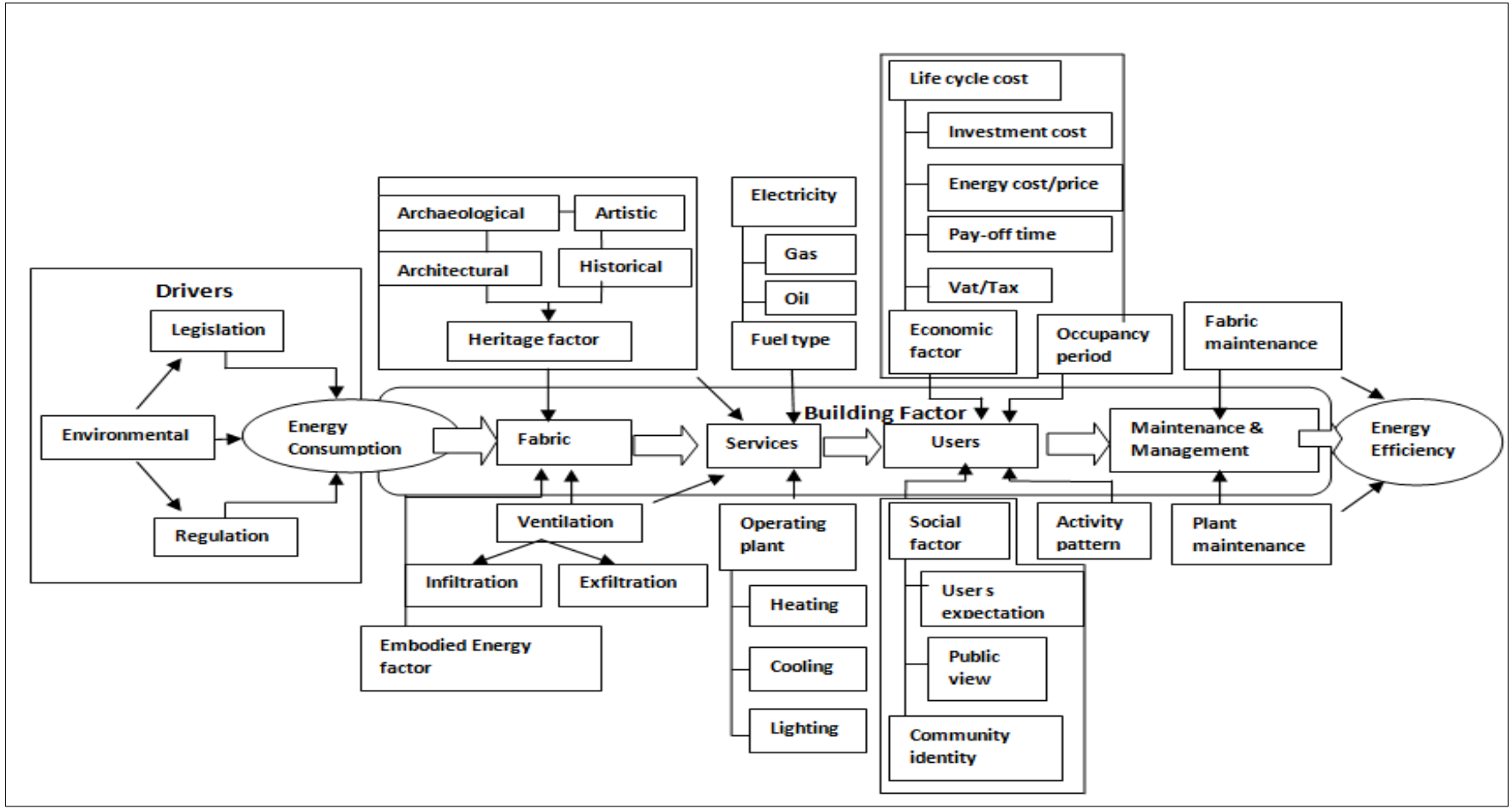


Figure 3.10: Multiple influences on energy consumption in listed churches

Source: Author's survey (2012)

To achieve the Governmental targets and commitment to emissions reduction which has been adjusted from 60% of 1990 levels (DTI, 2003) to 80% by 2050 and currently legally binding UK Parliament with the urgency of circumventing anthropogenic climate change, it becomes essential to recognise how heritage buildings are used and managed so as to reduce their energy consumption and to make them more efficient. Following the extensive review of relevant literature in the previous chapter (i.e. Chapter 2) and this current chapter, this research argued that there is a need for an all-inclusive attention to viewing heritage buildings as systems. Additionally, there should be considerations for heritage values coupled with the key stakeholders' perception and professionals' understanding of harnessing the sustainable (bioclimatic) principles of heritage buildings. It is with these that the efforts required to achieve energy use reduction in heritage buildings can become successful.

3.9 Chapter Summary and Conclusion

Given the summary of the literature reviewed (Figure 3.11) operational energy use reduction in the reuse of LCB projects could be perceived to be impacted by the interplay of multiple influences; resulting in complex problems requiring not just a single approach to adequately address. Rather, there is a need to explore multiple approaches to investigate these problems so as to devise the most appropriate interventions suitable to them in such a way that they could still be conserved and at the same time have their operational performance less environmentally burdensome. It could be understood from the literature that LCBs' energy use is not just a problem of their thermal performance; the problem could be compounded by other underlying factors associated to the key stakeholders in

practice. The following chapter reviewed various theories relevant to address these problems as the appropriate theoretical perspectives underpinning this study.

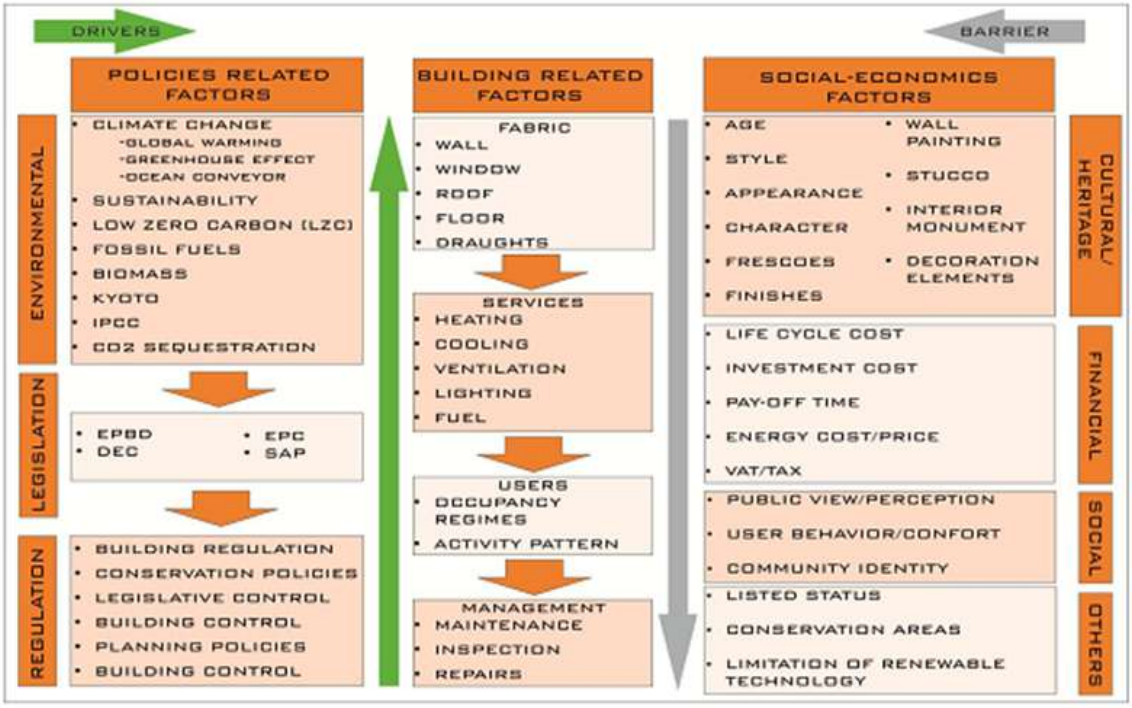


Figure 3.11: Drivers and barriers to energy efficiency in historic churches

CHAPTER 4: THEORETICAL PERSPECTIVE AND CONCEPTUAL FRAMEWORK

4.0 CHAPTER OBJECTIVES

- To review theories that form the bases for the theoretical perspectives of this study
- To present and discuss the main theoretical approach relevant to this study and their implications for heritage buildings.
- To develop, present and discuss the conceptual framework that guides this study
- To establish the methodological framework that forms the bases for research design and data analysis.

4.1 Background to Theoretical Perspectives

There has been a growing concern in the latter half of the twentieth century about the assumption of social science research being dominated by dominant empirical, analytical methodologies which characterised the 'hard' or 'natural sciences' (Candy, 1989 p.2). This concern has led to increasing awareness of the appropriateness of alternative approaches which has led to the recognition of alternative paradigms, epistemologies and application of a variety of methodologies and methods (Tobert, 1981; Wiersma, 2001; Jacob, 1998). This shift has led to the development of new epistemologies, theoretical perspectives, methodologies and methods which emerge as theoretical constructs on which research can be based along with the dominant objectivist's perspective of the limits and nature of human knowledge. Crotty (1998) referred to these epistemologies as objectivism, constructionism and subjectivism. In this study, the identification of the theoretical framework is guided by the schema of epistemologies and theoretical perspectives suggested by Crotty (1998).

4.2 Justification for a Multi–Theoretical Approach

In order to find a supportive theoretical foundation that will give reliability of the design of the study, it was necessary to adopt a combination of theories to establish the theoretical foundation of the study from different perspectives as a basis on which to build and to provide a robust framework for the study. Gelso (2006, p.2) suggested four functions of theories, namely: descriptive, delimiting, generative, and integrative. The use of theory in this study adopts the integrative function which, according to Gelso (2006, p.3) provides a logically incorporated depiction of frequently different and apparently contrasting facts. Cobb (2007, p.3) argued that for a study to stand scrutiny the choice of the theoretical perspective require some justifications.

The theoretical lens that provides an appropriate framework for this study was given consideration firstly to aid the type of data to be collected; secondly to facilitate the analysis and interpretation of the collected data and thirdly, to justify the theoretical perspective used for the study. Adopting more than one theory in this study has not just a theoretical and methodological implications; similarly, the synthesis of more than one perspective could also provide a more robust theoretical underpinning and framework for the study which enables better understanding of the context from which the study is approached. A similar stance is taken by Schoenfeld (1999) who supports the use of two or more theoretical perspectives in a single study. The author stated that the researcher could utilise the advantages of each perspective if they are taken into consideration when the theories are combined in such a manner that complement each other. Consequently, the synthesis of more than one perspective in this present study is considered appropriate firstly, because the study aims at investigating the perceptions and practice of heritage

building industry stakeholders regarding energy use reduction in reuse of public heritage projects and operational performance of existing reused projects. This necessitated the study to be viewed not only from cognitive or phenomenological perspective, but also from a sociocultural and environmental perspective.

Secondly, incorporation of cognitive, socio-cultural and environmental perspectives presents diverse theoretical backgrounds leading to a different approach for each perspective than if only one approach was used. Therefore, a 'one size fits all' theoretical perspective for this study would not have been adequate because of the multi-dimensional nature and complexity of the problem. According to Cobb (2007) using only one theory in such a study would restrict the study to a particular point of view. The consequences of this is that it might result in the findings of the study not being trustworthy or sufficiently valid to draw conclusions. This could lead to difficulties of finding an appropriate solution to the problem investigated. Therefore, this researcher considers it necessary to draw from the multiplicity of theoretical perspectives informed by the nature of the research problem under investigation and the researcher's worldview (i.e. The philosophical assumption about the researcher's perception of the human and social life within the world). Thus, considering the purpose of this study and the research questions posed to guide the study, it was found appropriate to encapsulate this study within the theoretical perspective of interpretivism rather than positivism.

The decision taken on the theoretical perspectives would thus help to incorporate relevant aspects relating to energy use in heritage management as well as aid in providing better insight into the theoretical framework of the study. It is hoped that this approach will

assist the reader's understanding of the basis on which the philosophy of the study is established. Key theoretical perspectives which have dominated the literature and found relevant to this study are: systems theory, stakeholders' theory, value theory and sustainable design theory. For the purpose of this study, these theories are categorised into two main areas, namely: technical and management theories. The systems and sustainable design theory and principles are reviewed and discussed under technical oriented theories. Meanwhile, the stakeholders' and value theory is reviewed and discussed under the management oriented theories. However, the main theoretical orientation of this research is guided using the systems theory.

4.3 Technical Oriented Theories

4.3.1 Systems theory

Systems theory is an interdisciplinary theory and multiperspectival domain about the nature of complex systems in nature, society and science providing a framework by which objects can be investigated and/or described to produce some result. Hjørland and Nicolaisen (2005) defined a system to consist a group of social, biological, technological or material partners working together for a common purpose. Systems theory is a philosophical doctrine of explaining systems as abstract organizations not dependent on substance, type, time and space. Systems theories are linked to ontological and epistemological views. The ontological view implies that the world consists of "systems" or "integrative levels". The epistemological view implies a holistic perspective, emphasizing the interplay between the systems and their elements in determining their respective functions. It opposes more atomistic approaches in which objects are investigated as single phenomena . Since Angyal (1941) and von Bertalanffy

(1950) work in the early 1940s to 1950s the 'systems approach' has assumed increasing importance in various branches of social analysis. In psychology, anthropology, archaeology, organisation theory, sociology, engineering, economics and many other social science subjects, systems theory has become established as an important method of analysis that connects the interdisciplinary exchange of ideas between independent areas of study and within the area of system science.

Contemporary ideas from systems theory are exemplified by the work of numerous scholars and theorists such as von Bertalanffy (1950); Beer (1975); Ackoff (1978); Checkland (1981); Banathy (1996); Capra (1997); Flood (1999); Jackson (2000) and Morin (2008). Although the system theory has been extensively explored by several prominent scholars, the notion of 'system' is still considered as an elusive one. In an attempt to find a formal definition of systems theory, Angyal (1941, p.243) argued that 'there is a logical genus suitable for the treatment of wholes which is called 'system'. von Bertalanffy (1956) in line with the view of Angyal (1941, p.1-2) stated that

> *'there are correspondences in the principles which govern the behaviour of entities that are intrinsically widely different. This correspondence is due to the fact that they all can be considered, in certain respects as "systems", that is complexes of elements standing in interaction.*

From the above views, it might be argued that systems theory is based on the premise of comprehensive view on the interrelationship of different parts of a component. Hence, the notions of 'holism' and 'interaction' of the parts are not exclusive to systems theory. von Bertalanffy's view of systems theory provides alternative to reductionism which

characterises most areas of scientific endeavour and with most emphasis based upon modes of enquiry on the methods and principles of conventional physics (Burrell and Morgan, 1979). von Bertalanffy's view on systems theory can be regarded as archetypical of the positivist perspective, he further argued that instead of reducing all phenomena of study to physical events, they should be viewed as systems. Thus his positivism could be viewed as that of a non-traditional kind that is dominated by the metaphor of 'system' as an organising concept.

According to Barry (2012) systems thinking is needed to understand critical issues confronting humanity and to deal with complex situations where there are many interacting elements causing big problems. Checkland (1981) however, holds the view that problems no matter their size can be classified either as 'hard' or 'soft' problem, each with unparalleled features that distinctly require diverse methods to resolve. Checkland (1981) along with other analysts (Checkland and Scholes, 1990) argued that system thinking display two different kinds of approaches, namely: 'hard' and 'soft systems thinking'. These views has long been clearly articulated and considered by social scientists in the literature to be the two types of systems perspectives - 'closed' and 'open' systems.

According to von Bertalanffy (1950) closed systems are systems which are considered to be isolated from their environment while open systems are characterised by an exchange with their environment. The description of open system was extended by Buckley (1967, p.50) that '*a system is open means not simply that it engages in interchanges with the environment, but that this interchange is an essential factor underlying the system's*

viability, continuity and/or its ability to change'. In view of the above definitions, heritage buildings cannot be viewed and treated solely as a closed system.

Due to the way heritage buildings engage and interact with their immediate environment by the process of 'importing' and 'exporting' heat in the process; they are best perceived as open systems when dealing with issues that relates to their energy consumption. For this study and the purpose of consistency, the term 'hard' and 'soft' systems thinking as suggested by Checkland (1981) are used to represent 'closed' and 'open' systems. Checkland (1981) argued that the term 'hard' and 'soft' systems thinking revolves about the supposition of 'systems' theory and its use of symbolizing the actual world. These terms are further elaborated in the following sections.

4.3.1.1 Hard (closed) systems thinking

According to Checkland (1981) and Checkland and Scholes (1990), the hard systems method includes an ontological view on the concept of a 'system' used to label objects in the actual world. It assumes the apparent world include *holons* in which the problem-solver thinks in terms of 'holons' as if they are real and can be engineered (Checkland and Scholes, 1990). Lane and Oliva (1998) viewed a Holon as a special kind of model that organizes thinking by means of systemic ideas. A similar view held by another proponent of hard systems thinking such as Lewis (1994) believes that the world consists of systems and subsystems that can be 'engineered' to achieve their objectives. The assumption of hard systems is based on viewing reality as being ordered and stable system, thus placing hard systems thinking in an understandable, correct and proper idea of world representation. Thus, to analyse an apparent problem in hard systems method as

argued by Checkland and Holwell (1998) is for 'engineer' improvements in the real-world systems. Meanwhile, to discover the optimal solutions to the perceived problem in the most effective way, the problem-solver would need to find methods that could change the system in some way.

The engineering approach in hard system thinking as opined by Avison and Fitzgerald (1995) and Checkland (1981) relates and is targeted to what is particular and precise in a specific area thus, is observed from a single perspective leading to a definite solution. von Bertalanffy (1950) however, argued that these systems thinking being characterised by isolation from their environment (Figure 4.1) has proved overwhelmingly successful in persuading social theorists that the hard (closed) systems approach is inappropriate as guiding principle for the conceptualisation of social phenomena. Thus, the rationale why 'hard' systems approaches are not considered approriate for this study is that they do not take into account social and cultural aspects of a problem situation.

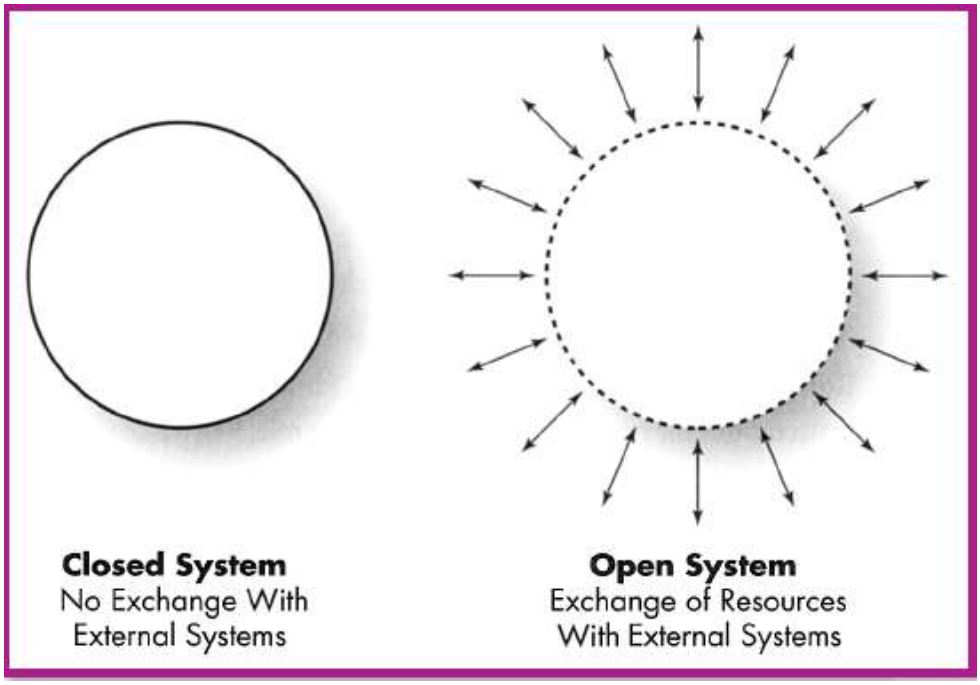


Figure 4.1: Closed and Open Systems
Source: Hutchison (2012)

4.3.1.2 Soft (open) systems thinking

In contrast to hard systems, soft problems consist of social and political elements that confound problem definition and resolution. Thus, the key question posed for this study "*How can energy use in heritage buildings be more effectively managed to improve the energy performance of heritage buildings*" indicates a soft problem. In soft systems thinking, the basic assumption is that there is quite a lot of equally probable perception of the social world. Theorists of soft system thinking (Checkland, 1981; Checkland and Scholes, 1990; Checkland and Scholes, 1999) postulate that the world could be perceived as being shaped by knowledge of the observer, it is therefore subject to the history, culture, norms, values and aspirations of the person perceiving it. They argued that the world we live in is the world we perceive. Thus, according to soft systems engineering, there is no such thing as a 'right' perception of the real world.

Dahlbom and Mathiassen (1993), suggested strategy for the expression of diverse perspectives in soft systems method as involving the engagement of people in discussions and deliberation with the goal of arriving at consensus on a possible solution to the problem situation. By contrast, this approach to problem solving presumes the purpose of the system is multifaceted with purposes rather than an achievable and measurable goal as adopted by hard systems. Thus the situation can be better understood through discussion and debate with the problem solver (i.e. The researcher) and stakeholders. In dealing with soft problems, Checkland (1981) proposed an iterative method called the Soft Systems Methodology (SSM). The methodology presents a balance to usual, reductionist scientific enquiry with the possibility of reducing the observable fact into lesser components in order to study and understand them (Checkland, 1976). The method comprises of seven different steps highlighted below:

- Identify and be aware of the problem situation (i.e. Nature of the procedure, key stakeholder, etc.).
- Convey the problem situation graphically.
- Decide on method of investigating the problem from different perspectives and generate root definitions.
- Develop conceptual models of the system requirements to sufficiently tackle each of the root definitions.
- Evaluate the conceptual models (step 4) to the factual world expression (step 2).
- Recognize possible and acceptable changes to improve the situation.
- Develop recommendations for taking action to improve the problem situation (implementing step 6).

The purpose of SSM framework is to address the ill-structured and complex energy use problem in LCBs containing quite a significant social impact and outcome. The researcher would therefore need to investigate solutions that possess other aspects rather merely concentrating only on technical and functional aspects. However, current scholarly arguments in literature relies too heavily on investigating issues that borders on technical and functional aspects of the sustainability of heritage buildings. Meanwhile, review of literature indicates that there is a paucity of emphasis in the literature addressing the issues of energy consumption in LCBs from social-cultural and environmental perspective; consequently shaped and defined by the constant interaction of roles, norms and values. These issues are perceived as a complex set of problems that currently holds between energy efficiency and conservation perspectives of heritage buildings.

According to soft system thinking such complex problems could be perceived to have changed entities whose nature are repeatedly redefined by the people associated with it. Therefore, soft systems thinking provides a framework for exploring and understanding the problem situation as it embraces multi-level views of stakeholders and their varied perspectives. From a decision-making perspective, Mitroff and Linstone (1993) views these perspectives, approach as an attempt “to sweep in” all possible perspectives on the problem. This author’s views are an extension of Churchman’s (1971) perception of systems thinking which assumes that any problem is a member of another problem. Thus, the soft system thinking provides a methodology to draw into the process of determining appropriate interventions from the different stakeholders that may be associated with solving the problem. It should be noted that the multiple perspectives approach from SSM would help in the classification of the perspectives as either being technical, organisational or individual in nature. Thus help to guide in the analysis, interpretation

and discussion of findings from the data collected. From the perspective of other scholars (Turpin and Marais, 2004), the framework developed for data collection as a basis of using the system theory would come under the technical perspective. They argued that though different projects may present different technical views and may claim to also present an objective or rational picture of the situation or problem; the authors suggested more than one technical view of the system be obtained.

Turpin and Marais (2004, p143-160) further suggested that covering the organisational and individual perspectives would require investigating the perceptions of as many stakeholders as possible. They proposed the data collection to follow the "sweeping in" approach and also opined that the organisational and technical perspectives data would require multiple modes and from as many sources as possible. In addition, to using adopting the SSM approach, Mitroff and Linstone (1993) caution that apart from the technical, organisational and individual perspectives involved from the perspective of this theory; similarly, ethical and aesthetical perspectives should be kept in mind. The authors' argument is based on the premise that decision taken using this approach may make sense from a technical perspective or may be endorsed by a particular group of stakeholders, it may however, not be ethical. From the foregoing discussion and differences in soft and hard systems approaches, SSM is considered potentially well-suited to the investigation of the complex energy use problem in heritage buildings.

Figure 4.2 presents the framework of SSM as proposed by Checkland (1981) is illustrated and adapted to develop the conceptual framework for this study. Since the philosophical underpinnings of SSM are interpretive and evaluative in nature as well as focused on qualitative issues and participative in approach; its approach thus makes it suitable for

investigating the multifaceted energy use problem in heritage buildings. Therefore, the characteristics of SSM make it to be able to explicitly handle differing and constantly changing stakeholder perspectives through the concept of differing worldviews. Thus, its epistemological premise is neither dependent on measurement techniques, nor establishing causal validity.

It could be concluded that the best way to approach the issues of energy use in heritage buildings is from the soft systems engineering perception. This decision is based on the premise of the nature of the problem situation, the need to shed light on the problem and to come up with systemically acceptable and culturally possible approach to improve the situation. The rationale behind the selection of soft systems approach is thus based on its holistic approach to problem-solving and its ability to address overall patterns and relationships between different factors interacting to contribute to energy use in public heritage buildings as opposed to approaching the problem from a single perspective which has been the approach adopted by researchers in the past.

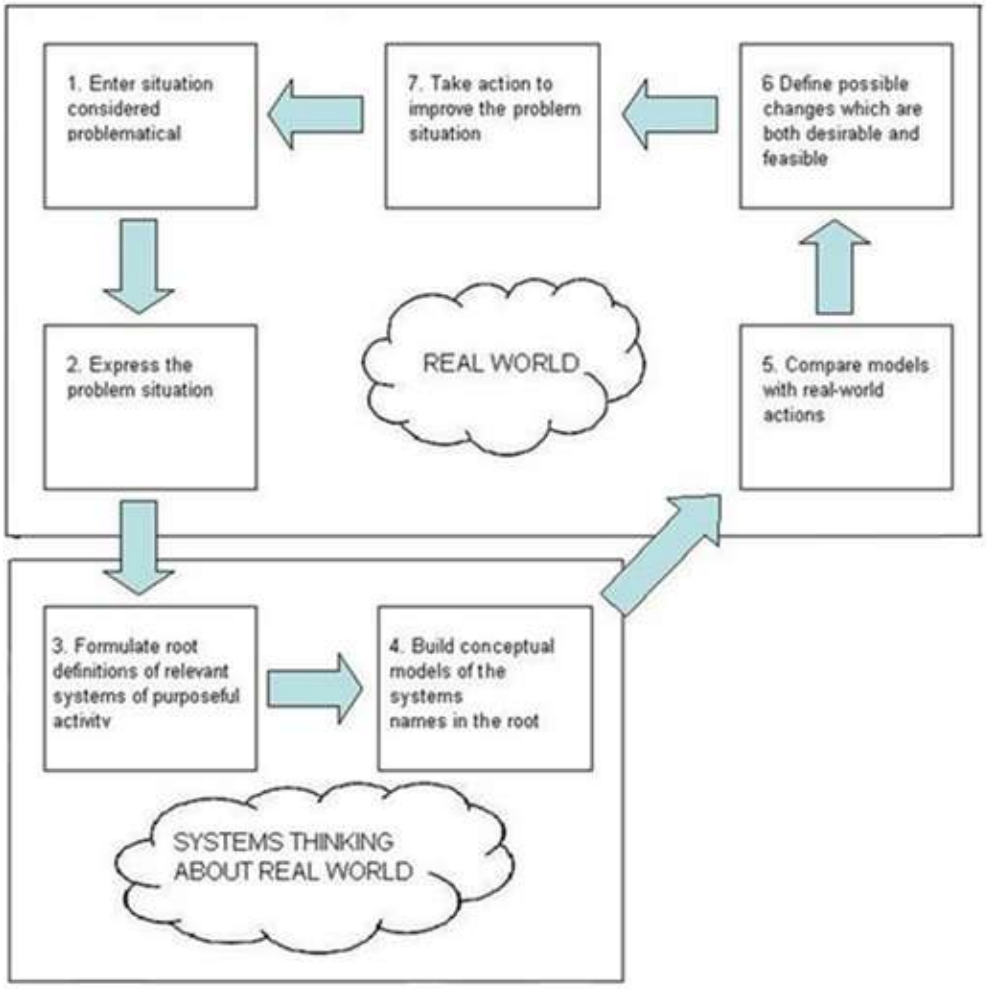


Figure 4.2: Framework of SSM for exploring energy use in LCBs
Source: Adapted after Checkland (1981)

4.4 Theory of Sustainable Design

4.4.1 Sustainable design in the context of sustainable development

The dominant concept in literature on heritage conservation encompasses the concept of sustainability. Sustainability is a concept that ranges across disciplines, resonating with economists, ecologists, social scientists and system theorists. Sustainability according to (Markusen, 1999) is an unclear concept that puts forward a thing, an occurrence or procedure which has two or more different connotation known and applied by diverse readers or scholars. Several reasons for this lack of clarity was argued by Markusen (1999,

p.870) to include: the idea that all new concepts are fuzzy while they are in the process of being defined; they may be addressed to different audiences or forums and thus take on different meanings; or they are used as an umbrella term to pull together various concepts, particularly in connection to political organizers.

The definition of "sustainable development" was widely accepted in 1987 in the Brundtland Report as: "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs" (WCED, 1987; Botta, 2005, p 39). The concept of sustainable development became extended in 1999 by the Wuppertal Institute in Germany in a model called" the prism of sustainability" when the forth dimension of sustainable development components was presented by the institute as its institutional aspect in addition to its environmental, social and economic aspects. The institutional aspect of sustainable development as suggested by the Wuppertal Institute in Germany includes management, regulations and democratic processes. Thus, the implication of this addition is that any actions aimed to be sustainable must take cognisance of the equal importance of these four components of sustainable development without undermining the other (Botta, 2005). Consequently, it might be argued from a heritage conservation perspective that management of energy use or responsible use of energy for the heritage building project should constitute fundamental consideration in its sustainable future; this would align with the concept and the goal of sustainable development.

According to the theoretical underpinning guiding the principles of sustainable design, this process should integrate energy use awareness, energy conservation, and energy efficiency along with the application of primary renewable energy resources. Therefore, since the emergence of sustainable development and practices, the concept of sustainable development has triggered the building sector to start to assume a key role in inculcating this concept and its implications for the built environment. While it is worth noting that in the past, building-design has been adapted to harmonise with the natural environment. However, there has been a departure from this approach as a result of the industrial revoultion and advancement in modern technology and the use of modern materials that has placed a heavy demand on the natural environment.

Since the first oil crisis in the early 70s, Tzonis (2006) noted that the quest for environmental alternatives such as more energy-efficient buildings began with some early designers who adopted a design approach called 'low tech'(i.e. The use of passive design strategies before the active strategies). Brunskill, 1978 (cited in Forster *et al.*, 2015) refers to this early design approach as traditionally evolved design having weathered features borne out of the hostility of the climatic conditions that a building would be exposed to, and as well responsible for regional vernacular building aesthetics. Similarly, Lehmann (2008) supported and extended these views by arguing that traditional built heritage demonstrates designing buildings using 'low tech' approach because they were built using processes and materials that were environmentally friendly.

The importance of the traditional design approach is further buttressed in BS 8104 (1992) stating that understanding and designing buildings to accommodate climatic conditions and exposure is primary design parameter. Whilst some researchers (Cairns, 1994; Forster

and Carter, 2011) have emphasised the essential of the interrelationship between design, materials and detailing to good and holistic long term performance and avoidance of premature failure of these buildings. Other authors such as Marsh (1977); Cook and Hinks (1992) (cited in Forster *et al., 2015*) have noted that breaking from the traditional approach and changing it towards modernist architectural forms and unfamiliar construction systems has resulted to increase in the rate of defects.

According to Oxley and Gobert (1994) this predominantly concern moisture related issues such as penetrating dampness. Thus, the built heritage offers a large resource of knowledge about sustainable design principles and could serve as an educational resource of design approaches that achieve 'more with less'. In modern times, environmentally-friendly approach has necessitated the need to lighten human activities and damages on the natural environment by reducing over-consumption. This paradigm shift to environmentally-friendly approach has led numerous researchers (Vale and Vale, 1991; 2000; Hyde, 2000) to posit that successful buildings for the future will have to increasingly rely on the critical examination of and learning from building of the past. This paradigm shift to environmentally-friendly approach to building projects is therefore concentrated on saving natural resources and reducing environmental impacts (Botta, 2005).

As a result of the search for an environmentally-friendly approach to sustainability in the building sector, many sustainability advocates have also been directed to addressing the significance of sustainable building practices. This necessitated more focus on minimizing the impact of new and/or existing building on the natural environment and concentrating efforts on improving the ecological performance of existing building as the

main concerns of sustainable building concept. However, from sustainability perspectives, modern architecture presents a unique challenge. As it is found that construction projects typically consume large amounts of materials, produce tons of waste, and more often than not also involve weighing conservation of buildings with historical significance against the desire for the development of newer, more modern designs.

4.4.2 Concepts of sustainable design and building

Several authors and international experts (Calthorpe and Sim, 1991; McDonough, 1992 and McLennan, 2004) in the field of sustainable design have addressed the fundamental issues of sustainable design and its principles. McLennan (2004) defined sustainable design as the philosophy of designing physical objects, the built environment, and services to comply with the principles of social, economic, and ecological sustainability. The author argued that a truly sustainable building is one that has no negative operational impacts on the environment. According to McLennan (2004) the familiar reference to reduce, reuse, and recycle forms the ecological background of sustainable design and green building practice.

In the field of architecture, the concept of sustainable design is synonymous with other related concepts such as designing with nature, high-performance design, integrated design, environmentally sensitive design and green building. However, McDonough (1992) and McLennan (2004) reinforces the notion of sustainable design as a philosophy, and not merely physical components of green design, stating that it is not about features,

but a design philosophy that seeks to maximize the quality of the built environment, while minimizing or eliminating negative impact to the natural environment (McLennan, 2004 p.4-6).

An OECD Project (cited in Hui, 2002) gave the definition of sustainable building in terms of building practices which strive for integral quality (including economic, social and environmental performance) in a very broad way. According to Yan and Stellios (2006), this design practice should emphasise and be centred around efficiency of heating and cooling systems; alternative energy sources; appropriate building siting, reused or recycled building materials; on-site power generation etc. However, they argued that close cooperation among the design team such as the architects, the engineers, and the client at all project stages including procurement and project implementation will be required to truly deliver a sustainable building project. In addition, the OECD project puts it more elaborately that the rational use of natural resources and appropriate management of the building stock will contribute to saving scarce resources, reducing energy consumption (energy conservation), and improve environmental quality. Accordingly, the project inferred that sustainable building involves considering the entire life cycle of buildings, taking environmental quality, functional quality and future values into account.

Thus, drawing from an environmental perspective, Fisher (1992) summarised and put forward what constitute the principles of sustainable design and environmental architecture outlining them as a healthy interior environment; energy efficient; ecologically benign materials; environmental form and good design. The adoption of

these principles from the outset of a project can minimize the building's overall environmental impacts and maximize operational and maintenance savings. Each sustainability principle introduces an implementation approach that guides professionals to make smarter design decisions and seek synergies between natural systems and technologies. Table 4.1 highlighted the checklists for application of sustainable design principles for sustainable reuse of PHBs.

Table 4.1: Checklists for Application of Sustainable Design Principles for Energy Efficient Refurbishment of Heritage Buildings

Ranking 1= absolutely important 8 = equal importance	**Sustainable Design Dimension**	**Sustainable Design Principles**	**Active/ Passive Approach**	**Global improvemnet measures of energy efficiency to existing buildings**	**Applicability to Heritage Building(s)**	**Comments on various improvement measures in application to refurbishment of heritage building(s)**
1	Climatic and Site Environment	**Site and Orientation of Building**				
		a) Alignment of building to allow maximum sunshine for warmth and lighting (b) Consideration of overshadowing (c) Consideration of wind flow pattern (e) Consideration of temperature and humidity DTI (1999); Fisher (1992)	Passive	(i) High consideration for building facade orientation with significant window to wall area ratio. (ii) Avoidance of overshadowing (i.e. careful spacing of building) (iii)Protection from prevailing (northerly) wind	Not Applicable	Most vernacular buildings are already facing south to gain the benefits of sunshine and minimise the chill of northerly winds or planned around courtyards to optimise daylighting and natural ventilation
2	Building and Landscape Design	**Design**				
		(a) Layout, form and organisational structure of the design in relation to the site, region and the climate (b) Use of frequently occupied rooms positioned to south side of the building to take advantage of natural heating and lighting Fisher (1992); DTI (1999)	Passive	(i) Co-operation between various experts (ii) Use of innovative design tools for simulations, calculations and analyses (iii) Selection of best options according to results and criteria of experts involved	Applicable	Locating spaces in their ideal thermal location during the design development to take the advantage of the building's natural thermal responses will reduce dependence on active use of energy. However, a clear reasoned justification for the proposed design and works explaining why they are needed and why they are

Source: Study Author (2012)

Table 4.1(Contd): Checklists for Application of Sustainable Design Principles for Energy Efficient Refurbishment of Heritage Buildings

				(iv) Specifying materials and energy efficient components and systems (v) Design of renewable energy technology installation (vi) Selection of monitoring and BMS componets and systems		desirable in the context of listed building legislation and planning policy objectives will be required to secure planning approaval.
		Landscaping Considerations (c) Use of landscaping,effect of landscaping on the building.e.g. types and species of trees (DTI, 1999; MofEnv,2008			Applicable	Optimal application of vegetation can play a strong role in maximising energy efficiency during refurbishment.This can be achieved through proper planting of deciduos vegetation to provide shade in summer and allow sunshine in winter
3	Fabric of the Building (Construction Techniques and Materials	**Thermal Mass**				
		(a) Consideration of mass storage systems (MofEnv, 2008)	Passive	Intermittent heating strategies with varying occupancy levels	Applicable	Condensation problems arise with inadequate moisture control which can ultimately result in mould growth and damage to the fabric of the building.
		Glazing and Daylighting				
		(b) Sizing and positioning of windows to maximise heat gain and natural lighting when required (c) Selection of appropriate glazing types to control glare and solar gain (d) Consideration for thermal implication of	Passive	(i) Secondary glazing, (ii)Double glazing (iii) Triple glazin (iv) Daylighting technologies (Double and triple glazing can offer the extra benefits of an element of Noise	Applicable with the exception in the case of item (ii) & (iii)	Secondary glazing is permitted for heritage buildings. However, caution is required if the installation will be difficult to open, clean or remove. Double and triple glazing is often considered to result in significant change to the

Source: Study Author (2012)

Table 4.1(Contd): Checklists for Application of Sustainable Design Principles for Energy Efficient Refurbishment of Heritage Buildings

		daylight design (e) Selection of interior colour scheme for suitable daylight design DTI (1999)		insulation and greater internal comfort levels)		appearance of the building and irreversible loss of character hence, unlikely to be given consent for listed buildings.
		Solar Shading				
		(f) Assesment of potential areas of concern for glare and overheating (g) Selection of appropriate shading solution for each facade depending on orientation and site conditon (h) Incorporating shading with intended daylighting strategy DTI (1999)	Passive	(g & h) Window shading devices to reduce heat gain and solar controls	Applicable with the exception of items (g & h)	Can be very effective. However, its proper design is critical and the shading elements may have a strong visual impact on the exterior of the building.
		Insulation (Control of infilteration)				
		(i) Minimising heat loss from walls, roofs, windows, doors, and floor(s) DTI (1999)	Passive	(i)External wall insulation (ii)Internal wall insulation (iii)Floor insulation (iv)Making roof reflective (v)Draughtproofing of doors and windows	Applicable with the exception in the case of item (i)	External wall insulation is considered often incompatible with listed heritage buildings. Internal wall and floor insulation are practicable but making roof reflective is often prohibitive.

Source: Study Author (2012)

Table 4.1(Contd): Checklists for Application of Sustainable Design Principles for Energy Efficient Refurbishment of Heritage Buildings

		Ventilation				
		(j) Application of building form and orientation to explore high and low gain areas for ventilation purposes (k) Consideration of windows and vents (l) Ventilation design strategy to align with heating,cooling and shading strategies (m) Application of evaporative cooling and wind vanes (n) Use of ventilation and solar chimneys (o) Use of night cooling strategy DTI (1999)	Passive and Active	(i) Natural ventilation (ii) Installation of energy efficient ventilation (iii) Mechanical extract ventilation (iv) Mechanical ventilation with heat recovery	Applicable	Historic buildings usually need more ventilation than modern ones. In some cases, original ventilation strategies will have been poorly designed and inadequate for the healthy functioning of some of the buildings and will require additional means of ventilation to be added. However, Great care is required in selecting an appropriate ventilation strategies and rate during refurbishment of a historic building.
4	Indoor Comfort and Health	**Indoor Environment**				
		Application of the use of materials and building systems that do not emit toxic substances and gases into the interior atmosphere Fisher (1992); Lee and Tiong (2007); (Kibert, 2005); (WBDG Sustainable Commitee, 2006)	Passive	Range of building products such as paints,varnishes,wood preservatives,glues and adhesives, cleaning products and insulation materials .	Applicable	Materials orginally used in historic buildings emit little or no toxic substances and there are also a number of modern building materials that do not emit VOCs such as cellulose insulation and some new generation of paints that are compatible with heritage buildings.

Source: Study Author (2012)

Table 4.1(Contd): Checklists for Application of Sustainable Design Principles for Energy Efficient Refurbishment of Heritage Buildings

5	Building Services	**Building systems**				
		(a)Use of energy efficient appliances (b)Use of energy efficient heating sources (c) Methods and products of heating, cooling and lighting systems that conserve or eliminate energy use Lee and Tiong (2007); Fisher (1992)	Active	(i) Installation of energy efficient heating, cooling, control and hot water systems (ii) Installation of energy efficient lighting, appliances and control systems (iii) Optimizing pipe sizes (iv) Optimizing ducts (v) Upgrading pumps (vi)Upgrading of chillers	Applicable	This is unlikely to be a problem to listed buildings. However, extra care is required not to damage historic fabric when installing new pipework and cabling.
6	Building Facilities and Energy Management	**Operation and maintanance**				
		(a) Optimisation of operation and maintenace practices (b) Application of waste water management and reuse (c) Application of life cycle costing Lee and Tiong (2007); (Kibert, 2005); (WBDG Sustainable Commitee, 2006)	Passive	(i)Installation of building energy management system (BEMS) (ii) Implementation of efficient maintenance strategies (iii) Implementation of energy efficient policies and users awareness and training	Applicable	This unlikely to be a problem
7	Localized Renewable Energy	**Localized Renewable Energy**				
		Use of localized renewable energy sources Lee and	Active	(i) Installation of solar water heating	Applicable with some	Unlikely to be granted permission if the building is

Source: Study Author (2012)

Table 4.1(Contd): Checklists for Application of Sustainable Design Principles for Energy Efficient Refurbishment of Heritage Buildings

		Tiong (2007)		(ii) Installation of solar photo voltaic (iii) Installation of combined heat and power (micro) (iv) Installation of district heating and combined heat and power (v) Installation of ground source heating and cooling pumps (vi) Installation of air source heat pump (vii) Installation of micro wind turbines (viii) Use of biomass	special consideration	listed or in a conservation area, national park, area of outstanding natural beauty or world heritage site, unless it can be sited unobstructively and with minimal impact on listed buildings. However, the impact of ducts and associated infrastructure on the character and appearance of a listed building and its fabric will need to be given careful consideration and consultation with the Conservation Department.
8	Greening of Buildings	**Green building strategies**				
		(a)Exploring the use of green roofs (b)Exploring the use of green walls Lee and Tiong (2007)	Passive		Not applicable	Green roofs can be retrofitted to existing buildings. However, they generally require a flat or gently pitched roof so the number of historic properties to which they are applicable may be limited. With respect to listed buildings, there is also the need to ensure that the installation of the green roof will not involve loss of historic fabric and historic roof form

Source: Study Author (2012)

A close observation and reflection of the characteristics and checklists of sustainable design principles presented in Table 4.1 shows that the built heritage contains a large resource of knowledge on sustainable design principles and how architects of the past operated within the constraints and challenges of extreme climatic conditions. This is why several authors (Vale and Vale, 1991; 2000; Hyde, 2000; Hausladen *et al.*, 2005) argued that successful buildings of the future will increasingly need to rely on critical examination of, and learning from buildings of the past; to optimize buildings through the application of their passive design principles which has the potential to deliver energy savings of up to 80 per cent. This reflection shows that passive design principles can be found in heritage buildings from the pre-air conditioning period. And one of these fundamental principles is designing 'low tech'; an approach in which passive strategies are employed before active ones. Thus, while considering long term sustainable reuse of heritage buildings these sustainable design principles would need to be harnessed in order to be able to deliver a 21st century project with the most energy savings.

From the foregoing discussion, it could be concluded that if a holistic approach to sustainable reuse of public heritage building is required, sustainable design theory and principles is best suited for consideration as it takes into account a range of factors from material resources to community sensitivity. Ultimately, this factor defines the end goal of any high performance building that is ecologically responsible and minimizes the impact on the environment. Whilst, it might be argued that design alone may not be the only approach to solving all the issues of sustainability, however, the application of sustainable design principles to the built environment could bring it more in sync with other approaches.

4.5 Management Oriented Theories

4.5.1 Stakeholder theory

The stakeholder theory originated as a school of philosophical thought far back in the 60s in a number of disciplines with its elements, including: operational planning (Ansoff, 1965); organisational theory (Mintzberg 1983) and game theory (Aoki 1984) and has continued to develop over the years (Charron, 2007; Freeman, 1984). According to Merriam Webster's online dictionary (2007) the word stakeholder was originally used in law and was later transferred to several other fields such as management and economy, implying a person or company that is involved in a particular organization, project or system. In 1984, stakeholders' theory became prominent in the management literature when Freeman (1984) wrote Operational Management: Stakeholder Approach.

Since the writing of Freeman (1984), stakeholder theory has been popularised by several other authors such as Clarkson (1995); Donaldson and Preston (1995); Mitchell, Agle and Wood (1997); Rowley (1997); Key (1999); Sautter and Leisen (1999); Frooman (2002); Schwager (2004); Polonsky and Scott (2005) and Kolk and Pinkse (2006). In recent years, research based on stakeholder theory has continued to advance, Jones and Wicks (1999) categorised stakeholder theory based research in two divergent areas such as social science-based theory and ethics-based theory. The social science-based stakeholder theory deals with the instrumental and descriptive/empirical variants category, while the ethics-based theory of stakeholders concentrate on normative aspect. The social science based theory is also referred to as descriptive and instrumental stakeholder theory. Jones (1995) while describing this theory argues that the theory is used in describing actual

behaviour and/or rather contend that certain outcomes will be obtained if certain behaviours are adopted (Jones and Wicks, 1999, p.208).

The ethics-based stakeholder theory of normative-ethics point of view is different as it addresses normative issues such as moral obligations rather than the use of data collection and scientific methods to test hypotheses (Jones and Wicks, 1999, p.206-221). The above views on different categories of stakeholders dominate the primary focus of the present theories on stakeholders. Although, the author posits that neither of the theory category is absolute, however, they advanced a new stakeholder theory called convergent stakeholder theory.

The new stakeholder theory is a combination of social science-based and ethics-based theory which could both be described as "*normatively sound and practically viable with each version having well-defended normative core and supporting instrumental arguments to demonstrate its practicability*" (Jones and Wicks, 1999, p.206-221). This study argues that in respect of the theory in which stakeholder is based either divergent or convergent based perspectives, the most acceptable perspectives are taken from the views of Sutterfield *et al.* (2006) that stakeholders have a stake in the entity or task and their objectives are the same. Based on the argument put forward by the various authors, it could be observed that stakeholder theory proposes better collaboration in order to achieve mutual goals among stakeholders at most time. This argument is supported by Freeman (1984) who draws attention to the fact that the environmental turbulence of the early 1980s had overwhelmed managers. The author posits that the existing operational frameworks could neither resolve current difficulties, nor provide future, operational solutions.

According to Freeman (1984) managers needed to draw on a new theory to cope with the complexity in which solution could be obtained from better collaboration between organisations involved and the diverse groups or persons that interacted with it, whom he referred to as stakeholders. Following the development of stakeholder theory by Freeman (1984) the theory has continually advanced into different domains such as in economy and business management literature (Stoney and Winstanley 2001; Jones 1995; Donaldson and Preston 1995 and Clarkson 1995). Furthermore, stakeholder theory incorporated different theories and perspectives from organisational theory, systems theory, corporate social responsibility and planning.

The proponents of stakeholder theory also posit that an organisation that adopts a more inclusive approach towards the groups it interacted with could improve its performance and the society would benefit (Donaldson and Preston, 1995; Jones, 1995; Mitchell *et al.*, 1997; Rowley, 1997; Freeman and McVea, 2001; Frooman, 2002; Wolfe and Puttler, 2002; Carroll and Buchholtz, 2003; Kaler, 2003; Simmons, 2004; Steurer, 2006). Thus, by extension the management of heritage assets, the organisations involved, the myriads of groups of persons interacting with it, their perceptions and practices and decisions taken on these assets could better be perceived through the explanatory lens of stakeholder theory. The perception of heritage property management is built upon De Lopez (2001: p.48) explanations on stakeholder management, which consists an "understanding and predictions of behaviour and actions of the stakeholders and devising strategies to ethically and effectively deal with them".

4.5.2 Heritage management and stakeholder theory

Freeman (1984, p.46) identified a stakeholder as "*any group or individual who can affect or is affected by the achievement of the organisation's objectives*". Other writers such as Donaldson and Preston (1995) expanded this theory, arguing that to be identified as a stakeholder, the group or individual must have a legitimate interest in the organisation. Thus, the implication of this definition for heritage management reflects the perspectives of Throsby (1997, p.24) that stakeholders are "*those who assume or are charged with the responsibility of making decisions relating to particular heritage items or to cultural heritage matters more generally, such as heritage policy matters*".

Investigations on stakeholders' perceptions using the lens of stakeholder theory regarding energy use reduction in a heritage building projects, thus help in handling multiple perceptions regarding energy use of the buildings after the projects. The first issue is that heritage building project decisions are made by heritage industry professionals and policy makers. More often the decisions made by these stakeholders are perceived to be varied and conflicting on what could be acceptable for heritage projects. Another issue is that the decision making system is perceived to have competing interests within it. Thus, according to Healey (1998) there is the potential of avoiding major conflicts between stakeholder group (Figure 4.3) when they participate on issues of common interest as stakeholders.

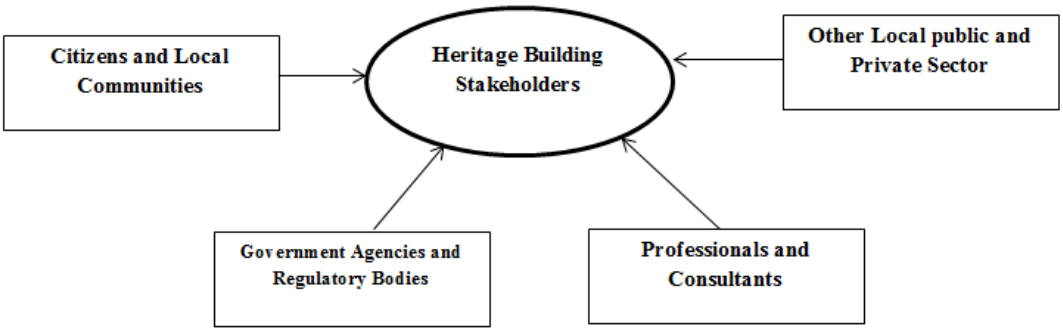


Figure 4.3: Specific groups of stakeholders in heritage building industry
Source: Study Author (2013)

This study holds the view that considering stakeholder perception on management issues relating to heritage properties, has the potential to help maintain balance between reuse of heritage properties in a sustainable way along side economics, social and environmental concerns associated with them. Thus, providing an adequate framework within which energy use reduction for sustainable reuse of heritage properties can be delivered. Additionally, several researchers (Fiorino, 1990; Simrell King and Feltey, 1998; Beierle, 1998; Steelman, 2001; Carmin *et al.* 2003) posits that adequate involvement and participation of stakeholders could lead to multiple outcomes based on the approach adopted and the stakeholders involved. Some of the outcomes suggested by the researchers include:

- The public will become educated and informed on the topics and issues concerned (Simrell King and Feltey, 1998; Beierle 1998);
- Values as perceived by the public and their opinions could become incorporated in the decision making process (Carmin *et al.* 2003; Beierle, 1998);
- Quality and improvement in decisions taken (Beierle, 1998; Fiorino, 1990);Potential of generating new ideas to discuss challenging issues (Carmin *et al.* 2003; Steelman, 2001; Fiorino, 1990)

- Effeciveness in cost process (Beierle, 1998)

Although, it might be argued that in order to achieve the above stated outcomes, not all stakeholders identified in the heritage building industry may be involved equally in the decision making process. However, it is important to include the interests of those primarily identified as stakeholders (Donaldson and Preston 1995). Hence, according to Clarkson (1995), the failure to include the interest of any primary stakeholder group may result in the failure of the outcome of the process. An analysis of 400 operational decisions examined by Nutt (2002) revealed that nearly half of the decisions 'failed' implying not implemented and/or probably partially implemented or rather they produced poor results. This is partly and probably due to decision makers failing to attend to the interests and information held by the key stakeholders.

Similarly, findings by other researchers (Bryson *et al.*, 1990; Bryson and Bromiley, 1993; Margerum, 2002; Burby, 2003) from their quantitative and qualitative approach also reported related results in line with the importance of paying attention to stakeholders. Thus, according to Bryson (2004, p.23) "*the inability to attend to the information and concerns from stakeholders could be described as a kind of flaw in thinking or action that too often and too predictably leads to poor performance, outright failure or even disaster*". Arguably, if primary stakeholders' perceptions and suggestions are well captured and given consideration in the decision process, holistic approach to energy management for sustainable reuse of public heritage buildings could be harnessed by utilizing the collective wisdom of all the stakeholders. Therefore, the adoption of the principles of sustainable development could become realized through the effectiveness of partnerships and practices among heritage stakeholders.

4.6 Value Theory

Generally, value theory covers a range of approaches to understanding how, why and to what degree people value things; whether the thing is a person, idea, object, or something else. Studies on value theory began in ancient philosophy where it is referred to as axiology or ethics. The early philosophical approach to value theory aims at understanding the subject of good and evil and the concept of "the good". Meanwhile, much of the theory of value today is scientifically empirical dealing with what people do value and attempting to understand why they value it in the context of psychology, sociology, and economics.

According to Bergström and Taylor (2006) value theory can be described as the philosophical study that characterised the basis of norms and valuations where the judgement of value is scrutinized from logical, semantic, ontological and epistemological aspects. It also involves a form of valuations like within meta-ethical, aesthetic, technical science, jurisprudence and theory of science. Value theory and its philososphy are differentiated from empiric research on valuations such as studies that deals with different individuals and ethnic groups. In the emprirical sciences, value theory is targeted towards the values that people actually have. On the other hand, in philosophy, it is rather directed towards what it consist and for whom it is real. This many-sided view of value theory has led to different perspectives in literature in identifying and discussing cultural value. Currently, the discussion on the meaning of value from the review of literature concentrates on the features of cultural goods perceived to be valuable. This has resulted in researchers (Scott, 2009; McMaster, 2008) and organisations engaging with the

question of cultural value as well as asserting what the values of culture are in terms of 'the qualities and characteristics seen in things' (Mason 2002, p.7).

According to Webster (1988) value is defined to be a measure of how strongly something is desired for its physical or moral beauty, usefulness and rarity which may be expressed in terms of money, effort and goods. What this implies is the willingness to expend in acquiring, retaining possession of, or preserving it. The above definition suggests that value has more substantial meaning and implication for preservation than its view in monetary terms. Thus, the most applicable meaning of value relevant to this study is the preserving part which apparently implies that there are other things that worth more than the money, time and efforts people invest and value in order to preserve it. In heritage terms, value according to Clark (2006) is a nucleus of all heritage practice; which justifies legal protection, funding or regulation. Kelly *et al.* (2002, p.4 cited in Clark, 2006) argued that in public value terms, something is only of value if citizens – either individually or collectively – are willing to give something up in return for it.

4.6.1 Economics theory of value

Literature differentiates between moral and natural goods. While studies on moral goods are those that have to do with the conduct of persons, natural goods, on the other hand, rather deals with objects. Proponents of theorists of moral goods include Marx (1990), Weber, Émile Durkheim, Talcott Parsons and Jurgen Habermas. While literature on ethics focus mainly on moral goods, economics on the other hand, has a concern with what is naturally and economically good for the society rather than an individual person. In ecological economics, value theory is divided into two types: Donor-

type value and receiver-type value. Ecological economists as perceived by Odum (1996) tend to believe that 'real wealth' needs a donor-determined value as a measure of what things were needed to make an item or generate a service.

A receiver-type value can be likened to what is called market value or what could be referred to as willingness to pay. This view is captured from neo-classical economics method adopted from accounting. According to Marx (1990) the 'Energy' concept could be considered to be donor-type value relevant to the field of philosophy, economics, sociology, psychology and environmental science. Arguably, the application of value theory is relevant to environmental sustainability. Meanwhile, other concepts suggest differences in the understanding of value differentiating them as intrinsic and instrumental value.

4.6.2 Intrinsic and instrumental value

Generally, intrinsic value can be conceptualised as a tangible object or an intangible relation, that possess a value in itself. For instance, culture could be perceived as something that enrich human life by intrinsic values. The opposite of intrinsic values is referred to as extrinsic or instrumental values where an entity or a tangible object become valued by the effects that it causes. These effects could either be intrinsically or instrumentally. Thus, anything having instrumental value has direct relation to other instrumentally valuable agents and to something of intrinsic value. Hewison and Holden (2006, p.14-16) described intrinsic and instrumental value as related to the concept of heritage. They developed a conceptual framework based on three different types of value,

namely: intrinsic, instrumental and institutional value.Their conceptual framework explains the differences in value with demonstration of how they are integral to the concept of heritage and the context from which they are articulated. This has been known and referred to as a cultural value. The advantage of the framework as expressed by the authors is that "*it can be employed to order a mass of different data from different sources*" (Hewison, 1987; Holden and Hewison, 2004; Hewison and Holden, 2006).

According to the authors, 'heritage generates three types of cultural value'. The first is the value of heritage in itself, its intrinsic value in terms of the individual's experience of heritage intellectually, emotionally and spiritually. The authors expressed that it is these values that people refer to when they say things like *'This tells me who I am', or 'This moves me' or quite simply 'This is beautiful'.* They argued that people will differ in their individual judgments, and because these values are experienced at the level of the individual, they are hard to quantify – yet we all know they exist. Jowell (2005 cited in Clark, 2006 p.14-16) earlier advanced this view by stating that

> *'Historic sites, objects, modern or historic architecture can move us in just the same way as literature, music and the fine arts well, but how they move us, and how far, is not yet part of the calculus of funding or service level agreements'.*

Another proposition put forward by Hewison and Holden (2006 p.14-16) is predicated on the premise of the other type of value they referred to as instrumental value. They posited that instrumental value is the ancillary effects of heritage where it is used to achieve a social or economic purpose. In taking their argument further, Hewison and Holden (2006 p.14-16) described the third value as institutional. The authors' explanations were

connected to what they suggested to be the processes and techniques that organisations adopt in how they work to create value for the public. According to the authors, institutional value flows from the organisations working practices and attitudes and is established on the idea of the public good. Hewison and Holden (2006) illustrated the three categories of value visually in a form of three angles of a triangle as shown in Figure 4.4. This is referred to as the Demos triangle of heritage values.

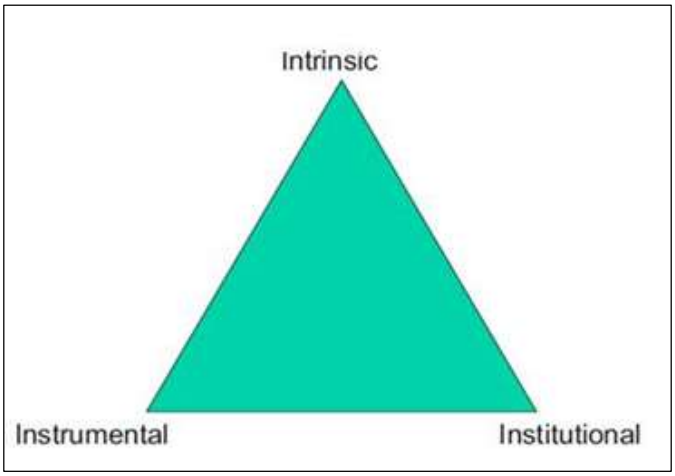


Figure 4.4: The Demos triangle of heritage values
Source: Hewison and Holden, 2006)

The authors further argued that cultural values are plural and their relative importance depend on individual perspective. In addition, they further proposed a conceptual model (Figure 4.5) based on the three sets of value illustrating those with three distinctive groups of people with an interest namely: politicians and policymakers, the professionals and the public. Other perspectives on cultural value could be understood from the perception of Throsby (2001) about a strong connection between economic value and the intrinsic culture value although with an attempt to separate them. On the other hand, O'Brien (2010) deconstructs cultural value into aesthetic, spiritual, social, historic, symbolic and authenticity, value, each of which contribute to a different facet of the overall value

subsisting in a cultural object, institution or experience. In recent times, Bakhshi and Throsby (2010, p.55) pointed out the connection between economic value and intrinsic value of culture indicating the essential role cultural value plays in determining the economic value most especially in regard to the quality of aesthetic experiences.

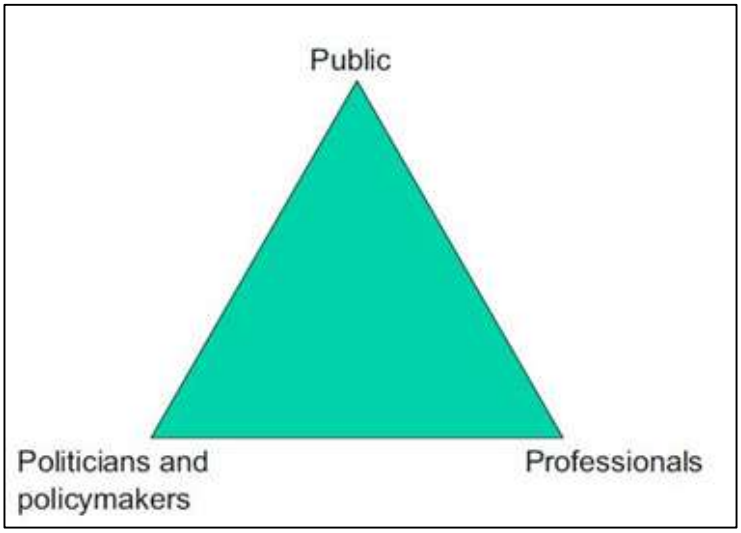


Figure 4.5: The Demos triangle of heritage stakeholders
Source: (After Hewison and Holden, 2006)

According to Hewison (2010), the view of Throsby (2010) on cultural value is closely related to that of Holden's (2006; 2004) intrinsic and institutional values, where the cultural value forms the basis for instrumental value. Parasuranam and Grewal (2000) suggest that the value is comprised of four different types, namely: acquisition value, transaction value, in-use value and redemption value. Parasuranam and Grewal (2000) defined in-use value as the utility that is possessed by using a good or a service while redemption value is considered to be a residual benefit received in the course of trade-in or rather precisely at the end of life (for products) or termination (for services). Meanwhile Holbrook (1999) perceived the consumer value to be compared. This implies the possibility of a product value is through the relationship it has to another. While it

could be viewed that both moral and natural goods are relevant to goodness and value theory, nonetheless, this study is centred on theory that focuses on natural goods which covers the field of cultural heritage in relation to value theory.

Cultural heritage can also be referred to as cultural goods which have several tangible (immovable and movable) and intangible values. One view, expressed by Throsby (1997) about cultural heritage is that it can be seen as a cultural capital not unlike other forms of capital, but with important differences which is possibly irreplaceable along with its social value that makes it likely to be higher than its market value. Thus, it might be argued that this irreplaceability of cultural heritage established them as a non-renewable resource a nation possesses, which demand careful and efficient value management to preserve them for future generations. Furthermore, Throsby (1997) extended his argument by drawing attention to cultural goods and their values as possessing aesthetic, sacred and spiritual values which by extension contribute to a community's 'cultural capital'. In this regard, Throsby said:

.....cultural capital can be seen, like the physical capital in which it is contained, to be subject to decay if neglected. Existing cultural capital can have its asset value enhanced by investment in its maintenance or improvement; new cultural capital can be created by new investment. If these interpretations are accepted, the social decision problem in regard to this type of cultural capital might be seen within the framework of social benefit-cost analysis, and approached by ranking projects according to their social rate of return (1997, p.15).

Klamer (2003, p.465) on the other hand advanced Throsby (1997) views by describing them to account for economic, cultural and social value. Since cultural heritage has several values with a broad meaning, the perspective on cultural heritage in this study

follows after the description of cultural heritage by UNESCO (1972) as physical historic built environment that includes, but not limited to monuments, groups of buildings, sites, installations and remains which possess outstanding values. Thus, it can be inferred from the proponents of theorists on the value that these outstanding values are aesthetic, historic, scientific, social and cultural preserved and transferred between generations because of their importance.

Cultural heritage could be viewed as national pride and identity of a nation. Thus, it might be argued that its social value supports the public perception of its educational values which are good for both personal and community development. Wood (2005) stresses this opinion further that peoples' lives are rooted in built heritage as it affects the area in which it is located, determines their lifestyles and dictates the structure of the built environment. In this study, the term 'cultural heritage' refers to historic buildings which may be used interchangeably within the study.

4.6.3 Sustainability and aspects of value

The principles of sustainable development have proven to be quite useful, influential robust and already been proposed as an ideal and guide to policy in the heritage field (English Heritage, 1997; US/ICOMOS, 2000). The principles are based on the notion of sustainability, which accords with the principles underlying values-based conservation planning. The principles adopt a holistic view of cultural resources and their contexts and aligns it with the goal of taking account of the widest range of heritage values. Sustainability principles also deal with the problem of making decisions in the present,

but essentially for longer term acknowledging the role of heritage as an inheritance to be passed on to future generations. However, the scope and perspectives on heritage values is all embracing to consider in a single study. Hence, identifying a set of relevant elements or aspects of values relevant to reusing religious heritage helps to keep this study in focus. Thus, the aspects of values considered are those related to the general dimensions of sustainability, such as ecological values, economic value and social value and/or cultural and historical value.

Kohler (1999) developed a theory which encapsulates the general aspects of sustainability in the built environment and relevant to the aspects of values embedded in heritage buildings, namely: ecological values comprising of embedded energy resource use of building; economic values with components of market value, running costs and revenues; social values which comprise functional values and cultural values which is subdivided into documentary values and experiential values. These values are conceptualised and graphically illustrated in Figure 4.6 based on Vitruvius' take on value and its elements.

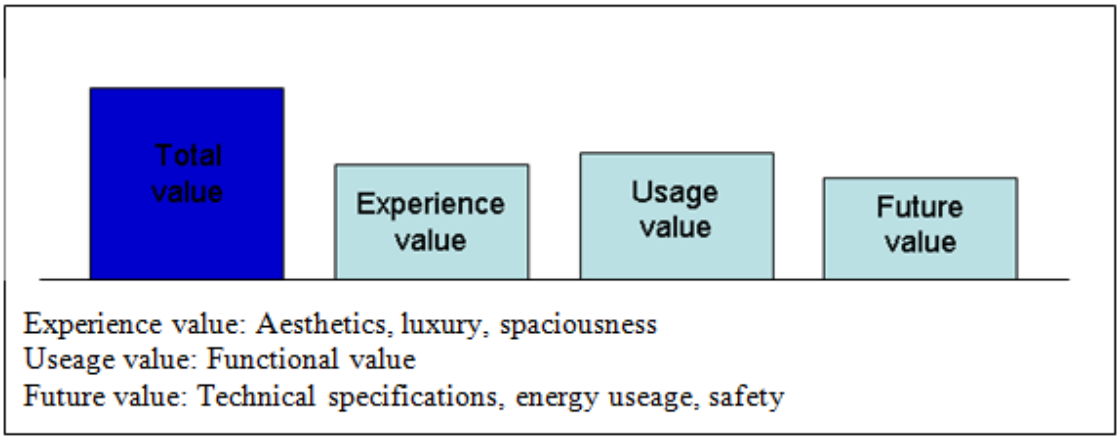


Figure 4.6: Elements of value (value aspects)
Source: Quick Scan Adapted from van der Kemp (2009)

A cursory observation of the model shown above evidenced that total value does not constitute the addition of its parts rather it is determined by partial values. However, it might be argued that the future value which partly constitute energy usage of the total value has been given low consideration and/or priority in most heritage projects. Hence, to achieve long term sustainable management for heritage buildings, the interplay of different categories of values should be one of the determining factors that should be taken into account. This theory is also supported by Kohler (1999) and suggests that a sustainable approach to the built heritage requires showing far-sighted consideration of all categories of value with the aim of seeking balance between them as well as understanding their mutual dependency rather than as isolated quantities. In order to understand the appropriate management to be given to heritage architecture, it is helpful to explore the values assigned to the built heritage heritage more closely.

4.6.4 Value theory and adaptive reuse of historic buildings

Kloch (2012) drew attention to the option value attached to historic buildings and argued that their continued existence provides numerous outcomes within the community. According to the author, the outcomes could be the knowledge and excitement that they have the option to visit these buildings if they want, at some time in the future. Furthermore, people in the community often have a heartwarming feeling towards historic buildings showing how their existence influences their thinking and the values they attach to them. These numerous outcomes are also transferred to the upcoming generations as they become part of the norms and sets of values which constitute part of the people's identity. Conservation projects involving re-use of historic buildings and more especially historic churches has become a complex issue because they are value-laden, although

with loads of possibilities for different functions when considered for reuse. According to Kloch (2012), the values that historic churches have formed the bases why conservation minded individuals perceives not only what they represent spiritually but what they represent to the built environment. However, when it comes to the question of their energy use reduction, the possibilities can be slim primarily because of their complexity, their value laden features and other factors such as location. As observed from the review of value theory, the issue of value is varied with perspectives from different authors on what should be taken into account when considering the value of heritage properties.

Whilst there are several values that make historic churches significant, it could be argued that their overall value could be enhanced if energy use reduction is adequately put into consideration when they are considered for reuse. The interest in the choice of this building type lies in their population in the UK constituting 45% of all Grade I listed buildings; they have different variety of reuse for community purposes and their present condition brings pressure for change and adaptation. Listed churches when considered for reuse more often than not are required to be upgraded. Meanwhile, the inability to modernise these buildings could result in the loss of their economic value. While efforts made to conserve them and other built heritage assets are commended, it could be detrimental to the buildings if nothing is done to ensure they are still able to achieve the same or even higher economic value as other buildings when they are converted to other uses. A view expressed by Araoz (2011) is that restrictions imposed on heritage buildings often make them less functional and competitive in the real estate market, because the economic and use value rest upon the ability of the building to serve their desired purpose apart from maintaining their fabric and material form.

A similar stance is taken by Grigg (1996) arguing that if there are no feasible alternative use to heritage buildings, their property value could be impacted if they are only viewed based on a partial value. This is reflected through heritage listing which the building possesses and not given consideration to its total value, which also include its future value. Although, it could be argued that the issue of heritage listing status affecting its property value is one which is complex and most often is property or location specific. However, the complexity and the difficulty of quantifying the value of historic buildings has also been acknowledged and discussed by Sayce (2009). When it comes to taking decisions on energy use reduction in reuse of historic churches, challenges arise on weighing the consideration between its varied values such as its cultural and historical value, economic value, and most importantly its future value in relation to its energy usage. The consideration of the values as afore mentioned should constitute the major determinants in any projects involving reuse of any listed churches in order to continually make it a living monument which generates income and not seen as a burden both the owners and to the environment.

Based on the perspective of value theory as discussed above, it could be perceived that both cultural and historical value aspects of historic churches summarize all soft values listed churches possesses, such as its architectural value, emotional value, spiritual value, identity value and historic value therefore surpasses or outweighed others. Hence, should be given considerable attention when they are considered for upgrading, refurbishment, reuse, and adaptation. When considering user's perception, these cultural and historical values are interpreted as the collective memory of a given community. Thus, the preservation of this collective memory is a reaction to some of the basic psychological needs of the users. One of the major considerations in conservation projects should be to

minimise the impact of any interventions that could lead to the loss of this memory. This is because historic churches do not just serve as the centre of community life; they also take a prominent place in the collective memory of the community and serves as symbols of their identity and heritage. The value aspects of historic churches are difficult to quantify because they matter to the community; personal to them and helps them to achieve economic, cultural and social values (McDonald, 2006). Therefore, there is a need for adequate communication, interaction and agreement among stakeholders involved in the conversion of these buildings to deal with issues that affects its sustainable reuse.

In summary, the theoretical framework for this study consists of two phased theoretical perspectives, namely: technical and management based theory. The main theoretical perspective is based on systems theory which serves as a logical foundation and is used as an integrating theory for other supplemental theories under which different phenomena identified from the literature can be organized into a reasoned whole. Figure 4.7 shows how the theoretical perspectives are integrated to develop the conceptual framework for this study. The characteristics of systems theory coupled with its focus on the nature of its subjectivity are the primary reasons why it provides the theoretical foundation for this study. Thus, the integration of the foundational theory and the supplemental theories informed the development of the conceptual framework and consequently, provided the foundations for the mixed-methodological design explored in Chapter 5.

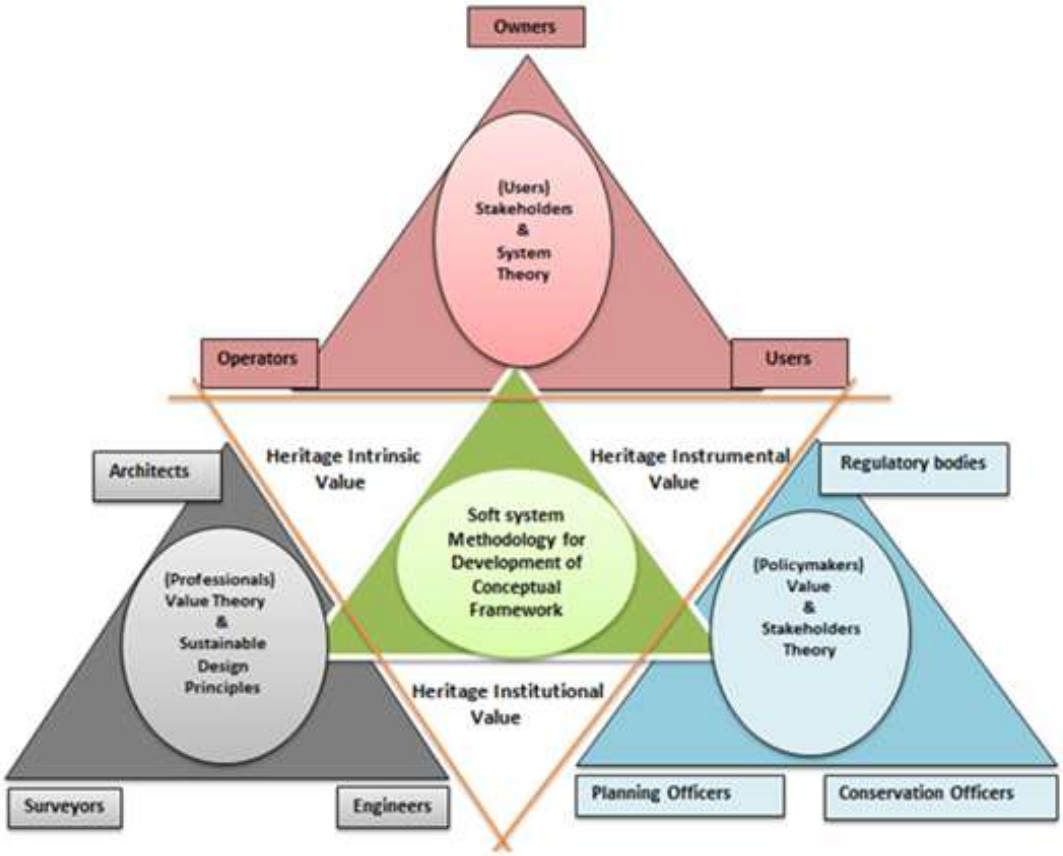


Figure 4.7: Integration of theoretical perspectives leading to the conceptual framework
Source: Study Author (2013)

4.7 Conceptual Framework for the Study

It is difficult to think comprehensively about how energy use can be more effectively managed in reuse of LCBs to improve their performance when the literature on the subject is rather thin and the few studies available have focused mainly on domestic heritage. The task of understanding the issues, operations and performance of LCB's problems is particularly daunting given the amount of diverse literature on heritage buildings. In addition, most of the literature and projects tend to focus either on thermal performance investigating U-values or technical performance (STBA, 2012; Gorse and Highfield, 2009). Neglecting how the operational performance could be improved for sustainable

project delivery has therefore led to a disconnection between theory and practice. Thus, the gap that exists on the question of how energy could be managed in PHBs informed the choice of reuse of listed churches - a population of heritage building types selected for research. The goal of this research is to investigate critical factors influencing energy use in the reuse of LCBs with special attention to stakeholders' perception, practices and strategies of design professionals and building operational performance. To achieve this, a conceptual framework no matter how simple and basic is necessary to aid the research design and strategy needed for the study.

Miles and Huberman (1994, p.18) stated that "*conceptual framework explains either graphically or in narrative form the main things to be studied (i.e. The key concepts, constructs or variables and the presumed relationships among them)*". According to Rapoport (1985, p.256) there are differences between conceptual frameworks, models and theories. He argued that conceptual frameworks are neither models nor theories, instead they "*help to think about phenomena, to order material, reveal patterns while the pattern recognition typically leads to models and theories*". Polit and Hungler (1995, p.101) take this view further by stating that "*frameworks are efficient mechanisms for drawing together and summarizing accumulated facts*". In investigating energy use in the reuse of LCBs, a conceptual framework helps to provide guidance for investigating the perceptions, the practices as well as the operational performance of the existing buildings.

The conceptual framework for this study was developed based on the steps outlined and proposed by Checkland (1981) and Checkland and Scholes (1990) on soft systems

methodology (SSM) and after the protocol suggested by Creswell (1994, p.82). The rationale is to identify the likely important variables relevant to the problem and to organize the constructs such as dependent and independent variables, processes, and boundaries to be investigated in the study. This approach incorporates systems ideas and concepts from other fields of anthropology, urban planning and systems engineering as discussed above. Using the SSM approach thus assisted the researcher to approach and manage the subject by reducing the vagueness or the complexity of the subject to a set of simple questions.

In addition, as suggested by Sharp and McDermott (2000, p.33), the SSM approach also provided the guidance needed to provide visual representation of theoretical constructs (and variables) of interest, organise the study, giving direction to the researcher towards inclusion and openness to what data to collect, maintain focus during interviews, ensure coverage of important aspects of the topic as well as facilitates understanding of the study's findings for practitioners and researchers. Establishing this current study's structure upon this evidence, three dominant concepts which are key inputs in the development of the conceptual framework are briefly reviewed and presented in the following sections.

4.8 Explanations of Basic Concepts in the Conceptual Framework

4.8.1 Concept of perception

One of the basis for the concept of perception in the conceptual framework is centered around a key aim of this current study - to investigate heritage industry stakeholders perception of energy use reduction in reuse of PHBs. The heritage industry consists of

diverse stakeholder beginning from properties belonging to person(s) to voluntary and public sector organisations concern and involve with heritage building projects. This current study focuses on stakeholders' perception who could also be referred to as " key influencers" as a result of being involved in project development that relate to heritage buildings.

From the review of stakeholder theory, it was concluded that the support of key stakeholders was essential for any heritage building project to be successful (Project Management Institute, 2004; Post *et al.*, 2002 and Pinto, 2000). This formed the basis for investigating what the stakeholders perceived to be the most sustainable approach to energy use reduction in heritage building projects. Similarly, from systems theory perspectives, soft systems methodology's approach is participatory in nature by which socially based issues can best be approached to bring about significant solutions simply on the condition that persons, mainly liable for the outcome contribute in seeking the solution and decide on how it could be put into operation. Likewise, in SSM, people's involvement is also very significant, therefore, solutions have to unavoidably incorporate and originate through them. Thus, systems investigation provides a sufficient range of theoretical tools for the study of perception.

The procedure to generate meaning that has to do with perception, explanation, conceptualization, expression, consideration, clarification and communication may be tackled through the multiplicity of systems perspectives as already discussed. In this present study, the researcher considered it appropriate to concentrate on cognitive aspect.

This is to show how systems theoretic tools (characterized by the concept of individual and collective cognitive aspect) can assist in the exploration of linkage between perception and individual tendencies. Hence, a concise overview of few definitions of the concept of perception is presented. Schiffman *et al.,* (2001, p.148) defined perception as the " process by which an individual receives, selects and interprets stimuli to form a meaningful and coherent picture of the world". Meanwhile, in service organisation's literature, perceptions are regarded as the judgement of the service organisation's performance. For the purpose of this current study, perception is considered to be the interpretations and the judgement and/or appraisal of the heritage industry stakeholders regarding energy use reduction and strategies for improving its energy performance for sustainable reuse.

According to Merleau-Ponty (1964), all perceptions occur in a certain landscape of a person's mind which could be regarded as mental landscape. Thus, it could be argued that every individual perception is based upon the person's position in life socially, emotionally, mentally etc. Thus, as positions in life changes so do perception changes. Therefore, through perception people are able to prioritise their values and can understand the limitations of objectivity. Following this line of argument, it might be concluded that stakeholders' perception is an essential construct which could be a critical influencing factor in considering energy use reduction for sustainable reuse of heritage buildings (Figure 4.8). Consequently, the stakeholders' perception is considered as a major determining factor in designing and developing strategies for the operational energy management framework to improve energy performance in the reuse of LCBs.

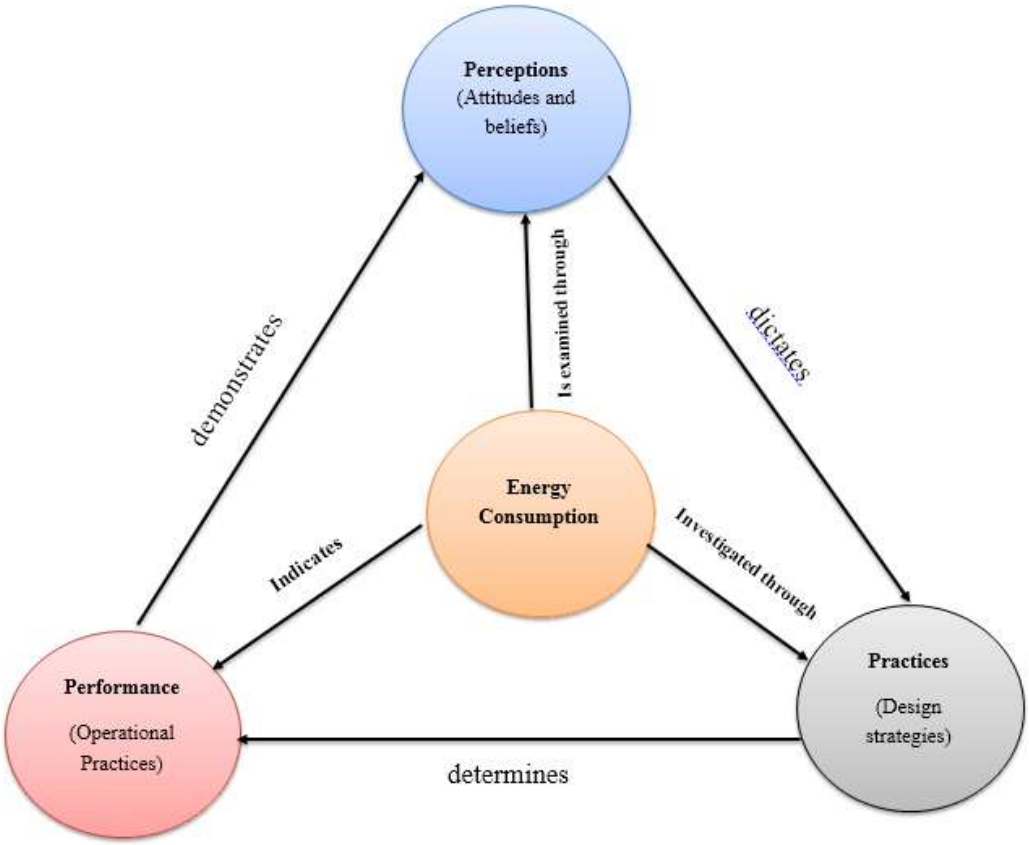


Figure 4.8: Conceptual process for investigation energy use in LCBs
Source Study Author (2014)

4.8.2 Concept of practice

The concept of practice in this study is considered and viewed in the context of 'Best Practice' as defined by Brannan (2008). Best Practice is considered to be a means of adopting a practice or policy generally accepted among some practitioners of what a 'state of the art' is. In this study, it is used in the form of a tool to 'benchmark' a particular practice among heritage building professionals against other practices in the delivery of sustainable reuse projects. The best practice concept is investigated with the view that it could generate new ideas to improve energy performance of other heritage building projects. The rationale behind the investigation is that heritage building operators, owners, and practitioners looking for solutions to the problems of energy use can utilize

the strategies and lessons learned from other buildings surveyed with better energy performance. As such, they can develop strategies to reduce their energy consumption, the operating cost of running their building and efforts required to develop solutions to the reduction of CO_2 emissions from their building by learning from the experiences and strategies of others.

In the context of this study, the concept of Best Practice is primarily motivated by the researchers' search to improve energy performance in the reuse of LCB project delivery and outcomes. In other contexts, the concept is situated within the realm of performance management (Brannan, 2008). This stance is taken from the identification of a virtuous cycle of Best Practice by Newman *et al.*, (2000) in which innovation is stimulated, identified and distributed, resulting in considerable improvement. Thus, part of the objective of this study is to examine the effectiveness of current practice of the stakeholders in delivering of reuse of LCB projects along with its relationship with the operational performance of the existing projects (Figure 4.8). To achieve this, the researcher surveyed and investigated a considerable number of existing reused of listed church projects with the hope to address some of the gaps identified in the literature.

4.8.3 Concept of performance

According to Foliente and Tucker (2004), assessing the performance of any building could be carried out in diverse phase of its life cycle. This could be during planning and design, at construction stage, while commissioning, and in the course of building occupancy or use. The authors posit that assessing performance may be indirect or by

direct measurements which could be carried out for the purpose of checking whether the indicators of performance meet up with targets for performance determined ahead of time. Alternatively, the performance of a building could be determined for the purpose of understanding the performance to which comparison of current and future improvement could be made. Further aim could also result from comparing a particular building performance either proposed or already in use to other similar type and size (Foliente and Tucker, 2004).

Foliente and Tucker (2004), opines that actually in use performance is especially important as the outcomes and significance is actual while it also helps to confirm (or not) design or refurbishment goal contributing to knowledge and consequently improving future practice. In this present study, the concept of performance is investigated from the view of actual in-service performance (during occupancy) of existing reuse of LCBs (Figure 4.8) in order to establish their actual performance level and their impact on the environment. This is hoped to contribute to improving the decision involving any refurbishment/reuse design, choice of materials and adoption of appropriate technologies in heritage projects and consequently avoid leading to costly and/or adverse impacts on heritage buildings and the environment.

Furthermore, the knowledge of current heritage building energy performance could also benefit the owners, facility managers and tenants in identifying areas where operational energy savings could be made. In considering the above discussed concepts, critical factors influencing energy use in LCB projects as identified from the literature can be

explored and made more explicit. Thus, the conceptual framework developed and presented in Figure 4.9 nonetheless constitutes an attempt from a systems perspective. It is proposed that critical factors influencing energy use in LCB projects can be viewed from three perspectives: the stakeholders' analysis stream, the professional analysis stream and the existing heritage building projects operational based analysis stream.

As shown in Figure 4.9 these three perspectives will interact, each informing and giving feedback to each other. Meanwhile, the stakeholder perceptions and the professional practices analysis stream will put into consideration the social and cultural context of the problem situation. The conceptual framework was developed based on the research problem, the questions arising from the problem, and the basic assumptions of the study. The relationships between issues identified are conceptualised in Figure 4.9 which shows priorities and value of the stakeholders and building operational practices. They are categorised into the building use pattern; plant efficiency; operation and maintenance; micro regeneration technologies etc.

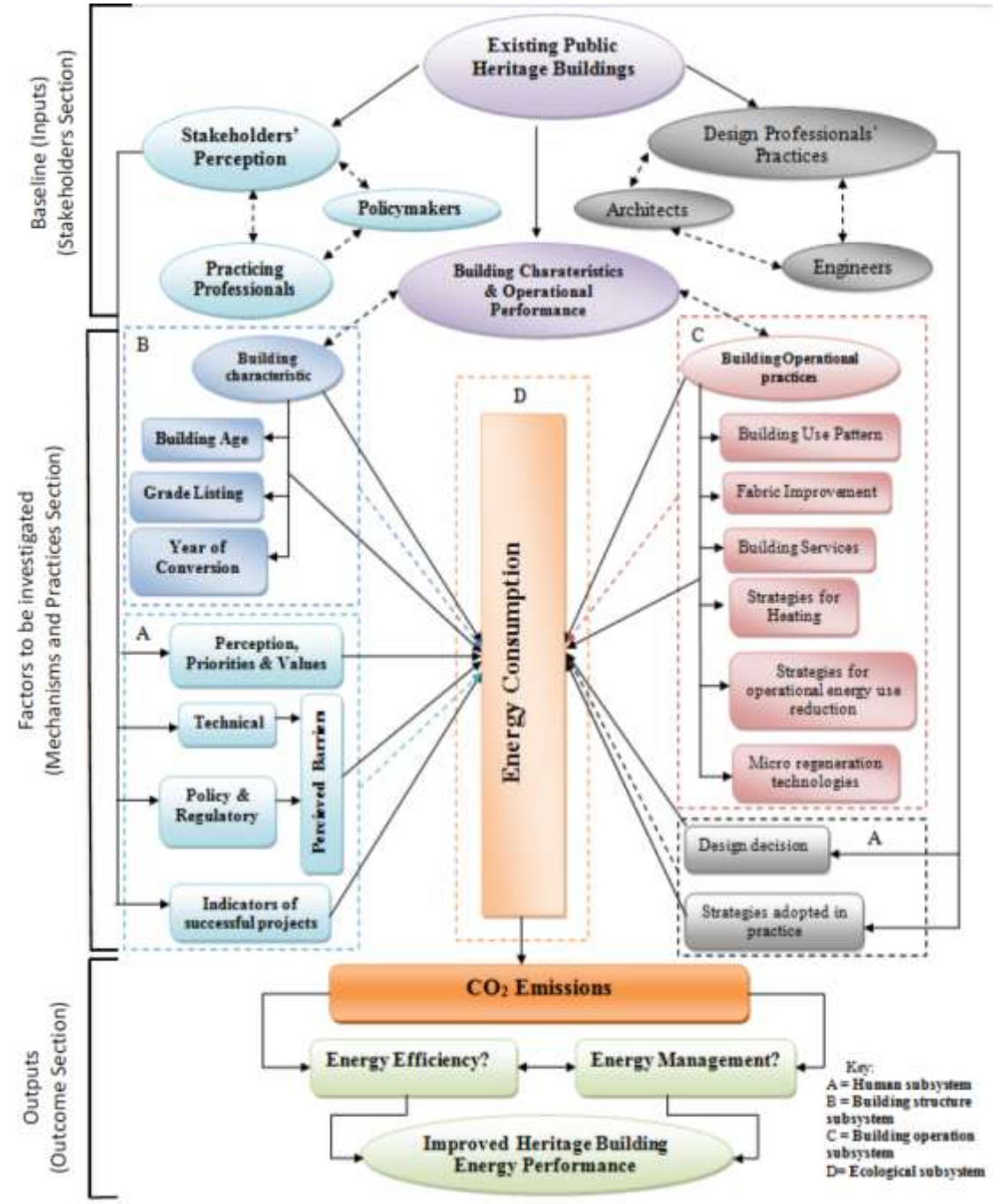


Figure 4.9: Conceptual framework developed for this current study

These are possible influencing factors impacting on heritage building energy consumption. This provides a methodology based on mixed method approach (Figure 4.10) to investigate and examine these issues.

Figure 4.10: Rationale for research methods derived from the conceptual framework
Source: Study Author (2013)

The basic assumption of this study is that energy use in reuse of heritage buildings can originate from three possible ways; the professionals' priorities; conservation practices and the operational practices of building itself. These are referred to as subsystems to be investigated in the study (Table 4.2). As observed from the conceptual framework the identification of the critical factors arising from these assumptions could result in the emergence or non-emergence of energy efficient or energy management strategies as a more effective approach to managing energy use in public heritage buildings. Thus, the development of an operational energy management framework to address these factors could improve the building operational energy performance; consequently benefiting the building owner, occupier and the society due to less resource depletion and lower CO_2 emissions.

4.9 Chapter Summary and Conclusion

The outcome of this chapter has further enhanced the understanding of the importance of values attached to heritage buildings. Churches in particular are laden with diverse cultural and historic values; summarized and referred to as 'soft values' because of emotional attachment people have for them. For instance, historic churches are more than symbols of faith but reminders of the history of people who gave their funds and provided their labour; built these monuments to reflect their culture, heritage and religious freedom which makes these buildings very significant. However, due to the challenges of climate change, environmental sustainability, which constitutes part of their ecological value and their refurbishment, requires attention with a balance of approach.

In this chapter, historic churches have been understood as a system possessing soft values; thus requires soft systems methodology (i.e. A non-intrusive and minimum intervention approach) to investigate them. By using four theoretical perspectives in this chapter, a better understanding of the problems contributing to energy use in LCBs was gained. The theoretical combination serves to discover the complexities involved with the issues of energy use in heritage buildings and conservation. Similarly, other considerations are involved in order to utilize many approaches to resolve the research problem. The gaps identified in the review of literature evidenced that little or no effort have successfully addressed these problems. As a result of this, soft systems methodology based on soft systems theory is considered appropriate to encapsulate the complexities involved. This theory provides the rationale and support for adopting other theories such as value theory, stakeholder theory and sustainable design principles which are seen as an important choice to tackling the problem. Thus, a conceptual framework has been developed to

guide the study and as the basis for analysis. The dominant concepts surrounding the conceptual framework were discussed. The following chapter presents the research design and the method employed in this study.

Table 4.2: Identification of subsystems and analytical framework for data collection

Subsystems	Data to be collected	Instrument of data collection	Mode of data collection
A. Human subsystem			
Key stakeholders	• Perception, priorities and values • Percieved barriers • Indicators of successful projects	Structured questionnaire	Stakeholders' virtual (online) environment
Design professional practices	• Design decision • Strategies adopted in practice	Interview	Designers (real) environment
B. Building structure subsystem			
Building structure (envelope) subsystem	• Building age • Building size • Building conversion year • Grade listing • Architectural style	Semi structured questionnaire	Buildings (physical) enviroment
C. Building operation subsystem			
Building operation subsystem	• Activity/function • Intensity of use • Building services (heating and lighting system) • Strategies for operational energy use • Operations and maitenance • Renewable technologies	Semi structured questionnaire	Buildings (physical) enviroment
D. Ecological subsystem			
Building energy use subsystem	• Energy consumption data	Semi structured questionnaire	Energy bills/invoice

PART B: METHODOLOGIES AND ANALYSES

CHAPTER 5: METHODOLOGY AND RESEARCH PROCEDURE

5.0 CHAPTER OBJECTIVES

- To present research paradigm and philosophical orientation of this study.
- To review relevant methods of research applicable to this present study.
- To develop and present the research design to guide this study.

5.1 Research Paradigm

Paradigms refer to a worldview that guides decision-making. It originates from the Greek word paradeigma which means pattern. The term paradigm was initially employed and popularized by Kuhn (1962) to connote a conceptual framework with mutual acceptance by the scientific community, providing them with a suitable model for investigating problems and seeking for ways to solve them. The author's definition of a paradigm is presented as a unified cluster of definite concepts, variables and problems linked to similar methodological approaches and tools. He refers to the term paradigm as a culture of research comprising a group of values, assumptions and beliefs that people conducting research share in common. Paradigm is basically philosophical in nature and according to Greene and Caracelli (1997); it is all encompassing of one's perspective regarding the reality and sources of knowledge.

A paradigm could be described by its ontological, epistemological, and axiological stand. Hence, the paradigm of the researcher dictates the type of research questions he uses, the method of getting and interpreting information. Architecture research in the built environment is grounded in social science and this association brings with it several

established research paradigms. When employed in a study, it influences the methods, strategies and the resulting interpretations. Furthermore, each paradigm has wider implications for the study as well as the resources required. Therefore, this necessitates some justification as regards the choice of research paradigm considered for this study. Guba and Lincoln (1994) also give primacy to paradigm over methodology, and define it as a world view guiding the researcher, not only in the choice of method but in ontologically and epistemologically ways. The ontology and epistemology parts are concerned with what is referred as an individual's world view having a notable effect on the perceived relative importance of the aspect of reality.

In the field of human sciences, there are many competing paradigms identified. Identifying of the main paradigms differs from one researcher to another. Researchers have categorised this in many ways; Guba (1990); Guba and Lincoln (1994) categorised the options into constructivism, positivism, postpositivism and critical theory. While, Smith (1993) had the options divided into interpretivism empiricism, critical theory and postempiricism. According to Willis *et al.* (2007, p.8) in human sciences, the three most common paradigms employed as the guiding framework are interpretivism, critical theory and postpositivism. Whilst critical theory and postpositivism have some aspects that are overlapping, ontological realism (in its different forms), interpretivism and critical theory share some common areas as well.

The present research study adopted the explanation of paradigm classification as posited by Guba (1990), Guba and Lincoln (1994) and Willis *et al.* (2007, p.8). The Encyclopaedia Britannica (2008) defines positivism in philosophy as a system that confines itself to the data of experience and rules out metaphysical speculations or a

priori. The main affirmations of positivism are that all knowledge pertaining to the matter of fact is grounded on the "positive" data of experience (i.e "Mirror" reality); and that beyond the realm of fact is only that of pure mathematics and pure logic. The positivist paradigm, therefore, places importance on the precise measurement of phenomena. Basically, within the coverage of this study, it is not likely that all measurements can be possible, especially as regards the determination of U-values of heritage buildings, due to the exploratory nature of this research study.

The post-positivist paradigm also depends on a tendency to measure by asserting that truth may be discovered and that it is understood best by deductive reasoning, objectivity, standardization and control within the research process (Yu, 2006). The major concern of post-positivist research methods or techniques are causality and is established by research design, statistical hypothesis testing, and earnestly assessing alternative likely explanation for research findings. The advantages of post-positivist research are its reliability, precision, generalizability and replicability. Post-positivist research concentrates on addressing causality in research questions and is generally considered to be suitable for confirmatory research study (Shadish et al., 2002). This paradigm is considered not suitable for this present research because it does not aim to develop new relationships or seek to challenge the prior causative theory.

The interpretivist paradigm is arguably well suited to the social sciences therefore, it was considered suitable for this study. Basically, in its most extreme form, it contends that reality is constructed and that no universal truth exists. Generally, interpretivism asserts that multiple truths exist, as determined by individuals' unique perspectives on the world. This paradigm, thus help to illuminate the individuals' perspectives and experiences. In

consequence, it has less stringent claims of causation. The strengths of interpretive research include a strong understanding of context, rich detail, and flexibility in addressing emerging issues. Therefore, it is generally considered to be very suitable for exploratory research. The limitation of employing an interpretive approach in research is the cost of being able to generalise the findings of the research beyond the scope of the study. This inability to generalise the findings of the research does not necessarily affect the overall value of the study, as the selected buildings for investigation is representative of the sample frame used. In conducting research, two possible worldviews exists which include objectivity and constructivist ways of seeing the world. These views may be appropriate for some purposes and inadequate for other purposes. However, this study makes use of the elements from both views and consider them to be complementing each other, as explained in the following sections.

5.2 Philosophical Assumption

All research is based on certain underlying philosophical assumptions about what constitutes 'valid' research and what research technique or method is appropriate and adequate for the development of knowledge in a particular research study. Therefore, certain philosophical perspectives in a research may be based on one or more paradigm, depending on the nature of the research. The key philosophical assumption underlying this study as discussed earlier, come mainly from interpretivism. Nonetheless, the study also draws upon other perspectives such as postpositivism (a modified Objectivist stance) and critical postmodernism (a perspective that supports different world views such as constructivist philosophies that often uses interpretivist methods).

Interpretive approaches were chosen in this research as the main philosophical stance because it gives the researcher a greater scope to address issues that influence energy consumption in heritage buildings. In the ontological position, the quantitative research views reality as objective and independent of the researcher, measurement of things are carried out objectively by means of a questionnaire or an instrument. In qualitative research, reality is viewed as that constructed by the persons involved in the research situation. In terms of epistemology, the qualitative researcher requires to take into consideration their own subjectivity, the nature of the individuals being investigated and the reader. Conclusively, the researcher basically interacts with the researched; thus, the study can be referred to be value-laden.

This study employs mixed-method which combines the use of quantitative and qualitative data collection tools to address the key issues in the research. In the literature, two main paradigms that are recognised for conducting a research are qualitative and quantitative in nature (Creswell, 1994). The quantitative method is associated to the positivist, the traditional, the experimental, or the empiricist paradigm. Whereas, the qualitative paradigm is classified into 'the constructivist approach, the naturalistic' (Lincoln and Guba, 1985) and the interpretative (Smith, 1993).

5.3 Methodology

Creswell (1998) defines methodology as 'the analysis of the principles of methods, rules and postulates used by a discipline' or 'the development of methods, to be applied within a particular discipline'. The methodology of the research is to be determined by the

purpose or aim of the research study. The literature on methodology attributes the method of study to the paradigm that determines the approach of the research study. Basically, the quantitative method is related to the positivist or empiricist paradigm whereas, the qualitative method relates to post-positivist or post-modem perspectives. Lee (1991, p.350) observed that "The positivist approach makes the claim that its methods are the only truly scientific ones, on the other hand, the interpretive approach makes the opposing claim that studying people and their establishments demand methods that are altogether alien to those of natural science. Thus, it could be argued that the positivist and interpretive approaches would appear to be in opposition. Jick (1983) observes a distinct tradition in the literature on social science research methods, advocating the use of several methods. However, this type of research strategy has been depicted as multi-methods or multi-trait (Campbell and Fiske, 1959), convergent validation, or triangulation (Webb *et al.*, 1966). There is the general idea that qualitative and quantitative research methods should be considered complementary to each other.

Jick (1983) indicates the need to mix methods given the strength and weakness found in single method designs. Through the application of multiple methods the robustness of research results can be increased and findings can be established through cross-validation when different types and sources of data converge and are found to be congruent or when proper explanation is given to account for divergence (Kaplan and Duchon, 1988: 575). Some authors contend that research belongs to one of the two paradigms, themselves based on a philosophical position. Niglas (1999, cited in Greene and Caracelli, 2003) argued that it is not the philosophical position that determines the methodology of a research but that it is the needs of a specific research problem.

It is not a fast rule to choose or select the research techniques or methods. Thus, employing each research method relies on the research objectives, the type of research question and contextual situation (Yin, 1994). In view of the above rationale for the selection of the most suitable research methods, the selection of research methods for this study mostly depends on the goals of the stated research objectives which thereby informed the kind of data to be collected for the study. Thus, due to the nature of the broad scope of the research study as well as the context of the research, a wide range of research techniques was adopted to achieve the research aim and objectives.

5.4 Research Design

To address the research aim and objectives, this study employed a mixed method approach (Tashakkori and Teddlie, 2003; Creswell and Plano Clark, 2010). Johnson and Onwuebuzie (2004) refers to mixed methods research as the class of research where the researcher combines quantitative and qualitative research methods, approaches, techniques, concepts or language into a single research study. The authors further described the method as an attempt to legitimate the use of multiple approaches in answering research questions, instead of restricting researchers' choices. The rationale for adopting mix-method is because this study involves or deals with controversial and complex issues about energy efficiency in heritage buildings, and either quantitative or qualitative research methods are sufficient by themselves to cover the trends and details required for the study. In addition to this, no research has specifically answered the research questions asked in this present study.

In general, the purpose of using a mixed method research methodology in this study was to use different data collection and analysis procedures in finding answers to the different research questions raised. That is, the research questions was approached by different data collection methods and procedures comprising of both quantitative and qualitative procedures for the purpose of collecting enough data which can be compared, combined or integrated to develop a deeper understanding of the problem under investigation. Thus, by giving equal weight to both quantitative and qualitative evidence sought to address the research problem in this study, the findings from the study could help to construct a holistic understanding of the phenomenon by synthesizing the inductive and deductive data obtained in the epistemological process. Figure 5.1 shows the visual model and sequence of mixed methods research approach use for this study.

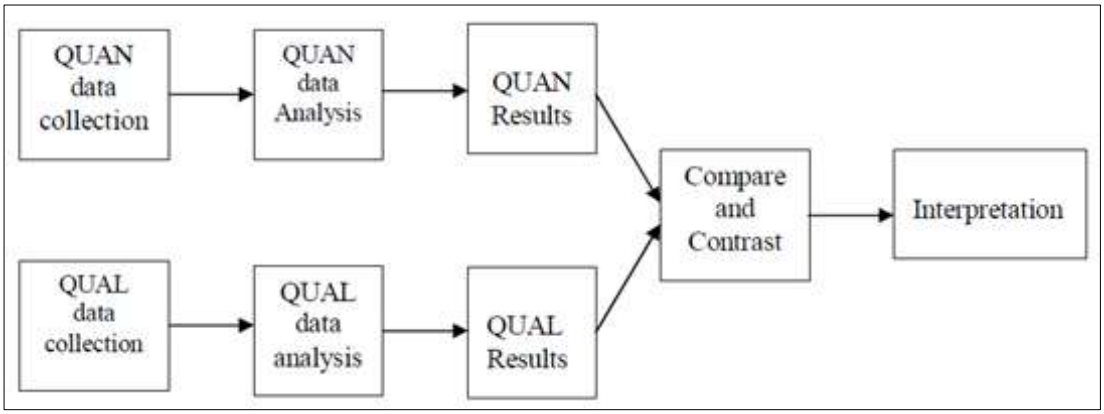


Figure 5.1: Model of sequence of mixed methods research approach
Source: Creswell (2009)

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By adopting this approach, the outcome of both data sets could act as a check against overstating the case for conclusions derived from either approach alone. Therefore, the data collection in this study involves gathering both numeric and text information so that

both quantitative and qualitative information are represented in the final database (Creswell, 2002 p.18-19). The research design adopted for this study is the triangulation method**.** The aim of employing the triangulation method is to enhance the reliability and validity of the research findings. The mixed method design used in this study, therefore, involves the separate collection and analysis of the two sets of data: quantitative and qualitative data. Thus, by using quantitative and qualitative methods in combination, the study sought to provide an in-depth understanding of the research topic than could be achieved if only one of the methods was used (Morse, 2005; Creswell and Plano Clark, 2007). Figure 5.2 shows the research design as applied in this present study.

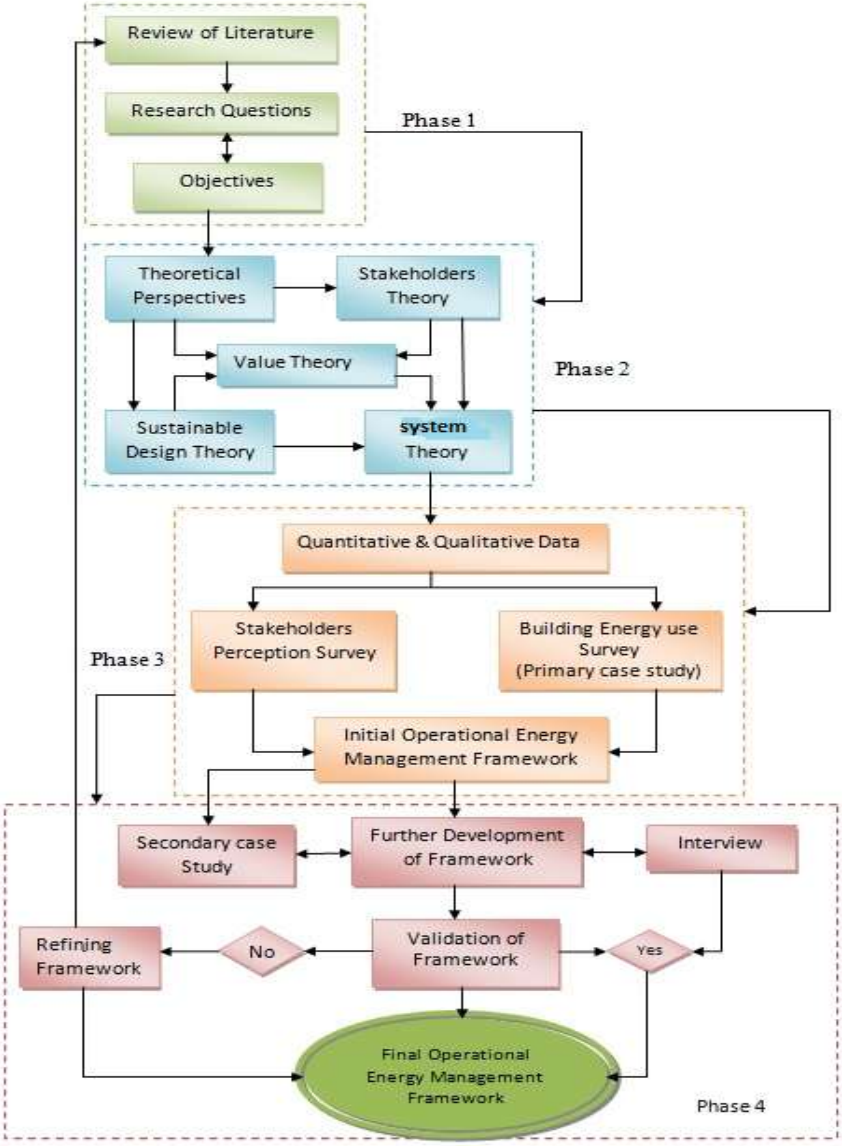


Figure 5.2: Research design developed for this study

The mixing of quantitative and qualitative methods in this study, therefore, demonstrates how the context and in-depth nature of qualitative findings can be used to complement the representativeness and generalizability of quantitative findings (Greene and Caracelli, 2003). Thus, when quantitative and qualitative methods are used in combination, they complement each other and allow for more complete analysis (Green *et al.*, 1989; Tashakkori and Teddlie, 1998). Figure 5.3 shows the methodological framework developed for this study.

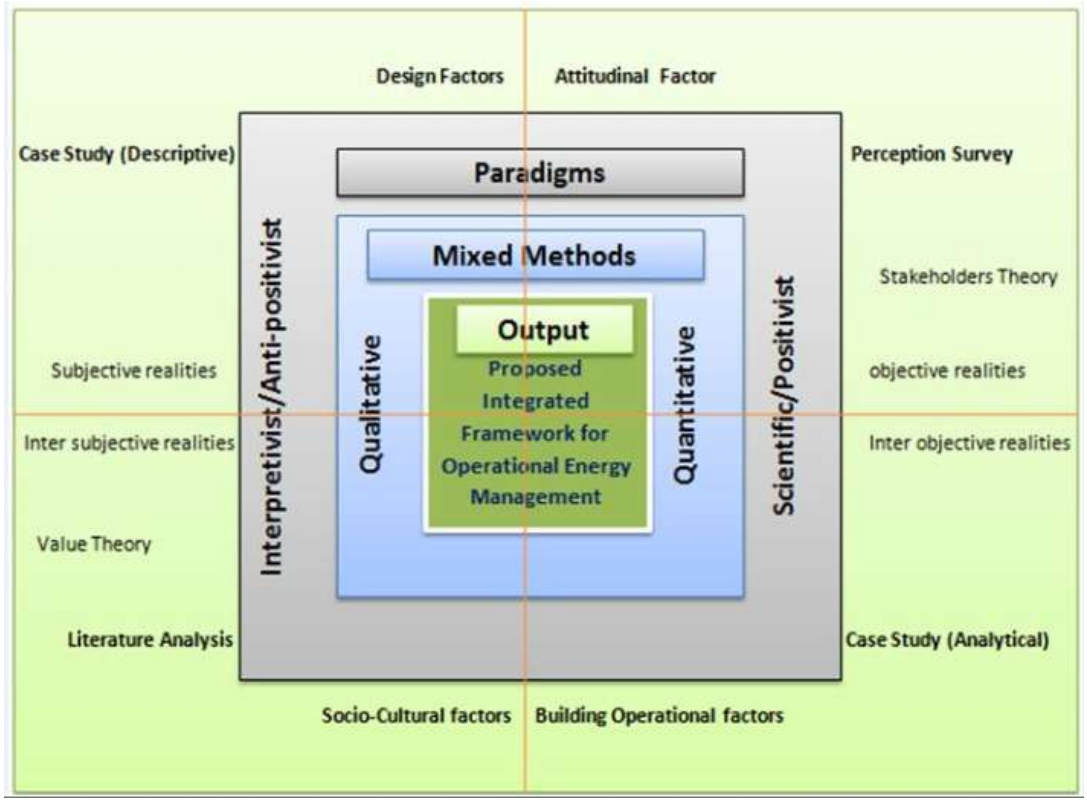


Figure 5.3: Methodological framework developed for this study

In spite of the significant benefits of mixed methods research, however, like any other research design is not without some limitations. Bryman (2004) argued that mixed methodology is two different paradigms with their own epistemological consideration and they are incompatible. Hence, the integration is only at a superficial level and within a simple paradigm. In spite of the limitation, the case for combining methods generally, and more specifically that for combining qualitative and quantitative methods is stronger than using a single method. Hence, the priority of selection of mixed methods research design in this study. Table 5.1 presents the justification for the chosen research method.

5.5 Multiple Case Study

A case study as defined by Bryman (2004) and Yin (2003) is a research design that focuses on the intensive and detailed analysis of one or more cases and is preferred when asking why or how questions. This approach among other reasons is likewise considered viable for this research because of the fact that the research is being conducted in an aspect where few, if any, earlier studies have been undertaken (Benbasat et al., 1987, P.370). The primary motivation for using a case study approach in this research was informed by its connection with the chosen research paradigm and the philosophical underpinnings of the chosen research design for this study.

Building projects are principally unique, especially when it comes to the issues regarding the energy efficiency of heritage buildings, it is highly unlikely that conclusions can be drawn based on the findings from a single building as each building requires to be examined on a case by case basis. Therefore, it was necessary to use multiple case studies as part of the research strategy to answer some of the research questions in this study and to generate more reliable data for inferences as well as minimise misrepresentation.

Table 5.1: Justification of the chosen research methods for each research question and objective of this study

Justification of mixed method adopted for this study A mixed-methods approach was adopted to achieve the output of this study as no single method is without weakness or bias (Webb et al., 1981). Quantitative approach though objective was adopted to investigate critical factors influencing energy use arising from stakeholders' perceptions, priorities and values in heritage building projects and operation of existing buildings. However, it lack the depth needed to elucidate the 'how' and 'why' aspect of this study. Qualitative approach was further employed to limit the weakness of quantitative approach and to deepen the depth of understanding of other possible factors influencing energy use from design and project implementation and operation. Although, qualitative approach is considered subjective, however, the combination of the approaches makes this study both objective and rich.			
Research Questions	**Research Objectives**	**Research Method**	**Justification of Each Components of the Mixed Method**
(i) What are critical factors influencing energy use in the reuse of listed church buildings? How can they be identified and addressed to more effectively manage energy usage and improve performance for long term sustainability?	**(a)** To review existing literature and research relating to climate change, conservation policies and public heritage buildings'(PHBs) contribution to energy use and carbon emission reduction.	Literature Study	• Archival analysis was adopted as is considered to be the most efficient, effective and cheapest method for gathering the existing wealth of literature on the subject matter to identify range of factors (generic and specific to heritage buildings) in order to form a thorough understanding of the concept of sustainability approach to reuse of public heritage buildings. • Archival analysis was also useful in identifying gaps in knowledge (Bui, 2013) and also helped to form the basis for the output of this study (framework for operational energy management for sustainable project delivery and management of public heritage buildings).
	(b) To investigate the perceptions, priorities and values of heritage building Stakeholders and its influence on energy use reduction in reuse of public heritage buildings.	Online Stakeholders' Perception Survey	• For this part of study, a questionnaire survey method was preferred and chosen to serve as a tool to evaluate the attitudes and perceptions of stakeholders on energy use reduction in heritage building projects (Patton, 1996). This method was preferred on the grounds of its relevance to the participants as they are involved in the design process and projects delivery and/or implementation. • Surveys are quantitative method based on a questionnaire most often used to gather information from individuals or groups who affect, or are affected by an organization and/or projects (I.e. stakeholders) They are extremely useful in capturing divergent experiences, perspectives and interests of various stakeholder groups involved in projects delivery and/or implementation. • Questionnaire survey was considered appropriate above other methods because it could cover a wide range of individuals that have a variety of stakes in heritage building projects across the country as it would be challenging to interview as many as would give data saturation on a one to one basis. • The application of survey method in this study is well suited to this study in identifying other critical (i.e. attitudinal) factors which are perceived to have potentials to influence energy use in reuse of public heritage buildings. • The use survey method has the potential to enhance the quality, scope and the depth of the findings that could be useful, relevant and credible to address design, planning and management issues as well improve policy-making processes involving reuse of public heritage buildings.
	(c) To determine the relative importance of strategies perceived as most sustainable and implemented in practice by the stakeholders to improve energy efficiency in reuse of PHBs.	Online Stakeholders' Perception Survey	
	(d) To identify the critical actors responsible for energy use in public heritage buildings arising from stakeholders' perceptions that needs to be addressed to improve energy performance.	Online Stakeholders' Perception Survey	

Source: Study Author (2013)

Table 5.1(contd): Justification of the chosen research methods for each research question and objective of this study

(ii) How can these be influence built asset management (BAM) framework for refurbishment decision making?	(e) To assess the energy performance and operational practices of existing reuse of public heritage buildings projects and to determine the factors responsible for their current energy performance.	Building Technical and Energy use Survey (19 Existing Buildings)	• Multiple Case studies was chosen as an appropriate method to specifically answer part of the research questions pertaining to 'how' and 'why' in this study. Its selection also afforded the possibilities of using multiple methods and tools for data collection from a number of entities (Tellis, 1997). • The methods and tools from case study were employed in this study to take advantage of both analytical (quantitative) and descriptive (qualitative) case study approaches. The quantitative aspect of the case study was adopted to explore how and why reuse projects differ in energy performance providing insight into the factors that may be responsible for the differences. Multiple cases were adopted as it permits cross-case analysis in order to compare operational practices of high-performing buildings with low-performing buildings.
	(f) To identify the factors preventing energy use reduction for delivery of sustainable reuse of public heritage buildings projects in practice.	Case study (9 Qualitative Interview with Practicing Design Professionals)	• Interview technique was considered appropriate by the researcher to further ask open-ended questions from selected professionals identified through the perception survey in order to achieve in-depth understanding on strategies and factors preventing energy use reduction for delivery of sustainable reuse of public heritage buildings projects. This information could not be possible through the survey because of limitations of online survey method. • Lastly, the essence of selection of case study approach was to enable the researcher to take advantage of data triangulation which is a central element in case-study research design that helps to arrive at robust findings (Feagin, Orum, & Sjoberg, 1991). • Thus, the justification of this method is to assure the researcher that the facts collected are adequate and the mixture of quantitative and qualitative data is to increase the validity and reliability of the study.
	(g) To propose an operational energy management framework to serve as an achievable guideline for professionals and operators of public heritage buildings.	Interview for validation with Architect (1), Engineer (1) & Conservation Officer (1)	• The purpose of this study is to propose operational energy management framework primarily to improve energy performance in reuse of public heritage building projects. Therefore, interview technique with selected experts in heritage industry was considered appropriate to give a rational approach to validate the usefulness and workability of the framework to be proposed.

Source: Study Author (2013)

The results generated through these case studies could be considered more compelling and more robust (Yin, 2003) and hence will be more useful in developing a framework for the project. There are different forms or types of case studies with different assumptions and purposes that can be used in social science and in the built environment related research. Yin (2003, p.5) identified five types of case studies as follows: single-case study (i.e. Concentrating on a simple case only); multiple-case studies (i.e. Including two or more cases within the same study); exploratory case study (for defining the questions and hypothesis of a subsequent study); descriptive case study (representing a complete description of a phenomenon within its content) and explanatory case study (which presents data bearing on the cause-effect relationship).

In the choice of case study strategy and type of case study to be undertaken in a research, Stake (1994) suggested that the purpose of the study aid the motivation behind the study should be central in the selection strategy. Stake (1994) therefore, identified three purposes: intrinsic (motivated by personal desire and experience), instrumental (to generate theory or greater insight where the specific cases become secondary), and collective (applying instrumental study to multiple cases within the same system to generate or refine existing theory).

Generally, case studies have previously been adopted as a relevant and adequate research strategy in planning and as well have a long tradition in built-environment research. A number of researchers have adopted this approach in investigating different research problems. For example, in the studies on building adaptation; several authors (Kincaid, 2002; Arge, 2005 and Remoy and Van der Voord, 2007) have adopted a case study

approach on a very limited number of cases. These studies were designed within a case study approach and the researchers used different data collection instruments to develop understanding of the problems under investigation. Case studies allow an empirical inquiry into the real-life context of research work.

According to Yin (2003) and Stake (2005) the major strength of collecting data from different sources and settings is that it provides multiple measures of the problem under investigation and this is documented in the literature. For example, Boaler (2008) suggested that, it is critical for researchers to gather enough evidence from different settings and circumstances by using a range of quantitative and qualitative methods to better understand the issue under consideration. Critics of case study approach have argued that one of the major pitfalls of the approach is its subjective nature which normally contribute to a degree of biases and this makes it difficult in establishing reliability and validity in case study research (Patton 2002).

Another major pitfall of case study as argued by Petrou (2007) is the inability of researchers to generalise their findings to a larger population. Similarly, a view held by Schofield (1990, p.203) against case study research is that of its obvious inconsistency with the requirements of statistical sampling procedure, which is considered as fundamental to the generalisation of research findings. However, despite these criticisms against the case study approach, the case study strategy continues to be one of the most common approaches in social science research because of its numerous advantages.

In contrast to the above criticisms, Denscombe (2007) rather was of the opinion that using case study strategy helps in illuminating the general by looking at the particular and getting an insight looking at individual cases that can have wider implications that would not have come into light through the use of a strategy that covers a large number of instances. A similar stance is taken by Thomas (2003, p.31) that case study strategy can be used in collecting qualitative data to validate quantitative data and also help in revealing the way a multiplicity of factors can interact to produce a unique character of an entity which is the subject of the research.

5.5.1 Number of cases and sample size

The kind of the research question informs the choice of number of cases. Therefore, there are no definite rules, to the number of cases that should be selected in multiple case study research. Eisenhardt (1989, P. 545) suggests that four to ten cases work well, however, with fewer than four, it is hard to generate theory. Meanwhile, Miles and Huberman (1994) recommended a maximum of 15 cases. A greater than this number could make the data becomes thinner and the depth may be lost. It could therefore be argued that the sample size in case study research is relative and depends on the purpose of the research study, where different sample strategies require different minimum sample sizes (Sandelowski, 1995).

A similar view is held by Bernard (1995, p.94); Trotter and Schensul (1998, p.703), who observed that in theory, all research should as much as possible use probabilistic sampling methodology, nevertheless, in practice it is virtually not possible to be done in the field.

Thus, sampling in the qualitative approach as supported and argued by Coyne (1997); Hillebrand, Kok and Biemans (2001) is about purpose, appropriateness and access to good information instead of representative and random sampling.

5.6 Overview of Data Collection Phases of the Research

Each phase of this study has a specific aim and addresses different, but complementary concerns of the study consequently, the methods used vary accordingly. Phase one of the data collections made up the greater part of the project therefore uses survey research in the form of questionnaire to examine the views and opinions of heritage building industry professionals about energy use reduction in conversion of public heritage buildings. In phase two of this study, building technical survey was undertaken on a number of selected buildings to obtain information on energy consumption of heritage buildings. The following sections expand upon the practical implementation of the phases of the research project.

5.6.1 Conducting Phase One

5.6.1.1 Introduction

The aim of the first part of this project was to investigate perceptions and opinions on human factors that influence energy use in reuse of public heritage buildings that could affect sustainable delivery of heritage building projects and effective implementation and/or achievement of carbon emissions reduction agenda in the UK. In order to achieve this, information had to be obtained from representatives of professionals in the heritage

building industry. Survey research was identified as the most appropriate method to accomplish these objectives.

5.6.1.2 Survey research

A variety of research techniques are used for estimating conceives and perceptions of the concerned population. In this particular study, 'Survey technique' was used for reaching at findings and drawing the conclusions. Survey research allows the researchers to use instruments to collect data from a sample so as to measure their attitudes and opinions on any issue (Ary, Jacobs and Razavieh, 1996). Survey research also considers the most appropriate way of documenting human conceives, particularly when the researcher is to deal with massive populations (Grooves, 2006). It is considered as a standard and most frequently used instrument for gathering information in the social studies, through direct contact with the respective population (Bulmer and Warwick, 1993).

5.6.1.3 Methodology overview

Essentially, in the development of the methodology, the distinctive steps for any survey project were considered in this current study based on the recommendation of Creative Research Systems (2003) as follows:

- Establishing the goals of the project
- Determining the sample
- Choosing survey methodology
- Designing and creating the instrument (questionnaire)
- Piloting the questionnaire

- Conducting the interviews and entry of data
- Analysing the data
- Producing the report

5.6.1.4 Survey design

The survey design for this study adopted the following protocol:

Identification of the various types of respondents to be targeted for the survey; to ensure that the results from the survey would be representative of the different types of respondents across different regions in the UK

- Calculating the sample size and selection of the sampling frame,
- Developing the questionnaire
- Determining the data collection method

Table 5.2 outlined the ten step process used to summarise the methodology overview and survey design adopted for the survey.

Table 5.2: Perception survey summarised in a 10 step process

	Perception Survey Step	Brief Description
1	Detailed Literature Review	Reviewed of key policy/factors influencing energy consumption
2	Preliminary Survey Instrument Design	Drafted the survey questionnaire
3	Stakeholder Identification	Invitation to professionals in heritage building industry
4	Pilot Testing of Survey Instrument	Administered survey instrument to smaller sample
5	Finalization of Survey Instrument	Amended the survey design and questionnaire
6	Data Collection (Field Work)	Interviewed 211 professionals across the UK
7	Data Entry & Preliminary Data Analysis	Uploaded data in MS excel and SPSS software
8	Data Validation and dataset Clean Up	Validated the data and performed clean up
9	Detailed Data Analysis	Analysed data using SPSS & MS excel
10	Conclusions & Recommendations	Developed conclusions based on data

Source: Author's work (2012)

5.7 Population of the Study

The target population for this study encompassed all registered professionals in the heritage industry in the UK, who listed their email address in the 2011-2012 Directory of registered professional and websites (N = 11, 650). The population comprised of the architects, conservation officers, energy consultants, engineers, planning/development control officers, regulatory bodies' officers and building surveyors. These groups constituted a large group of the population having concerns and interests in heritage buildings.

5.7.1 Sampling

Due to many factors such as time, expenditure and accessibility, it is unrealistic for the researchers to approach the entire population for collecting required information (Cohen

et al., 2000). For this reason, it was necessary to adopt an appropriate sampling technique to help the researcher in the collection of needed data. A Sample is referred to as the representative component of the population (Oliver, 1997), while sampling is the recommended procedure of selecting adequate representatives out of the population. The study of the selected sample through the process of research makes it possible to generalize the attributes to the entire population (Sekaran, 1992).

5.7.2 Sampling technique

The anatomy of the sample population is outlined by the researcher on the basis of a keen approximation of all the elements in the target population (Neuman, 2000). The target population of the respondents was categorised into seven (i.e. Architects, conservation officers, energy consultants, engineers, planning/development control officers, regulatory bodies' officers and building surveyors) through a stratified sampling technique. The stratified sample is selected by sorting the population into subgroups or strata on the bases of some distinct features of the population, such as profession, refurbishment and conversion projects involvement in heritage building, conversion projects involving listed churches etc. There are two types of stratified sampling method (i.e. Proportionate and disproportionate). In this study, proportionate type of the stratified sampling was not adopted as it was not practicable to assort and enlist the constituents of each stratum for the selection of sample through random or systematic technique. Hence, a disproportionate sampling method was chosen.

5.7.3 Sampling frame

A sampling frame has been described as a list that contains and closely matches the elements of a defined population (Czaja and Blair, 1996: p.116). However, it is hard to obtain accurate listings of the theoretical population to be investigated, as a result the list of the accessible population from which a sample can be drawn, makes up the sampling frame (Trochim, 2006). Obtaining a listing of the whole spectrum of the theoretical population for this study, namely all the heritage industry stakeholders in the UK, was not possible as such a comprehensive list/database does not exist. Following the examples of Soetanto *et al.* (2001) and Xiao (2002), the sampling frame that was adopted for the selection of the sample was obtained from the following;

- List of registered Architects Accredited in Building Conservation (AABC & RIBA, **n=312**)
- List of conservation officers registered with the Institute of Historic Building Conservation (IHBC, **n=300**)
- Directory of practices and firms from Chartered Institute of Building Service Engineers (CIBSE, **n=236**)
- List of registered Conservationists with Planning Officers Society (POS, **n=100**)
- List of Registered Professional Energy Consultants (RPEC, **n=54**)
- Directory of Chartered Surveyors specialising in building conservation from the Royal Institution of Chartered Surveyors (RICS, **n=50**)
- List of other members of regulatory bodies (e.g. English Heritage, SPAB etc.) (**n=50**)

5.7.4 Sample size

Diverse procedures are used to determine the sample in research. The sample size is determined by the requirement of the study for obtaining accurate and authentic findings for reaching at ultimate conclusions (Fink, 1995). Factually, the size of the sample for a research study much depends upon the available resources and accuracy of the process according to Bulmer and Warwick (1993) "the size of the sample is more a matter of convenience", and a compromise among many factors (i.e. Expenses and precision etc.) (De Vaus, 1996). For this study, the sample size was determined from the formula adopted from Creative Research Systems (2003) and Czaja and Blair (1996) given as:

$$ss = \frac{Z^2*(p)*(1-p)}{C^2}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)
P = percentage picking a choice, expressed as decimal
(.5 used for sample size needed)
C = confidence interval, expressed as decimal

It is a usual practice in surveys to seek a 95% confidence level or precision levels of 5%. Therefore, as it is common with other research, a confidence level of 95% was assumed (Creative Research Systems, 2003). For 95% confidence level (i.e. Significance level of $\alpha = 0.05$), z = 1.96. Based on the need to find a balance between the level of precision, resources available and usefulness of the research findings, a confidence interval (c) of ±10% were deemed adequate for this study. In order to determine the sample size for a given level of accuracy, Czaja and Blair (1996) suggested the worst case

percentage picking a choice (p) should be assumed which is given as 50% or 0.5. On the basis of these assumptions, the sample size was calculated as follows:

$$ss = \frac{1.96^2 \times 0.5\ (1 - 0.5)}{0.1^2}$$

$$ss = 96.04$$

The required sample size for the questionnaire survey will be 96 professionals. However, the figure computed requires a further correction for finite populations. Thus, the formula to calculate for finite populations was adopted from Czaja and Blair (1996) as:

$$\text{new ss} = \frac{ss}{1 + \frac{ss - 1}{pop}}$$

Where:

Pop = population

$$\text{new ss} = \frac{96.04}{1 + \frac{96.04 - 1}{11{,}650}}$$

new ss = 95.23

Using this formula in calculating the finite populations, it could be observed that the sample size ranges between 95 and 96. However, it was considered necessary to factor in the sample size the problem of nonresponse rate that is common with questionnaire survey. Therefore, it was important to adjust the sample size to account for nonresponse.

Assuming a conservative response rate of 10% was expected from the survey, the appropriate sample size to be surveyed was thus calculated based on the formula adopted from Akadiri (2011) as:

$$\text{survey ss} = \frac{\text{new ss}}{\text{response rate}}$$

$$\text{survey ss} = \frac{95}{0.1} = 950 \text{ heritage building professionals}$$

Thus, a minimum of 950 heritage building professionals at 10% response rate are needed to be invited to participate in the survey. Following this procedure of obtaining the sample size, a random selection of registered professionals was made to provide a list comprising at least 1102 heritage building professionals in the UK. A computer based random number generator was used to generate the number required for the sample size.

5.8 Data Collection

To commence the data collection, every possible source of information concerning the research problem, including books, journals, magazines, newspapers and internet was minutely explored. The reason for this was to acquire enough knowledge and to understand the problem for the development of a more valuable research study.

5.8.1 Survey instrument – questionnaire and tool

The survey design has been informed by an in-depth situational analysis of the heritage industry through desktop literature. Similarly, informed by the literature review and

documentary analysis, a survey tool; "the questionnaire" was developed and was used to collect primary data. As a tool of data collection, the questionnaires are among the most popular and broadly applied instruments in the field of survey research. Questionnaires are less technical and comparatively easy to manage, and on the other hand, do not involve unbearable expenses (Sierles, 2003). The questionnaire was administered through SurveyMonkey. Survey Monkey is the leading online provider of tailored research surveys, enabling the user to design, label and brand a survey. SurveyMonkey is widely used by international institutions and educational establishments worldwide. The survey questionnaire that was administered for data collection purposes is attached as Appendix 1: *"Stakeholders Perception Survey – Data Collection Tool (Questionnaire)"* to this chapter.

5.8.2 Pilot study

In this study, measurement error was limited by establishing face and content validity through a pilot survey. The field test sample (n = 36) consisted of respondents in the target population, but not included in the sample. The participants were sent a cover email and the survey link containing the questionnaire and were equally encouraged to suggest corrections, changes or alterations in the phrases, wordings or conceptions of the questions. The pilot survey was conducted online using SurveyMonkey before launching the full scale research project. During the pilot study, the researcher discussed each item on the questionnaire with the respondents to determine their suitability and clarity for the purpose of the study. This was done physically where possible and by email where the respondents could not be easily reached. Minor revisions to the instrument (this relates to

the way in which some of the questions were presented in the questionnaire) were required. The survey questionnaire was continuously revised to incorporate the views and opinions obtained from the pilot test until the necessary revisions to the instrument were made and the questionnaire was finalized for the survey.

5.8.3 Data collection instrument

For obtaining needed information from the respondents, a questionnaire based on continuous scale was developed after the completion of due procedural formalities.

5.8.4.1 Questionnaire development

To answer part of the research question, a questionnaire was prepared for the survey to be administered to the intended respondents. It was indicated that this could be answered with no more than 15 minutes of the respondents' time. Furthermore, the answers would be totally confidential and anonymous. The questions concentrated on the perception of the respondent on the evaluation of factors that influence decision making and energy efficiency for sustainable conversion of heritage buildings. The responses were sought to evaluate the effectiveness of current practices in refurbishment and/or conversion of listed churches. An online covering letter preceded the questionnaire introducing the researcher and explaining the purpose of the study.

The questionnaire consisted of nineteen questions, which are organized into three sections. The first section of the survey asks questions related to the participants' background information. It includes questions related to the number of heritage refurbishment projects they have been directly involved and their years of experience in

working on heritage properties. The second section relates to the application of sustainability principles in heritage building conversion projects.

5.8.4.2 Questionnaire administration

A week before the survey was sent to the participants, they were given a notification from the researcher about the importance of their input for the study. This was necessary to reduce the possibility of low response rate. In order to further reduce the low response rate, tailored design method developed by Dillman (2000) was used to guide this study. Table 5.3 outlines the timeline adopted for the survey. The respondents who won't respond by the first week after sending the survey link, an email reminder was sent to them as a reminder and a thank you email to those who responded. Fourteen days after the first e-mail was sent, a replacement e-mail was sent to serve as a reminder to those who have not still responded. After week four, another e-mail reminder was sent stating the importance of the participant's input for the study.

Table 5.3: Timeline of Mail-outs: Based on Dillman's (2000) Design Method

Week	Procedure
Week One	Pre-notice Letter
Week Two	Questionnaire Mail-out
Week Three	Thank you /Reminder
Week Four	Replacement Questionnaire
Week Five	Invoking Special Procedures

The rationale for the approach was to contribute to the likelihood of doubling the initial response rate, generally less than 40% after sending the first email. The respondents

received all correspondence by e-mail. Data collection took place in May 2013 (see Table 5.4).

Table 5.4: Contact Methods and Timing

Method of Contact	Date of Contact
Pre-notice Letter	May 31, 2013
Questionnaire	June 7, 2013
Thank you /Reminder	June 14, 2013
Replacement Questionnaires	June 21, 2013
Final date of closing the survey	June 28, 2013

5.8.4.3 Measurement scale

A five-point Likert scale was used for most of the questions to measure agreeableness/disagreeableness of the respondents on the statement provided. In the Likert scale response represented in the form of numerical values ranging from 1.00 to 5.00. In order that all the numerical value could be computed from all the responses was allocated. The given equivalent weights for the answers was given range as illustrated in Table 5.5 below:

Table 5.5: Illustration of scale applied to data collection

Range of value	0.00 – 1.49	1.50 – 2.49	2.50 - 3.49	3.50 – 4.49	4.50 – 5.00
Interpretation	Strongly Disagree	Disagree	Niether agree nor Disagree	Agree	Strongly Agree

5.8.4.4 Response rate

A total of 1102 participants were invited via email to participate in the survey with 815 of them being valid emails. The remaining 287 contacts were returned as mail daemon as

it appears they did not contain valid email identification. As such, 815 participants were sent the survey link while 77 respondents declining participation, reducing the remaining participants to 738. Table 5.6 shows the category of respondents and their response rate.

Table 5.6: Category of participants and response rate

Heritage Industry professionals	No of invitation	No of failed mail notice	Number of mailed participants	Number of invitation declined	Actual number of participants	Number of respondents	Response rate per stakeholder (%)
	A	B	C (A-B)	D	E (C-D)	F	G(F/E)*100
Architects	312	71	241	13	228	63	28%
Conservation Officers	300	89	211	14	197	64	32%
Energy Consultants	54	-	54	2	52	20	38%
Engineers	236	101	135	14	121	28	23%
Planning officers	100	26	74	22	52	16	31%
Regulatory Bodies	50	-	50	2	48	10	21%
Surveyors	50	-	50	10	40	10	25%
Total	**1102**	**287**	**815**	**77**	**738**	**211**	**29%**

The total number of responses for this survey across the country was 211 responses out of 738 contacts, providing a response rate of 29%, which was considerably higher than the expected calculated response rate of 208 in this survey based on the formula adopted from Bryman (2004) as given below:

$$\text{Expected Response rate} = \frac{\text{Number of usable questionnaires}}{\text{Total sample – unsuitable or uncontactable members of the sample}} \times 100$$

$$\text{Expected Response rate} = \frac{1102}{815 - 287} \times 100$$

Response rate = 208

Findings in the literature show that response rates for questionnaire surveys are generally poor and commonly range from 20-30% (Takim *et al.,* 2004; Dulami *et al.,* 2003). Observations from the response rate per stakeholder reveals that the response rate for all the stakeholders falls within acceptable range (i.e. 20 – 30%). Considering the average response rate for questionnaire survey, the response rate obtained for this survey can be considered a good return rate. The response rate of 29% obtained for this study is acceptable and as it is higher than the response rate obtained by other researchers such as Ofori and Chan (2001) with a response rate of 26% and Black *et al.* (2000) with response rate of 26.7%. The response rate obtained from the survey confirms that the survey was well-received by stakeholders and that they clearly believed there was value in them responding. It could also be argued that the response rate obtained from this survey suggested that nonresponse bias should not be a major problem.

5.8.4.5 Margin of error

A very important aspect in survey research according to Czaja and Blair (1996) and Graziano and Raulin (2004) is reducing errors in sampling so as to deviate as little as possible from the population parameters. In this study, the sample size of 211 was obtained from the survey hence, could be considered adequate for the purpose of inferential statistical analysis. The margin of error calculated was based on the 211 responses and an estimate of 5.71% margin of error due to sampling was obtained at 95% confidence level. This can be interpreted as meaning that there is a 95% probability that results obtained from this survey lie within a ± 5.71% range. Analysis of the data was undertaken using IBM SPSS Statistics 20.

5.9 Method of Data Analysis

Prior to the commencement of the statistical analysis data screening was conducted on the raw data. The data screening includes descriptive statistics for the survey items which were reported in the text and presented in tabular form. Frequency analysis was carried out to identify valid percent for responses to all the questions in the survey. The research questions in this study predetermines the choice of statistical test and analysis conducted for the study.

5.9.1 Descriptive statistics analysis

Descriptive statistics used in the analysis of this study employed the use of frequencies, percentages and means for the descriptive presentation of the findings of the survey. These methods were used for the analyses of data, in relation to the characteristics of the respondents, their organisations, and in addition open ended questions/comments was used for the initial analysis of rating score data of the various research variables. Bar chart and tables were graphically used for the presentation results.

5.9.2 Factor analysis

Factor analysis is described by Hair *et al.* (1998) as a multivariate statistical technique for examining the underlying structure or the structure of interrelationships (or correlations) among a large number of variables. This approach was utilised in the work of Fahy (2002) on sustainability and was adopted in the analysis of this research. The analysis produces a group of factors to portray the data in a parsimonious but a more meaningful number of concepts than the original individual variables (Glynn *et al.*, 2009).

5.9.3 Relative index analysis

The relative index analysis was the method used in analysing responses related to ratings of the research variables. The relative index analysis technique is known as an excellent approach for aggregating the scores of the variables rated on an ordinal scale by respondents (Chinyio *et al.*, 1998b). The SPSS was first employed to determine the valid frequencies (in percentage terms) of the variables rated, which were then fed into Equation (1) to compute the variables' respective rank indices (RIs).

$$\text{Relative significance/difficulty index} = \frac{\sum w}{AN} \qquad (1)$$

Where w is the weighting given to each factor by the respondents, ranging from 1 to 5, where A is the highest weight (i.e. 5 in the study) and N is the total number of samples. On the basis of equation (1), the relative importance index (RII) can be computed ranging from 0 to1.

5.10 Implementing Phase Two

This second phase of the study draws from part of the explanation of the results of the statistical tests, obtained in phase one. Multiple case study approach, according to Stake (1995) is designed to be used for gathering and analysing qualitative data. Instrumental multiple cases were adopted in this phase to serve the purpose of illuminating issues around energy use for sustainable reuse of listed churches and as such they are described and compared to provide useful insight into the issue being investigated.

5.11 Building Technical and Energy Use Survey

5.11.1 Target population

The target population for the building technical survey consisted of all converted listed churches and their building manager within the East of England. In selecting a population and a sample of a case study research, Yin (1989) suggested that the researcher must select a site and participants that will contribute to the study as well as provide further information to the research. Initially, the entire country (i.e. United Kingdom) was initially chosen for this study, however, due to limitation of time and resources required to complete the study, East of England was finally chosen as the site for the study.

5.11.2 Geographical location

There are several reasons behind the selection of a particular site for a specific study. Audet and D'Amboise (2001) and Yin (2009) argued that researchers select a site because of its convenience, access and geographical proximity and others select a site which they think can yield similar results or on the contrary completely different results to answer the research questions raised. In the present study, East of England was selected for this study for the following reasons:

- The region comprises one of the highest number of Mediaeval church conversion in the country with a representative mix of Grade I, II* and II buildings.
- The region is the third largest in the United Kingdom in a number of listed buildings after South West and South East. The study site, East of England has over 2,300 places of worship (Norfolk alone has over 700).

- Furthermore, the study site is known in Medieval history with 32 Medieval churches in Norwich alone.
- The region has the highest number of converted churches to civic, cultural or community buildings.

By limiting the scope of this study to this site, the buildings would share the same regional identity and similar environmental characteristics and challenges. Similarly, constraining this study to this region will also allow flexibility in choosing the data collection method by eliminating travel distance which is also a potent and significant constraint. Moreover, the lack of study on energy consumption involving converted church in the region will also present the possibility to contribute to the field of knowledge, providing useful information to both church environmental groups looking to partner with church communities and the building owners themselves that are looking to better address environmental issues.

5.11.3 Building eligibility

The determination of the building eligibility for the technical survey was undertaken in a two-step process. The first step was undertaken during the development of the sample and then the second step was done during the interview with the building respondents. To be eligible for the survey, a building had to satisfy two major criteria: (1) it had to meet the location criteria described above; (2) it had to have one its uses for some community purpose. Other eligibility criteria included looking for buildings that had comprehensive data for the quantitative analysis and which represented different sizes, grade listing

status, construction methods, and year of adaptation or conversion in an attempt to provide an adequate coverage and to maximise variation in the sample.

5.11.4 Technical criteria

To investigate the energy performance of the selected buildings, a holistic analytical framework of technical criteria was developed considering environmental, economic and social sustainability principles that are connected with criteria affecting selecting sustainability of heritage buildings (see Table 5.7).

Table 5.7: Analytical framework of technical criteria developed for the study

	Unit of Analysis	Aspect analysed	Indicators	Issues considered
1	Energy Consumption	Energy bills Fuel Used Energy used per floor area	(i) Annual Energy Consumption (Kwh/m^2)	Any thermal upgrade done to the fabric? If yes how well has it been done in a benign and sympathetic manner to the building?
2	Carbon Dioxide Emissions	Environmental Impact	Annual CO_2 Emissions	What is the annual CO_2 emissions reduction achieved (kg/m^2) Is the heating system
3	Services	Heating System Lighting System	(i) Effectiveness of System Performance	Efficient (e.g. a seasonal efficiency of about 90%. Responsive (responding rapidly to heat loads and temperatures Well controlled (user-friendly time and temperature control
4	Operations & Maintenance	Hours of operation Frequency of maintenance	Building-specific operation and maintenance	Any provision made for users and managers with understanding of how the building is intended to work?
5	Building use pattern	Primary use Secondary use	Activities & functional use	
6	Control Mechanism for Operational Energy Usage Reduction	strategies methods approaches	Energy Management Strategy	Any building energy management system set up to provide appropriate reports and out-of range alarms to manage energy use efficiently?
7	Communication to Users	strategies methods approaches	Measures Taken to Change User Behaviour	Any programme, training, education and /or motivational activities to influence staff/user behaviour to maximise energy use?
8	Micro Regeneration Technologies	Type of Renewable Energy Used		How effective was it integrated to the building?

Source: Study Author (2012)

5.11.5 Sample size

The sample size in this phase of the study was determined by geographical location, travel costs and time factors. Thus, a purposive sampling of all potential building cases within the geographical region was used to select all the buildings from the area and special list sample frames. The total population of listed church converted to civic, cultural or community purposes is 33 with 2 buildings in rural areas and 31 buildings in urban areas. All the buildings in the urban areas were sampled for this study because this is where the

demand for community use and purposes is far greater than the rural areas. However, only 19 of the buildings were accessible and met the eligibility criteria (see Table 5.8).

Table 5.8: Selection criteria for the buildings sampled

Location	No of projects	No in rural area	No in urban area	No empty	Anticipated sample size	No of accessible building	Actual sample size
1 Cambridge	3	-	3	-	3	2	2
2 Colchester	3	-	3	1	2	2	2
3 Great Yarmouth	2	1	1	-	1	-	-
4 Ipswich	5	-	5	1	4	4	4
5 Norwich	18	-	18	4	14	10	10
6 Peterborough	2	1	1	-	1	1	1
Total	**33**	**2**	**31**	**6**	**25**	**19**	**19**

Source: Author's survey (2012)

Based on the arguments of Saunders *et al.* (1997), that there are no rules for sample size in non-probability sampling, rather, the actual size depends, amongst other things, on available resources and the logic behind the sample selection, the above sampling approach was deemed sufficient for the research.

5.11.6 Data collection

Data collection comprises of several phases, which includes: designing the questionnaire, pre-testing the questionnaire, carrying out interviews, minimizing nonresponse and data processing.

5.11.6.1 Questionnaire design

A self-developed questionnaire, containing items of different formats: asking either for one option or all that apply questions, dichotomous answers like "Yes" and "No" was designed and handed over to the building manager (s) in charge of the buildings to obtain

records of energy bills and other information on the characteristics of the building. The questionnaire presented an opportunity to gather necessary information on a range of parameters that would help to analyse the energy consumption. This included: type of energy use, construction material, building age, heating plant and age, heating pattern and set temperature, number of users and hours of operation. A copy of the questionnaire is included in appendix B of this thesis.

5.11.6.2 Pre-testing the questionnaire

One pilot study was carried out before fielding the full-scale survey to determine if the questionnaire worked as intended and to test the new procedures for interviewing the respondents. The researcher administered 19 questionnaires with building manager using both face to face and telephone techniques where the building manager was not easily accessible. The building questionnaire is a complex research instrument designed for data collection during a personal interview with a respondent at the building site.

5.11.6.3 Conducting the Interviews

The interviews began late November 2012, and closed at the end of August 2013. Data collection was performed by the researcher by firstly visiting the sampled building to locate the building and to ensure the building met the eligibility criteria. This was necessary because there were instances where the building could not be located. During this screening visit, the researcher listed the buildings that turned out to be empty and such buildings were removed from the list of selected buildings. During the first visit to the building and the tenants in the building, a knowledgeable person for the interview was identified and was left with an advance copy of the questionnaire and a note to book an

appointment to return for an interview after allowing enough time for the respondent to look over and complete the survey instrument. Following this step, another visit was made to the building at the set appointment to conduct the interview.

The questionnaire covered topics such as: characteristics of the building, building activity, size and year constructed, year converted, building use patterns such as operating hours, number of workers, number of occupancy; types of energy-using equipment such as heating, cooling, refrigeration, lighting and office equipment ; energy management practices; types of energy used in the building and whether that energy is used for heating, cooling, water heating, cooking, electricity generation; and the amount of and expenditures for energy used in the building in 2012.

5.11.6.4 Minimizing nonresponse

This plan was designed to achieve the highest possible response rate. Each week the researcher made efforts to contact all pending cases through emails and phone calls to encourage participation and to answer questions. Even with these efforts, confirmed nonresponse cases totaled 6 buildings at the end of data collection. They were divided into two categories: outright refusals and cases where an interview could not be obtained for some other reason, such as cases where the respondents were unable to be contacted because they were generally not available, and those who claimed they did not have time for the interview.

5.11.6.5 Response rates

A total of 25 sites or buildings was visited and their managers contacted and sent an invitation to participate in the building technical survey. The total respondents resulted in

19 completed building technical surveys and interviews out of 25 selected samples given a response rate of 79 percent.

5.11.6.6 Unit nonresponse

A selected building eligible for survey for which no information is obtained is referred to as a unit nonresponse. The main reasons for unit nonresponse among buildings sampled and selected was the respondent's refusal to participate in the research. Other reasons were the inability to contact and interview someone knowledgeable about the building. Among the tenants, 2 were refusals and 4 were unable to be contacted during the field data collection.

5.12 Confidentiality of Information

This study was conducted in compliance with the regulations of the university on ethical issues. The names and addresses of buildings and individual respondents or any other individually identifiable data that could be specifically linked to the building or respondents are seen only by the researcher. The data are kept secure and confidential at all times. The ethical issues require that identifiable data which respondents have been promised should be kept confidential and used exclusively for statistical purposes. The researcher met these criteria, and the survey was collected under the ethics protection.

5.13 Processing the data

Processing of the technical data included editing the questionnaires and checking for internal consistency and for missing data and preparing the data for cross-tabulations for analysis. Editing the data occurred at several points during data collection and processing, the primary editing occurred while inputting the responses into an excel spreadsheet after

each interview. Arithmetic checks were conducted for some items; consistency checks between items prompted the researcher to confirm unlikely responses. Additional editing was performed which included reviewing and updating data based on clarifying responses provided by the respondents, incorporating responses to open-ended questions, and reviewing 'Don't Knows' for certain "critical items." In some of these cases, it was determined that a callback was worthwhile, and the respondents were notified to confirm the missing data for data retrieval.

5.14 Research Bias

Leedy (1997) defines bias as any influence, condition or set of conditions that may singularly or together distort the data from what may have been obtained under the conditions of pure chance. There are several ways bias may be introduced into a study. One of the ways a researcher may bring bias into his/her study as described by Patton (2002) is by selecting data that best supports the theory/hypothesis, using statistical techniques that best show the particular results predicted or bringing personal perspectives in the analysis and interpretation of data. However, a thorough application of the criteria discussed in this study to ensure the quality of the methods applied in conducting this research and analysing its results helped to minimise the potential problem of bias.

CHAPTER 6: RESULTS (STAKEHOLDERS' PERCEPTION SURVEY)

6.0 CHAPTER OBJECTIVES

- To present the phase one of the quantitative analysis of this study
- To describe the process of the analysis of the data collected
- To make inferences and conclusions based on the findings from the analysis

6.1 Introduction

The online perception survey was used to reach a larger number of the respondents to capture their perspectives on energy use reduction in LCBs. However, to make better inference a complementing qualitative finding is also presented in chapter eight (8). The analysis employed in this phase consists of three sections. First, the procedures used for data preparation followed by descriptive statistics and finally the inferential statistics. The quantitative research methodology used in this study requires precise measurements for data collection. Based on the nature the investigations, quantitative researchers depend on statistical analysis, which has resulted to two main sets of statistical analysis used for analysing data in the two branches of statistics, namely 'descriptive' and 'inferential' statistics (De Vaus, 2002; Rosnow and Rosenthal, 2005; Best and Kahn, 2006). Descriptive statistics involve summarizing, tabulating, organizing and graphing data for the purpose of describing a sample of individuals that have been measured or observed.

Descriptive statistics are used to describe the data in terms of the characteristics of the variables under investigation (Marczyk, DeMatteo and Festinger, 2005) and no attempt are made to make inferences about relationships or infer the characteristics of individuals.

Meanwhile, Field (2005) referred to inferential statistics as statistics that takes descriptive data further by measuring correlations and relationships in an attempt to draw conclusions. In this study, both descriptive and inferential statistics are adopted in order to ascertain response consensus from the respondents.

6.2 Data Preparation

To ensure the accuracy and completeness of data, preparing it for statistical analysis is an important step. Certain procedures, coding, entry and editing the data are required prior to starting the statistical analysis (De Vaus, 2002).

6.2.1 Data coding

Data coding is a procedure used by researchers to extract categories and values of a variable so that responses can be translated to an appropriate form suitable for statistical analysis (De Vaus, 2002). By grouping similar responses, the data can be made manageable. It is important that the codes are differentiated and organised in a framework or pattern to facilitate interpretation, cross-referencing and comparing of the emerging information. For the purpose of this research project, a structured questionnaire on an ordinal five-point Likert scale, of choices. A number value was assigned to each choice (i.e. 5- strongly agree, 4 - agree, 3- neutral, 2 - disagree, and 1- strongly disagree). This was used for collecting required data from stakeholders, consisting of; architects, conservation officers, engineers, energy consultants, planning and development control officers, and surveyors. With respect to the statement relating to professional values and priorities applied to conversion project, which covers sections B and D of the questionnaire (Appendix A), participants were asked to provide scale. Whereas, for

questions in sections A, C, E and F that contain nominal and ratio data, a numeric value was assigned to each response provided by participants.

6.2.2 Data entry

Statistical Package for the Social Sciences (SPSS) as a widely used form of data entry and analysis (Byrne, 2002; Alreck and Settle, 2004) was used for entering the raw data obtained for this present study. The data entry was carefully edited to ensure its accuracy, completeness and acceptability of analysis (Robson, 2002). Certain editing procedures were taken into consideration to ensure the precision of the entered data. Whilst the data were first entered by the researcher, it was then reviewed by another person for entry errors. Preliminary editing analyses producing frequency tables were carried out to check for maximum and minimum values.

6.3 Stakeholder's Perception (Online) Survey

The survey was conducted between May and July 2013 with a response rate of 29 percent obtained. The response rate is fully discussed further in section 6.4 of this chapter. The quantitative data from the questionnaire survey were coded and entered into Microsoft Excel and SPSS 20.0; and were analysed using a number of descriptive statistical techniques such as classification, frequencies, percentages, mean, standard deviation, summation and cross tabulations.

6.3.1 Response rate

The sample of this study consists of seven heritage industry respondents' groups. The groups comprise of architects, conservation officers, energy consultants, engineers, planning and development control officers, regulatory bodies' officers and surveyors. Initially, 1102 participants were invited via email to participate in the survey with 815 of them with a valid email address. The remaining 287 contacts were returned as failed mail as it appears they did not contain valid email identification. Therefore, 815 participants were sent the survey link while 77 respondents declining participation, reducing the remaining participants to 738.

There were 211 individual responses to the survey across the UK out of 738 contacts, providing a response rate of 29%, which was considerably higher than the conservative response rate of 20%. Findings in the literature show that response rates for questionnaire surveys may be generally between the range of 20 – 30% (Dulami *et al.*, 2003; Takim *et al.*, 2004). Observations of the response rate per stakeholder reveals that the response rate for all the stakeholders falls within the common range of 20 – 30% obtained by many research outcomes. Considering the average response rate for the questionnaire survey, the response rate obtained from this survey can be considered a good return rate.

The response rate of 29% obtained in this study is higher when compared with those of other researchers such as Ofori and Chan (2001) with a response rate of 26% and Black

et al. (2000) with a response rate of 26.7%. Furthermore, the response rate obtained from the survey confirms that the survey was well-received from the stakeholders and that they clearly believed there was value in them responding. It could also be perceived that the level of response rate obtained from the survey suggested that non-response bias should not be a major problem. Table 6.1 presents analyses of the responses obtained from each category under consideration in this research study.

6.3.2 Reliability of the measuring scale

Joppe (2000) in Golafshani (2003) defines reliability as "the extent to which results are consistent over time" which also measures the degree to which a result accurately represents the total population under study. According to Sushil and Verma (2010), the purpose of reliability test for questionnaire is to determine its consistency and ability to measure a construct. The measuring scale was checked for its inter-item consistency and reliability on Cronbach's Alpha reliability coefficient using SPSS version 20. Cronbach's Alpha as one of the most important ways of measuring reliability (Yu, 2005) is an internal consistency method which examines the number of questions on a questionnaire and the average inter-item correlation. The result ranges between 0 for completely unreliable tests and 1 for completely unreliable tests (Hilton *et al*., 2004). The general acceptable range of Cronbach's Alpha is between 0.7 and 0.8.

Table 6.1: Category of participants and response rate

Categories of sampled stakeholders	Mailed participants	Invitation declined	Number of participants	Number of respondents	Response rate per stakeholder (%)
	A	B	C=A/B	D	E (D/C) ×100
1 Architects	241	13	228	63	28%
2 Conservation officers	211	14	197	64	32%
3 Energy consultants	54	2	52	20	38%
4 Engineers	135	14	121	28	23%
5 Planning and development control officers	74	22	52	16	31%
6 Regulatory bodies	50	2	48	10	21%
7 Surveyors	50	10	40	10	25%
Total	815	77	738	211	29%*

* Average response rate of stakeholders

The Cronbach's Alpha based on standardised items for this study indicated a score of 0.76 for the entire measuring scale which is considered to be adequate for the test of reliability (Table 6.2). The scores of sub-scales on Cronbach's Alpha reliability coefficient, concerning inter-item consistency and reliability of the subscales employed, have been given exclusively before the commencement of interpretation for each of the analyses carried out.

Table 6.2: Reliability Statistics

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	ANOVA's Cochran's Q	ANOVA's Sig
All Questions with a 5-point scale	0.76	0.757	658.364	<0.01

6.4 Questionnaire Analysis

The questionnaire comprised of six parts (i.e. Section A - F (Appendix A) covering questions on information about the respondents' role and experience; professional values and priorities for conversion projects; energy efficiency for sustainable conversion of listed churches; perceived barriers to energy efficiency improvements to conversion projects; current practice and strategies adopted for successful energy efficiency improvements in past projects.

6.4.1 Representativeness of the respondents by geographical location

Table 6.3 shows the breakdown of responses received across the UK. The current location of respondents was categorised namely; England, Scotland, Wales and Northern Ireland. It could be observed from Table 6.3 that a good representative sample of all locations in

the UK was obtained which in turn ensures that the survey could give good results. England had the largest (181) number of responses, followed by Scotland (23), Wales (6) and Northern Ireland (1). These figures indicate a relatively balanced distribution of responses across the UK. Respondents were categorised into two: practising professionals (121) and policymakers (90). The practising professional group includes; architects, energy consultants, engineers and surveyors. The policymakers include; conservation officers, planning and development control officers, regulatory bodies' officers.

Table 6.3: Current Location of respondents and their Professional role

Location	Practicing professionals	Policy makers	Total
England	109	72	181
Scotland	10	13	23
Wales	1	5	6
Northern Ireland	1	0	1
Total	121	90	211

6.4.2 Regional locations of the different categories of stakeholders (respondents)

The regional breakdown of the different categories of the respondents is shown in Table 6.4. The administration in involvement of participants in the research was voluntary, and there was no obligation for those who were contacted to participate. Therefore, not all that were contacted were involved in the survey. For the purpose of this present research study, due to the level of response rate obtained, the responses gather from the survey were analysed on the basis of the regional location of the different categories of stakeholders.

Table 6.4: Representation of the respondents and responses by region

Respondents	E/M	E/E	G/L	N/E	N/W	S/E	S/W	W/M	Y/H	S/L	N/I	Wales	Total
Architects	3	14	10	4	4	14	7	3	0	3	1	0	63
Conservation officers	6	4	3	3	6	11	9	5	5	8	0	4	64
Energy Consultants	1	1	1	1	3	3	2	1	2	4	0	1	20
Engineers	1	2	5	0	3	6	5	1	3	2	0	0	28
Planning/development control officers	1	2	1	1	2	2	0	3	0	4	0	0	16
Regulatory bodies officers	0	1	1	0	1	3	1	1	0	1	0	1	10
Surveyors	0	2	0	0	2	2	1	0	0	1	0	0	8
Others	0	0	1	0	1	0	0	0	0	0	0	0	2
Total	12	26	22	9	22	41	25	14	10	23	1	6	211

E/M = East Midlands, E/E= East England, G/L= Greater London, N/E= North East, S/E= South East, S/W= South West, W/M= West Midlands, Y/H= York & Humber, S/L= Scotlands, N/I= Northern Ireland

6.4.3 Representative of respondents' work experience on heritage property

According to Table 6.5, most of the respondents (54%) have over 20 years' experience working on heritage property, 10% has industry experience ranging between 16 and 20 years, 17% has experience ranging between 11 to 15 years while 17% have at least 10 years or less. From the analysis, it could be observed that the majority (81%) of the respondents has more than 10 years working experience on heritage property which further shows that respondents are well experienced to provide credible data. As respondent experience, is quite important, opinions and views obtained through the survey can be regarded as important and reliable.

6.4.4 Respondents number of heritage refurbishment projects

Within the combined valid response, more than 20 projects are the leading heritage refurbishment projects reported by 140 respondents to have been carried out (Table 6.6). This result to 66% of the total estimated projects (i.e. 3,236) the entire respondents was involved in. This was followed by 15 to 20 projects (7%) were carried out by the respondents constituting a total of 73% (i.e. 2362) of the entire projects which the respondents have been involved making a significant proportion of the entire projects. It could be observed that only 20 per cent of the projects constitutes projects that are less than ten. Therefore, the higher number of heritage refurbishment projects of the respondents further reflects the intended focus of the research which is on LCBs.

Table 6.5: Respondents' work experience on heritage property

Respondents	None	1 - 5	6 – 10	11 - 15	16 - 20	>20	Total
Architects	0	4	2	9	5	43	63
Conservation officers	0	3	15	14	8	24	64
Energy consultants	3	3	4	2	0	8	20
Engineers	0	2	1	4	2	19	28
Planning/development control officers	0	1	1	5	2	7	16
Regulatory bodies officers	1	0	1	2	2	4	10
Surveyors	0	0	0	0	2	6	8
Others	0	0	0	0	0	2	2
Total	4	13	24	36	21	113	211
%	2%	6%	11%	17%	10%	54%	100%

Table 6.6 Number of heritage refurbishment projects, respondents has been directly involved

Respondents	None	1 - 5	6 – 10	11 - 15	16 - 20	> 20	Total
Architects	0	4	3	3	4	49	63
Conservation officers	3	3	3	1	1	53	64
Energy consultants	5	7	4	1	0	3	20
Engineers	0	8	6	0	2	12	28
Planning/development control officers	5	2	0	0	0	9	16
Regulatory bodies officers	1	2	0	1	0	6	10
Surveyors	0	0	0	2	0	6	8
Others	0	0	0	0	0	2	2
Total	14	26	16	8	7	140	211
%	7%	12%	8%	4%	3%	66%	100%

6.4.5 Geographical distribution of refurbishment projects on heritage buildings

The geographical location covered for the purpose of this research was divided into 4 Major geographical zones as follows; England, Scotland, Northern Ireland and Wales and further subdivided into 12 geographical zones namely: East Midlands, East England, Greater London, North East, North West, South East, West Midlands, York and Humber, South London, Northern Ireland and Wales. The geographical distribution of the respondents and the number of heritage refurbishment projects were taken into account and this is presented in Table 6.7. The total estimated number of projects carried by each respondent was calculated using the average mean of the number of projects.

The respondents from South East England were involved in 666 (21%) projects out of the total number of the projects across the UK. South West comes in second with 421 (13%), which was closely followed by Eastern England with 384 (12%) projects, Scotland with 348 (11%) projects with Greater London 323 (10%) projects among the top five. The lower end of the scale consists of the North West 306 (9%) projects, West Midlands 226 (7%) projects, East Midlands 179 (6%) projects, Wales 100 (3%) projects and Northern Ireland recorded the least with 3 projects presenting (0%).

6.4.6 Respondent's location and number of conversions of listed church projects

Observation from the result obtained revealed that 64% of respondents had been involved in about 774 conversion projects in listed churches. South East England which was top of the list carried out 146 conversions of listed church projects representing 18.9% of the total projects. This was followed by North West England with 102 projects (13.2%). East England came in third place with 24 indicating their involvement in 99 projects (12.8%).

Others were West Midlands with 90 projects (11.6%), South West 85 projects (11%) and Scotland 80 projects (10.3%). On the lower end of the list was North East with 47 projects (6.1%), York and Humber 41 projects (5.3%), Wales 31 projects (4.0%) and East Midlands 26 projects (3.4%). Response from England predominated since there are more listed churches in England than other parts of the country. Therefore, the opinions obtained through this survey tend to be more representative of respondents involved with a number of conversions of listed churches across the country. Table 6.8 shows the distribution of the number of listed church projects across the country.

Table 6.7: Geographical distribution of heritage building refurbishment projects carried out in the UK

Location	None	1 - 5	6 – 10	11 - 15	16 - 20	More than 20	Total	Percentage of respondents	Estimated number of projects	Percentage of project
E/M	1	1	2	0	0	8	12	6%	179	6%
E/E	2	3	3	1	1	16	26	12%	384	12%
G/L	2	4	0	1	1	14	22	10%	323	10%
N/E	2	0	0	2	0	5	9	4%	126	4%
N/ W	2	4	1	2	0	13	22	10%	306	9%
S/ E	1	3	6	1	2	28	41	19%	666	21%
S/ W	0	4	0	1	2	18	25	12%	421	13%
W/ M	1	2	0	0	0	11	14	7%	226	7%
Y/ H	0	2	1	0	0	7	10	5%	154	5%
SL	2	2	3	0	1	15	23	11%	348	11%
N/ I	0	1	0	0	0	0	1	0%	3	0%
Wales	1	0	0	0	0	5	6	3%	100	3%
Total	14	26	16	8	7	140	211	100%	3,236	100%

E/M = East Midlands, E/E= East England, G/L= Greater London, N/E= North East, S/E= South East, S/W= South West, W/M= West Midlands, Y/H= York & Humber, S/L= Scotlands, N/I= Northern Ireland

Table 6.8: Number of conversions of listed church projects by location

Number of listed Church projects	E/M	E/E	G/L	N/E	N/W	S/E	S/W	W/M	Y/H	S/L	Wales	Total	(%)
None	5	8	12	3	6	16	5	6	2	6	1	70	36
1 – 5	6	13	9	2	10	14	12	3	5	12	1	87	45
6 – 10	1	0	0	1	1	3	2	1	1	3	1	14	7
11 – 15	0	0	0	1	2	0	1	1	0	0	0	5	3
16 – 20	0	0	0	0	1	0	0	0	1	0	0	2	1
> 20	0	3	0	1	1	4	1	3	0	1	1	15	8
Total	12	24	21	8	21	37	21	14	9	22	4	193	100
Average No of projects	26	99	27	47	102	146	85	90	41	80	31	774	
%	3.4%	12.8%	3.5%	6.1%	13.2%	18.9%	11.0%	11.6%	5.3%	10.3%	4.0%		

6.4.7 Respondents' professional role and number of projects involved

Observation of the results obtained showed that practicing professionals (57%) were the leading with 121 respondents across the country while 90 respondents (43%) constitute the policy makers. The higher number of the 211 respondents was from England, constituting 86% (181) of the total respondents, Scotland (10%), Wales (3%) and Northern Ireland (0.5%). Table 6.9 shows further analysis of the total estimated number (3236) of conversion projects across the country with listed churches constituting 24% (774) with 21% (663) of the projects located in England, Scotland 3% (80), Wales 1% (31) and Northern Ireland none. The highest number of respondents and listed church projects from England, particularly East England was one of the basis for selecting it as the main geographical location used for the collection of field data for this study on building technical and energy use survey.

Table 6.9: Respondents' professional role and number of projects involved

Location	Practicing Professionals	Policy makers	Total	No. of projects	No of listed church projects	% churches
England	109	72	181	2785	663	24%
Scotland	10	13	23	348	80	23%
Northern Ireland	1	0	1	3	0	0%
Wales	1	5	6	100	31	31%
Total	121	90	211	3236	774	24%
	57%	43%	100%			

6.5 Factors Influencing Energy Use in Reuse of LCB Projects

6.5.1 Professional values and priorities applied to conversion projects

In order to determine the perception of the respondents towards energy use reduction in the reuse of PHBs, the respondents' professional values and priorities applied to reuse

of public heritage buildings was taken into consideration. Table 6.10 presents both the practicing professionals and the policy makers in the heritage industry indicated that it is important to reduce energy consumption in conversion projects involving public heritage buildings just as modern buildings. The results showed that 68.6 percent of respondents considered modernisation of public heritage buildings a priority at conversion to other uses, and 49% agree on focussing on upgrading the energy efficiency of the buildings during adaptation while the majority of the respondents (74%) agreed that monitoring energy use is important after conversion. Whilst 61 per cent of the respondents agreed that taking advantage of current technologies and incorporation of secondary glazing to windows could facilitate minimal energy use for conversion projects. On the other hand, the majority (44%) of the respondents disagrees with reducing the U-value of the building to reduce energy consumption while 58 per cent also disagree on economic payback period if less than 10 years (Figure 6.1).

Table 6.10: Perceived factors based on professional values and priorities applied to conversion projects

	Frequency of response					Descriptive statistics		
Factors	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	SD	Mean	Rank
Building modernisation	6 (3.1%)	26 (13.2%)	30 (15.2%)	89 (45.2%)	46 (23.4%)	1.06	3.73	2
Adaptation for energy efficiency	12 (6.1%)	36 (18.4%)	53 (27.0%)	70 (36.0%)	25 (13.0%)	1.10	3.31	5
Building energy management	2 (1%)	5 (3%)	44 (23%)	106 (55%)	37 (19%)	0.78	3.88	1
Using technologies	2 (1%)	15 (8%)	58 (30%)	97 (49%)	24 (12%)	0.83	3.64	3
Visual impact	4 (2%)	19 (10%)	54 (28%)	92 (47%)	27 (14%)	0.91	3.61	4
Reducing fabric U-value	15 (8%)	71 (36%)	55 (28%)	45 (23%)	9 (5%)	1.03	2.81	6
Energy saving payback	26 (13%)	89 (45%)	54 (27%)	19 (10%)	9 (5%)	0.99	2.47	7

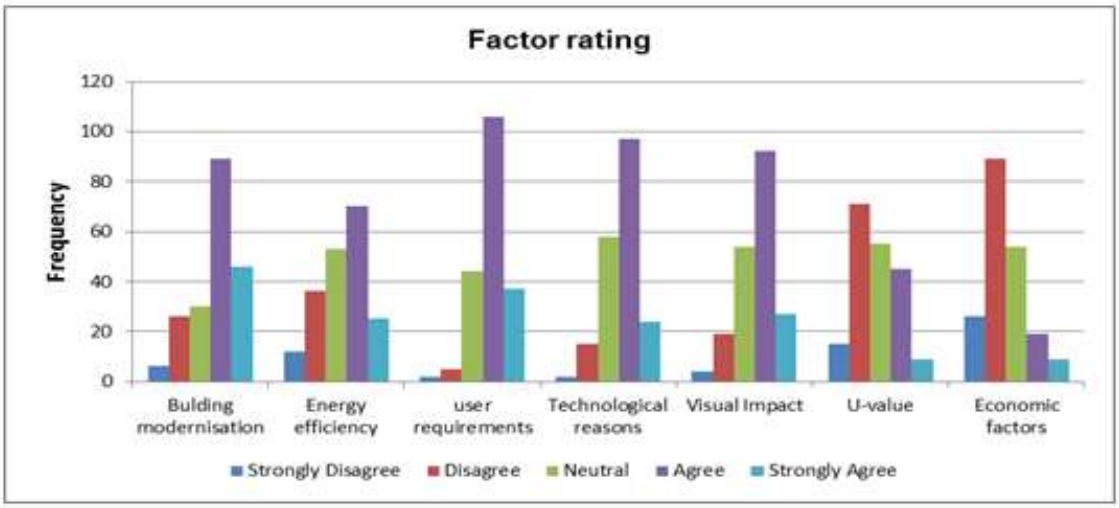


Figure 6.1: Factor rating based on professional values and priorities

6.5.2 Factors influencing the decision in the conversion of listed churches

An attempt was made to assess respondent's views on factors that influence their decision before listed churches are to be converted to other uses, especially in relation to sustainability of the reuse of the building. The results are presented in Table 6.11 and Figure 6.2. To investigate the extent to which energy efficiency for sustainable reuse is given priority in practice by respondents, they were asked to rank the factors that influence their decision using a 5-point scale (where '1= lowest' to '5 = highest'). This result suggests that on all the four propositions, conservation policies (mean = 4.44, SD = 0.80) were ranked the highest, performance for the intended use (mean = 3.50, SD = 1.11) was ranked second, life cycle cost (mean = 2.97, SD = 1.13) ranked third and sustainability in terms of energy efficiency (mean = 2.71, SD = 1.08) ranked the lowest. This implies that the respondents perceived conservation policies as the most critical decision in conversion projects.

Table 6.11: Perceived factors based on decision making

Decision influencing factors	Frequency - Respondents' ranking of the factors					Descriptive statistics		
	1	2	3	4	5	SD	Mean	Rank
Sustainability in terms of energy efficiency	20	29	43	26	4	1.08	2.71	4
Conservation policies	0	3	15	31	75	0.80	4.44	1
Performance for intended reuse	9	10	38	43	23	1.11	3.50	2
Lifecycle cost (capital cost, maintenance cost, repair cost)	16	22	45	30	10	1.13	2.97	3

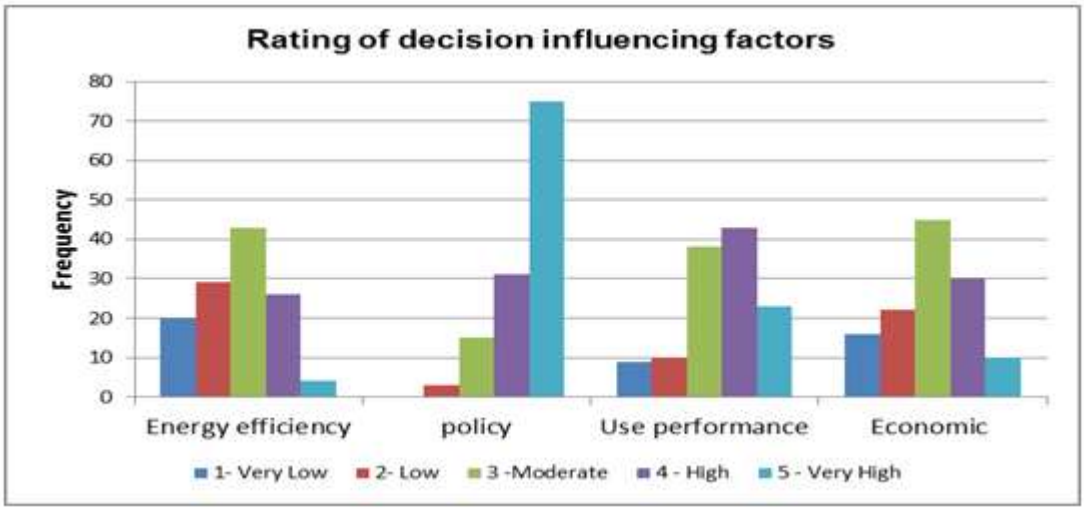


Figure 6.2: Rating of decision influencing factors

It could be observed that the respondents only ranked in the same direction on conservation policies, but ranked in the opposite direction in other factors. This finding was further investigated to test the significance of these factors using the Spearman rank order correlation (ρ). The Spearman Rank-Difference Correlation Coefficient is particularly useful in determining whether or not two people tend to agree with the ratings (Byrkit, 1987; Naoum, 1994). The Spearman's Rank Correlation Coefficient is commonly known as either *Spearman's Rho* or simply *rank correlation*. As there was

more than one category of respondents, it was performed in the category of respondents. Table 6.12 presents a summary of the results.

Table 6.12: Spearman's rank Correlation Coefficient test results on decision factors

	Mean		Spearman's Correlations	
Decision influencing factors	Professionals	Policy-makers	R-value	Sig (ρ)
Sustainability in terms of energy efficiency	3.075	2.273	-0.376	<0.01
Conservation policies	4.162	4.768	0.424	<0.01
Performance for intended reuse	3.824	3.091	-0.315	<0.01
Lifecycle cost (capital cost, maintenance cost, repair cost)	3.397	2.436	-0.424	<0.01

The result in Table 6.12 revealed that the professionals assigned high priority to performance for the intended use while sustainability in terms of energy efficiency was given lowest importance. Meanwhile, the policymakers concentrated only on the policy aspect and as well gave lowest importance of sustainability in terms of energy efficiency. However, when the level of significance is set at 0.05 the p value ($p < 0.01$) indicates a significant difference in respondents' rating on decision influencing factors on energy efficiency for sustainable conversion of listed churches. Thus, there is a significant difference amongst respondents with the policymakers group (mean rank = 2.273) contributing to this difference while the professionals overall ratings for energy efficiency is considerably higher than those of the policymakers.

6.5.3 Consideration of energy efficiency for sustainable church conversion projects

Table 6.13 and Figure 6.3 present the respondents rating on the considerations for sustainability in church conversion projects. The overall ranking, in ascending order is: conservation policies; users comfort; low energy operating cost; and low energy installation cost. The results show that conservation policies are consistently held in high consideration by the respondents in every project. Meanwhile, low energy consideration trails in the third and the least considered in the projects. The ranking of conservation policy as the most important is not unexpected as the policymakers' greatest obligation for any heritage building project is to ensure compliance with conservation policies.

Table 6.13: Energy efficiency as sustainable consideration factor for church conversion projects by ranking

Considerations for Church conversion	Frequency - Respondents' ranking of the factors							
	1	2	3	4	5	SD	Mean	Rank
Low energy installation costs	16	37	42	21	7	1.074	2.724	4
Low energy operational cost	16	18	42	37	10	1.140	3.057	3
Users comfort/productivity	6	13	43	46	15	0.999	3.415	2
Strict compliance to conservation Policies	0	5	25	40	52	0.884	4.139	1

While it was observed that the use performance is frequently the central concern of the practising professionals, it could be perceived that the gap lies in the understanding of operational sustainability measures that could be translated into concrete action plan at a project specific level. Thus, a lack of operational sustainability measures compatible with

heritage buildings could hamper the effective implementation of long term sustainable conversion projects.

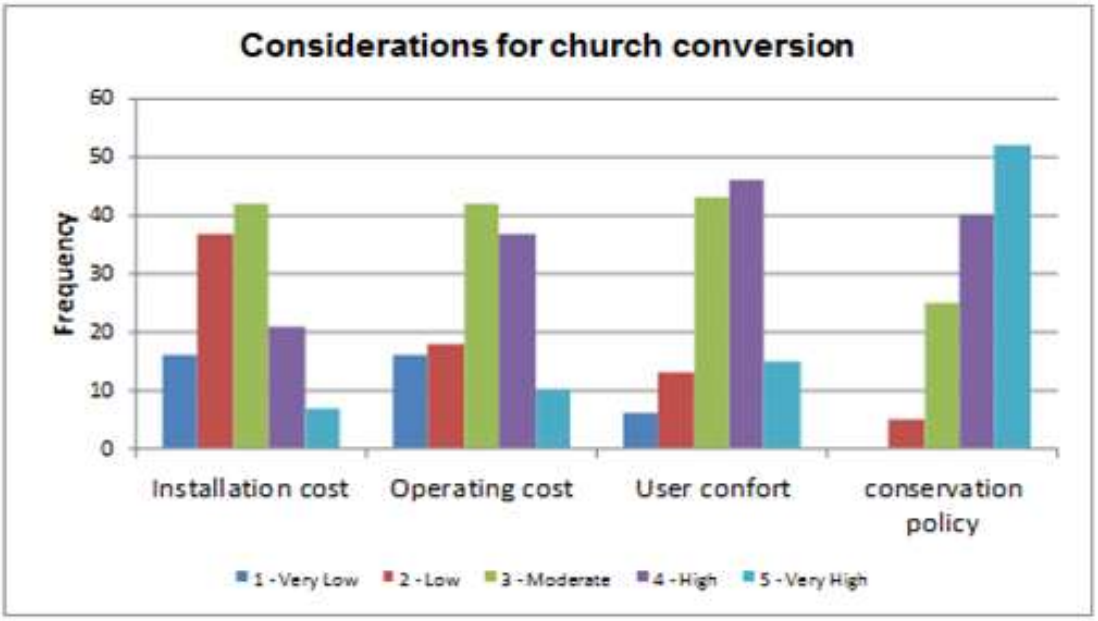


Figure 6.3: Rating of energy efficiency as sustainable consideration

When the Spearman's Rank Correlation Coefficient test was performed for energy efficiency as a sustainable consideration factor for church conversion projects, the result in Table 6.14 indicated that the p value ($\rho<0.01$) indicates significant differences in respondents' rating on decision influencing factors on energy efficiency for sustainable conversion of listed churches. Thus, there is a significant difference amongst respondents with the policymakers group (mean rank = 2.273) contributing to this difference while the professionals overall ratings for energy efficiency is considerably higher than those of the policymakers.

Table 6.14: Spearman's rank Correlation Coefficient test result of energy efficiency as sustainable consideration factor for church conversion projects

Considerations for Church conversion	Mean		Spearman's Correlations	
	Professionals	Policymakers	R-value	Sig (ρ)
Low energy installation costs	3.088	2.273	-0.39	<0.01
Low energy operational cost	3.529	2.473	-0.472	<0.01
Users comfort/productivity	3.809	2.927	-0.422	<0.01
Strict compliance to conservation Policies	3.985	4.327	0.218	0.016

6.5.4 Technical barriers to energy efficiency for sustainable reuse projects

In Figure 6.4 and Table 6.15, frequency analyses and descriptive statistics were used to report respondents' perceived barriers to energy efficiency improvements in conversion of public heritage buildings. The majority of the respondents (75.2%) agreed that listed churches are complex buildings with features limiting interventions on improving their energy efficiency. The outcome of the descriptive statistics shows that building complexity (mean = 3.85, SD = 0.99) top the highest among the technical barriers. Observation of the results revealed that 60.4 % of respondents ranked the risk of insulation of public heritage buildings as the second top technical barrier to improving energy efficiency for sustainability of the converted projects. However, the result shows that the decision of the respondents on other barriers were generally neutral. These include internal use of the space (mean = 3.33, SD = 0.90); energy efficiency not often considered as priority (mean = 3.26, SD = 1.07); unaffordability of sustainable options (mean = 3.16, SD = 0.99) and consideration to low energy consumption (mean = 2.63, SD = 0.98) which was ranked the lowest.

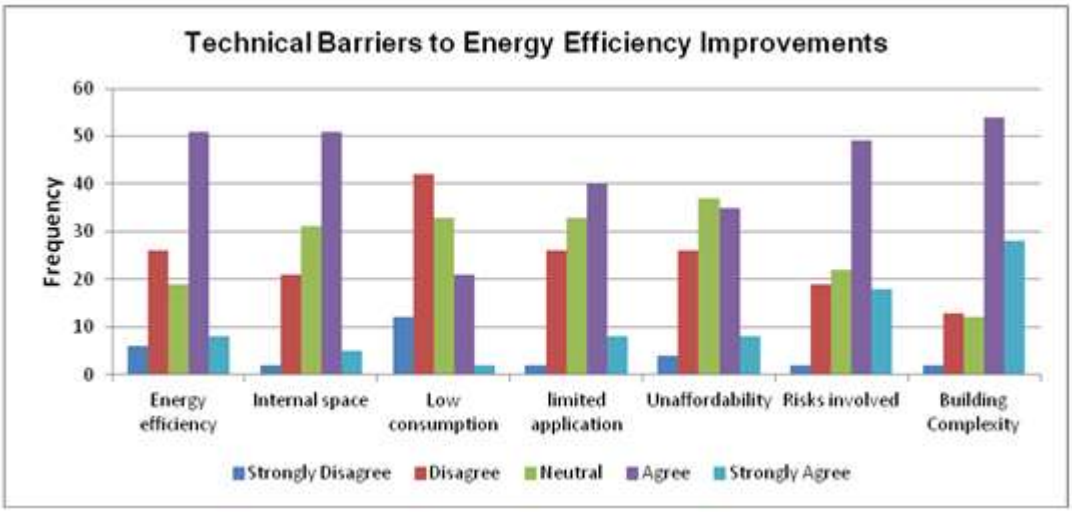


Figure 6.4: Rating of perceived technical barriers to energy efficiency

Table 6.15: Perceived technical barriers to energy efficiency improvement ranking

	Frequency of response					Descriptive statistics		
Technical barriers	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	SD	Mean	Rank
Energy efficiency	6 (5.6%)	26 (23.6%)	19 (17.3%)	51 (46.4%)	8 (7.3%)	1.072	3.264	4
Internal space	2 (1.8%)	21 (19%)	31 (28.2%)	51 (46.4%)	5 (4.6%)	0.900	3.327	3
Low consumption	12 (11%)	42 (38.2%)	33 (30%)	21 (19%)	2 (1.8%)	0.975	2.627	7
Limited application	2 (1.8%)	26 (24%)	33 (30.3%)	40 (36.7%)	8 (7.3%)	0.961	3.239	5
Unaffordability	4 (3.6%)	26 (24%)	37 (34%)	35 (32%)	8 (7.3%)	0.988	3.155	6
Risks involved	2 (1.8%)	19 (17.3%)	22 (20%)	49 (44%)	18 (16.4%)	1.018	3.564	2
Building Complexity	2 (1.8%)	13 (11.9%)	12 (11.0%)	54 (49.5%)	28 (25.7%)	0.998	3.853	1

This finding was further investigated using a non-parametric test to determine the significance of these factors using the Spearman rank order correlation (ρ). Table 6.16 shows that there is a significant degree of agreement among the practicing professionals and the policy makers as to the complexity of listed churches. However, even though the results show that there were some levels of consistency in the agreement of the

respondents on the other technical barriers, it could be observed there was no relationship between the remaining factors and conversion projects.

Table 6.16: Spearman's rank Correlation Coefficient test result on perceived technical barriers to energy efficiency improvements

	Mean		Spearman's Correlations	
Technical barriers	Professionals	Policymakers	R-value	Sig (ρ)
Energy efficiency	3.254	3.279	-0.001	0.995
Internal space	3.731	3.395	0.063	0.514
Low consumption	2.627	2.628	0.015	0.876
Limited application	3.242	3.233	-0.008	0.933
Unaffordability	3.164	3.140	-0.022	0.817
Risks involved	3.582	3.535	-0.059	0.543
Building Complexity	3.652	4.163	0.197	0.04

6.5.5 Policy and regulatory barriers to energy efficiency improvements

Figure 6.5, Table 6.17 and 6.18 showsthe results on the policy and regulatory barriers to energy efficiency improvements in reuse of PHBs. Although, listed church buildings are complex to deal with, recent planning guidance (PPS5 – 2010) still put more emphasis on sustainability when applications are made for changes to protected buildings. The local authorities are still required to look favourably at interventions that would lead to a net overall environmental gain in modification and reuse historic assets. Hence, the Government still encourages mitigation and adaptation to the effects of climate change with the aim to reduce carbon emissions and secure sustainable development.

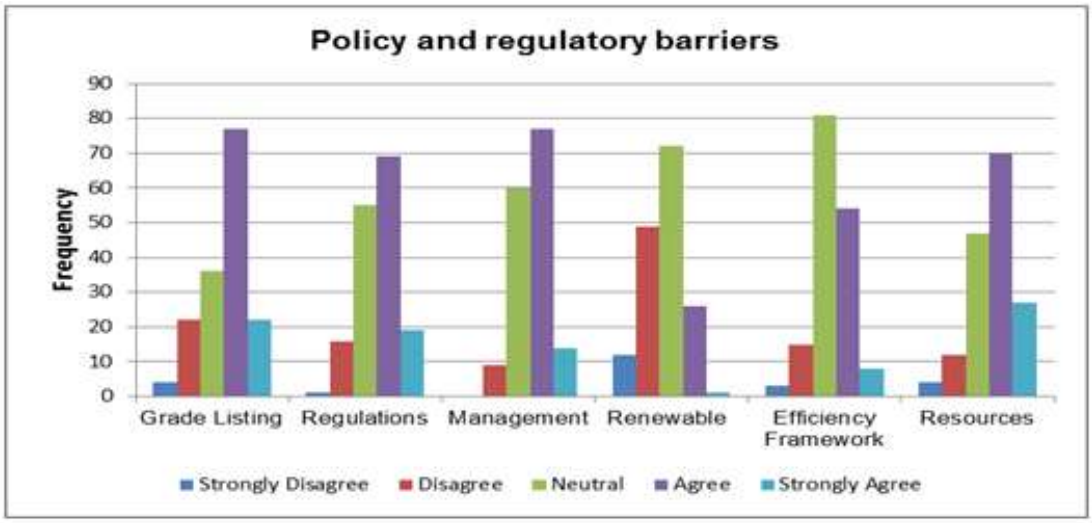


Figure 6.5: Rating of perceived policy and regulatory barriers to energy efficiency

Table 6.17: Perceived policy and regulatory barriers to energy efficiency improvements for sustainable conversion projects

	Frequency of response					Descriptive statistics		
Policy and Regulatory Barriers	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	SD	Mean	Rank
Grade Listing	4 (2.5%)	22 (13.7%)	36 (22.4%)	77 (47.8%)	22 (13.7)	0.97	3.56	3
Regulations	1 (0.6%)	16 (10%)	55 (34.4%)	69 (43.1%)	19 (11.9%)	0.85	3.56	3
Management	0 (0%)	9 (5.6%)	60 (37.5%)	77 (48.1%)	14 (9%)	0.73	3.60	2
Renewable	12 (7.5%)	49 (30.6%)	72 (45%)	26 (16.3%)	1 (0.6%)	0.85	2.72	6
Efficiency Framework	3 (1.9%)	15 (9.3%)	81 (50.3%)	54 (33.5%)	8 (5%)	0.78	3.30	5
Resources	4 (2.5%)	12 (7.5%)	47 (29.4%)	70 (43.6%)	27 (17%)	0.93	3.65	1

Table 6.18: Spearman's rank Correlation Coefficient test result of perceived policy and regulatory barriers

	Mean		Spearman's Correlations	
Policy and regulatory barriers	Professionals	Policymakers	R-value	Sig (ρ)
Grade Listing	3.596	3.516	-0.028	0.727
Regulations	3.612	3.468	-0.078	0.326
Management	3.639	3.540	-0.081	0.309
Renewable	2.877	2.468	-0.224	<0.01
Efficiency Framework	3.275	3.350	0.049	0.539
Resources	3.755	3.484	-0.134	0.091

Table 6.19 shows the Degree of acceptance (DoA) of the factors by the respondents according to their category.

Table 6.19: Respondents degree of acceptance (DoA) of factors influencing energy use reduction in LCBs

Factors		Professionals			Policymakers		
		D	N	A	D	N	A
Values and priorities factors							
F1	Building modernisation			√			√
F2	Adaptation for energy efficiency		√			√	
F3	Building energy management			√			√
F4	Using technologies			√			√
F5	Heritage visual impact			√			√
F6	Conflict over fabric U-value	√			√		
F7	Energy saving payback period	√			√		
Decision influencing factor							
F8	Sustainability in terms of energy efficiency		√		√		
F9	Conservation policies			√			√
F10	Performance for intended reuse			√		√	
F11	Lifecycle cost (capital cost, maintenance cost, repair cost)		√		√		
Energy reduction factor							
F12	Low energy installation costs		√		√		
F13	Low energy operational cost			√	√		
F14	Users comfort/productivity			√		√	
F15	Strict compliance to conservation Policies			√			√
Perceived technical barriers factor							
F16	Energy efficiency		√			√	
F17	Internal space			√		√	
F18	Low consumption	√			√		
F19	Limitations on sustainable options			√		√	
F20	Unaffordability		√			√	
F21	Risks of condensation			√			√
F22	Building Complexity			√			√
Perceived policy and regulatory barriers factor							
F23	Grade Listing			√			√
F24	Regulations			√			√
F25	Energy policy and awareness			√			√
F26	Restrictions on renewabless		√		√		
F27	Lack of adequate framework energy efficiency		√			√	
F28	Limited resources and grants			√			√

D = Disagree, N = Neutral, A = Agree

Table 6.20 shows the ranking and the degree of acceptance (DoA) of the factors according to their calculated mean values.

Table6.20: Ranking and the degree of acceptance of factors according to their calculated mean values

Code	Factors	Mean	DoA	Rank
F9	Conservation policies	4.436	Agree	1
F15	Strict compliance to conservation Policies	4.139	Agree	2
F3	Energy monitoring and analysis of energy consumption of public heritage buildings is important after conversion to other uses	3.881	Agree	3
F22	Listed churches are complex buildings with features limiting interventions on energy efficiency improvement	3.853	Agree	4
F1	It is just as important to reduce energy consumption in conversion projects of public heritage buildings as modern buildings.	3.726	Agree	5
F28	Inadequate resources and grants to encourage energy efficiency measures in conversion projects of listed churches	3.650	Agree	6
F4	With application of current technologies, energy consumption of public heritage buildings can be significantly minimised when they are converted to other uses	3.643	Agree	7
F5	Where possible with minimum visual impact on the character of public heritage buildings, secondary glazing should be incorporated to the windows during conversion to reduce their energy consumption	3.607	Agree	8
F25	Inadequate and/or absence of operational energy management policy and awareness	3.600	Agree	9
F23	Influence of grade listing (i.e. grade I,II*,II) on possible energy efficiency improvements	3.565	Agree	10
F21	Risks involved in the use of insulation that may lead to interstitial condensation in the walls or roof	3.564	Agree	11
F24	Government policies, regulations and requirements (e.g. Fits, VAT, etc.)	3.556	Agree	12
F10	Performance for intended reuse	3.496	Neutral	13
F14	Users comfort/productivity	3.415	Neutral	14
F17	Listed churches are often converted to other uses mainly for efficient use of their internal spaces	3.327	Neutral	15
F2	Adaptation of public heritage buildings should be done with focus to upgrade their energy efficiency	3.306	Neutral	16
F27	Inadequate energy efficiency framework disseminating effective strategies for conversion of listed churches	3.304	Neutral	17
F16	Energy efficiency is not often considered a priority for conversion projects	3.264	Neutral	18
F19	Most sustainable options in practice are limited in application to heritage buildings	3.239	Neutral	19
F20	Compatible and sustainable options for improving energy efficiency are capital intensive and unaffordable to owners	3.155	Neutral	20
F13	Low energy operational cost	3.057	Neutral	21
F11	Lifecycle cost (capital cost, maintenance cost, repair cost)	2.968	Neutral	22
F6	Significant reduction in energy use could only be achieved by reducing the U - value of the building at conversion	2.805	Neutral	23
F12	Low energy installation costs	2.724	Neutral	24
F26	Too much restrictions on renewable energy installations on listed churches	2.719	Neutral	25
F8	Sustainability in terms of energy efficiency	2.713	Neutral	26
F18	Little or no consideration is given to how their energy consumption can be minimised	2.627	Neutral	27
F7	Energy saving measures in conversion of public heritage buildings only make sense if payback is less than 10 years	2.472	Disagree	28

6.6 Quantitative Research Objectives

Checkland (1981) soft system methodology (SSM) approach based on systems theory was explored as the primary theoretical framework for this study. According to SSM, a general orientation is required to sustain a holistic, critically reflective position that seeks to integrate individual and collective perception of issues in their society and environments. It postulates that the reality that affects the existence of social institutions depends not only on what the issue is, but on what its "key influencers" perceive it to be. Thus, the SSM orientation allowed for integrated and complete interpretation of the perspectives of key stakeholders and using the sequential explanatory design (Creswell, 2003), the data from the following research objectives were assessed quantitatively:

1. To investigate the perceptions, priorities and values of stakeholders in heritage building industry and its influence on energy use reduction in reuse of public heritage buildings (LCBs).
2. To identify and establish the relative importance of the most sustainable strategies perceived and implemented in practice by the stakeholders to improve energy efficiency in the reuse of LCBs.
3. To determine the critical factors responsible for energy use in LCBs arising from stakeholders' perceptions that need to be addressed to improve energy performance.

6.6.1 Analysis of research objective 1

In order to achieve this objective, "To investigate the perceptions, priorities and values of stakeholders in heritage building industry and its influence on energy use reduction in the reuse of LCBs". Respondents' answers to three items included perception (i.e. Item 5 - general perception; 11 and 12 - perception of technical, policy and regulatory barriers) were scored in such a way that the responses on "strongly agree" was allotted a score of

5; responses on "agree" was scored 4; responses on "neither agree nor disagree" was scored 3; responses on "disagree" was scored 2 while responses on "strongly disagree" was scored 1. The resulting scores were cumulated to constitute a measure of the respondents' perception, priorities and values. On this measure, the maximum score was 81 while the minimum score was 11 with a mean value of 52.72 and a standard deviation of 18.24. The resulting measure was subjected to a binary logistic regression analysis to determine its ability to predict the adoption of giving strategies in item 18 in conversion projects to improve energy efficiency. The result is presented in Table 6.21. The adoption of the strategy was dummy-coded 0 for non-adoption of the strategy while 1 was dummy-coded for adoption of the strategy. In terms of adopting improvements of the building fabric to reduce U-value, it can be seen from Table 6.21 that the Wald statistic obtained in the test was 12.04 at the significance value of 0.001.

Since the value fails to attain the 0.05 threshold, it can be concluded that stakeholders' choice of adopting the improvement of the building fabric to reduce the U-value, is influenced by their perception. However, to confirm this, the -2 log likelihood value is presented as 255.468, which is fairly high and in accordance with the recommendations of Fields (2005) caution needs to be taken in concluding that the model could be good in the prediction of the strategies from the stakeholders' perception. In order to represent the overall model fit, the Cox and Snell R^2 and the Nagelkerke R^2 values categorized as pseudo R^2 are indicated in Table 6.21. The pseudo R^2 measures are interpreted in a similar way to the coefficient of determination in a multiple regression.

In other words, the Cox and Snell R^2 and the Nagelkerke R^2 values are interpreted to reflect the amount of variation accounted for by the logistic regression model, with 1.0 indicating a perfect model fit (Hair *et al.*, 2005). It could be observed that the Nagelkerke R^2 value is 0.084, meaning that a significant relationship to 8.4% can be found between stakeholders' perception and their adoption of improving the building fabric to reduce the U-value as a strategy for energy use reduction in the reuse of LCB projects . In addition, it can be seen from Table 6.21 that the odds ratio as expressed by Exp (B) = 1.029 and since it surpasses the threshold of 1.00; it can be deduced that any increase in the stakeholders' perception, priorities and values concerning energy use in the reuse of LCB projects will increase the odds of adoption of the strategy adopted for energy use reduction in the projects. This interpretation also goes for the choice of other strategies such as the building service upgrade, smart metering and energy management policy and awareness.

For other strategies such as energy management system, smart lighting control and renewable installations, it can be seen from the table that the significance value of the Wald statistic obtained was greater than 0.05. Since the value surpasses the 0.05 threshold, it is notable from the results that respondents' choice of adopting the stated strategies was not influenced by their perception. As it can be seen (Table 6.21) that the -2 log likelihood value were also very high and in accordance with the recommendations of Fields (2005), it can be concluded that the model would not be sufficient to predict the strategies adopted from the respondents' perception.

Table 6.21: Influence of stakeholders' perception, priorities and values on the strategies adopted for energy use reduction in the reuse of LCB projects

	Model Summary			Variables in the Equation						
Strategies Adopted	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2	Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Q 18_1 **(Improving building fabric to reduce U value)**	**255.468**	.063	**.084**	**Perception**	0.029	.008	**12.040**	1	**.001**	**1.029**
				Constant	-1.191	.457	6.796	1	.009	0.304
Q18_2 **(Building services upgrade)**	**256.671**	.047	**.063**	**Perception**	0.025	.008	**9.087**	1	**.003**	**1.025**
				Constant	-.911	.450	4.105	1	.043	.402
Q18_3 **(Energy management system)**	**244.788**	.011	**.015**	**Perception**	.013	.009	**2.080**	1	**.149**	**1.013**
				Constant	-1.425	.496	8.256	1	.004	.241
Q18_4 **(Smart lighting control)**	**259.988**	.009	**.012**	**Perception**	.011	.008	**1.757**	1	**.185**	**1.011**
				Constant	-1.068	.466	5.243	1	.022	.344
Q18_5 **(Smart metering)**	**180.661**	.033	**.054**	**Perception**	.029	.012	**5.924**	1	**.015**	**1.029**
				Constant	-3.090	.711	18.869	1	.000	.045
Q18_6 **(Renewables installations e.g. Solar, Geothermal, Biomass etc.)**	**261.756**	.005	**.007**	**Perception**	.008	.008	**.963**	1	**.326**	**1.008**
				Constant	-.890	.459	3.750	1	.053	.411
Q18_7 **(Operational energy management policy and awareness)**	**245.240**	.043	**.059**	**Perception**	.026	.009	**8.005**	1	**.005**	**1.026**
				Constant	-2.020	.524	14.884	1	.000	.133

In addition, it could be seen that the Nagelkerke R^2 value were generally low, meaning that there were very mild or no relationship between the respondents' perception and their adoption of the stated strategies for energy use reduction. However, the odds ratios as expressed by Exp (B), were all greater than 1.00. Since the odds ratio surpasses the threshold of 1.00, it can be concluded that any increase in the stakeholders' perception, priorities and values concerning energy use in the reuse of LCB projects concerning will increase the odds of adoption of the stated strategies for energy use reduction in reuse of the projects.

In order to test if there is a difference in the stakeholders' perception, priorities and values regarding energy use reduction in LCBs, the respondents' scores were subjected to One Way Analysis of Variance (ANOVA). The differentiating variables used includes their status, such as their profession or role in the heritage industry, their geographical base, their number years of working experience on heritage building projects and the number of refurbishment projects they have been directly involved. Moore and McCabe (1989) described the ANOVA test as a statistical method to compare the means of two or more groups and to determine if at least one group mean is different from the others. As test results have shown that data collected for this study are normally distributed, parametric ANOVA tests were considered appropriate to be used. The F-ratio in the results is used to determine statistical significance. Thus, the result of the test of difference on the basis of the respondents' profession or role in the heritage industry is presented in Table 6.22.

Table 6.22: Test of difference in the perception of the stakeholders on the basis of their profession and/or role in heritage industry

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6008.071	7	858.296	2.740	.010
Within Groups	59209.574	189	313.278		
Total	65217.645	196			

The result from Table 6.22 shows that the F-value obtained in the test was 2.740 at a p-value of 0.010. Since the p-value is less than 0.05, it can therefore be concluded that the stakeholders differ in their perception, priorities and values regarding energy use reduction in LCBs on the basis of their profession or role in the heritage industry. Meanwhile, since the F-value is significant, there is need to trace the source of the significant difference obtained in the stakeholders' perception, priorities and values, therefore a post-hoc multiple comparison tests was conducted via Tukey HSD (Honestly Significant Difference) and the result is presented in Table 6.23.

It can be deduced from Table 6.23 that Engineers seem to have the best perception, priorities and values regarding energy use reduction in LCBs. Their perception was significantly better than those of the energy consultants (mean difference = 16.74) and conservation officers (mean difference = 15.38). Although, conservation officers were found to possess better perception (mean difference = 1.37), the difference was not found to be significant. All other stakeholders were not found to be significantly different in their perception regarding energy use reduction in LCBs.

Table 6.23: Post-hoc multiple comparison test on source of difference stakeholder perception

(I) Profession and/or role in heritage industry	(J) Profession and/or role in heritage industry	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Architects	Conservation Officers	5.57701	3.25924	.680	-4.4132	15.5673
	Energy Consultants	6.94192	4.67864	.815	-7.3991	21.2829
	Engineers	-9.80077	4.12362	.259	-22.4405	2.8390
	Planning/Development Control Officers	5.18534	4.99812	.968	-10.1349	20.5056
	Regulatory Bodies Officers (e.g. English Heritage)	2.18534	6.67541	1.000	-18.2762	22.6468
	Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	5.73892	7.08205	.992	-15.9690	27.4468
	Others	-14.68966	12.72951	.944	-53.7082	24.3289
Conservation Officers	Architects	-5.57701	3.25924	.680	-15.5673	4.4132
	Energy Consultants	**1.36491**	4.65936	1.000	-12.9170	15.6468
	Engineers	**-15.37778***	4.10173	**.006**	-27.9504	-2.8051
	Planning/Development Control Officers	-.39167	4.98008	1.000	-15.6566	14.8733
	Regulatory Bodies Officers (e.g. English Heritage)	-3.39167	6.66191	1.000	-23.8118	17.0285
	Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	.16190	7.06932	1.000	-21.5070	21.8308
	Others	-20.26667	12.72244	.754	-59.2635	18.7302
Energy Consultants	Architects	-6.94192	4.67864	.815	-21.2829	7.3991
	Conservation Officers	-1.36491	4.65936	1.000	-15.6468	12.9170
	Engineers	**-16.74269***	5.30012	**.038**	-32.9886	-.4968
	Planning/Development Control Officers	-1.75658	6.00568	1.000	-20.1652	16.6521
	Regulatory Bodies Officers (e.g. English Heritage)	-4.75658	7.45977	.998	-27.6223	18.1091
	Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	-1.20301	7.82575	1.000	-25.1905	22.7845
	Others	-21.63158	13.15779	.723	-61.9629	18.6997
Engineers (e.g. Mechanical, Electrical etc.)	Architects	9.80077	4.12362	.259	-2.8390	22.4405
	Conservation Officers	**15.37778***	4.10173	**.006**	2.8051	27.9504
	Energy Consultants	**16.74269***	5.30012	**.038**	.4968	32.9886
	Planning/Development Control Officers	14.98611	5.58415	.134	-2.1305	32.1027
	Regulatory Bodies Officer (e.g. English Heritage)	11.98611	7.12479	.699	-9.8528	33.8251
	Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	15.53968	7.50712	.438	-7.4712	38.5506
	Others	-4.88889	12.97081	1.000	-44.6471	34.8693

Table 6.23 (Contd): Post-hoc multiple comparison test on source of difference stakeholder perception

Planning/ Development Control Officers	Architects	-5.18534	4.99812	.968	-20.5056	10.1349
	Conservation Officers	.39167	4.98008	1.000	-14.8733	15.6566
	Energy Consultants	1.75658	6.00568	1.000	-16.6521	20.1652
	Engineers (e.g. Mechanical, Electrical etc.)	-14.98611	5.58415	.134	-32.1027	2.1305
	Regulatory Bodies Officer (e.g. English Heritage)	-3.00000	7.66418	1.000	-26.4923	20.4923
	Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	.55357	8.02084	1.000	-24.0320	25.1391
	Others	-19.87500	13.27475	.808	-60.5648	20.8148
Regulatory Bodies Officers (e.g. English Heritage etc.)	Architects	-2.18534	6.67541	1.000	-22.6468	18.2762
	Conservation Officers	3.39167	6.66191	1.000	-17.0285	23.8118
	Energy Consultants	4.75658	7.45977	.998	-18.1091	27.6223
	Engineers (e.g. Mechanical, Electrical etc.,)	-11.98611	7.12479	.699	-33.8251	9.8528
	Planning/Development Control Officers	3.00000	7.66418	1.000	-20.4923	26.4923
	Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	3.55357	9.16045	1.000	-24.5251	31.6322
	Others	-16.87500	13.99281	.929	-59.7658	26.0158
Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	Architects	-5.73892	7.08205	.992	-27.4468	15.9690
	Conservation Officers	-.16190	7.06932	1.000	-21.8308	21.5070
	Energy Consultants	1.20301	7.82575	1.000	-22.7845	25.1905
	Engineers (e.g. Mechanical, Electrical etc.)	-15.53968	7.50712	.438	-38.5506	7.4712
	Planning/Development Control Officers	-.55357	8.02084	1.000	-25.1391	24.0320
	Regulatory Bodies Officer (e.g. English Heritage)	-3.55357	9.16045	1.000	-31.6322	24.5251
	Others	-20.42857	14.19130	.838	-63.9278	23.0707
Others	Architects	14.68966	12.72951	.944	-24.3289	53.7082
	Conservation Officers	20.26667	12.72244	.754	-18.7302	59.2635
	Energy Consultants	21.63158	13.15779	.723	-18.6997	61.9629
	Engineers (e.g. Mechanical, Electrical etc.)	4.88889	12.97081	1.000	-34.8693	44.6471
	Planning/Development Control Officers	19.87500	13.27475	.808	-20.8148	60.5648
	Regulatory Bodies Officers (e.g. English Heritage etc.)	16.87500	13.99281	.929	-26.0158	59.7658
	Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.)	20.42857	14.19130	.838	-23.0707	63.9278

*. The mean difference is significant at the 0.05 level.

Concerning the respondents' difference with regards to their current location, scores on perception, priorities and values regarding energy use reduction in LCBs were subjected

to One Way ANOVA using their current location as the differentiating variable. The result is presented in Table 6.24.

Table 6.24: Test of difference in the perception of the stakeholders on the basis of their current location

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5818.047	10	581.805	1.822	.059
Within Groups	59399.598	186	319.353		
Total	65217.645	196			

Table 6.24 shows the difference in the stakeholder perception regarding energy use reduction in LCBs on the basis of their current location. It can be seen from the table that the F-value obtained in the test was 1.822 at p-value of 0.059. Since the P-value is greater than 0.05, therefore, it can be concluded that stakeholders do not differ in their perception regarding energy use reduction in LCBs on the basis of their current location. The years of working experience of the stakeholders on heritage property were also used to differentiate their perception via one-way ANOVA. The result is presented in Table 6.25.

Table 6.25: Test of difference in the perception of the stakeholders on the basis of their years of working experience on heritage property

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	577.996	5	115.599	.342	.887
Within Groups	64639.649	191	338.427		
Total	65217.645	196			

Table 6.25 shows the difference in the stakeholder perception regarding energy use reduction in LCBs on the basis of their years of working experience on heritage property. It can be seen from the table that the F-value obtained in the test was 0.342 at p-value of 0.887. Since the P-value is greater than 0.05, Thus, it can be concluded that stakeholders do not differ in their perception regarding energy use reduction in LCBs on the basis of their years of working experience on heritage property. Finally, the study also sought for differences in stakeholders' perception, priorities and values on the basis of the number of heritage refurbishment projects earlier involved with directly via one-way ANOVA and the result is presented in Table 6.26.

Table 6.26: Test of difference in the perception of the stakeholders on the basis of the number of heritage refurbishment projects earlier involved with directly

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2841.837	5	568.367	1.740	.127
Within Groups	62375.808	191	326.575		
Total	65217.645	196			

Table 6.26 shows the difference in the stakeholders' perception regarding energy use reduction in LCBs on the basis of the number of heritage refurbishment projects earlier involved with directly. It can be seen from the table that the F-value obtained in the test was 1.740 at p-value of 0.127. Since the P-value is greater than 0.05, it can therefore be concluded that stakeholders do not differ in their perception regarding energy use reduction in LCBs on the basis of the number of heritage refurbishment projects earlier involved with directly.

Objective 2**:** To identify and establish the relative importance of the most sustainable strategies perceived and implemented in practice by the stakeholders to improve energy performance in the reuse of LCBs.

6.6.2 Research objective 2

In order to achieve this objective, "To identify and establish the relative importance of the most sustainable strategies perceived and implemented in practice by the stakeholders to improve energy efficiency in the reuse of LCBs. Item 18 of the online perception survey (OPS) was given a descriptive analysis. Since the respondents were given the opportunity of selecting more than one of the strategies, the descriptive analysis was limited to presenting those who adopt or do not adopt given strategies. The result is presented in Table 6.27.

Table 6.27: Sustainable strategies implemented for energy use reduction by heritage professionals in their projects

Strategies	Implemented by		Not implemented by	
	f	%	f	%
Improvements to building fabric to reduce U- value	114	54.0	97	46
Building services upgrade	117	55.5	94	44.5
Energy management system	63	29.9	148	70.1
Smart lighting control	75	35.5	136	64.5
Smart metering	36	17.1	175	82.9
Renewable installations (e.g. solar, geothermal, biomass)	76	36.0	135	64.0
Operational energy management policy & awareness	68	32.2	143	67.8
Others (careful attention to air leakage; draughtproofing of windows, passive design features, secondary glazing, voltage reduction, etc.)	14	6.6	197	93.4

Table 6.27 shows the sustainable strategies that have been implemented by heritage professionals for energy use reduction in their projects. It can be seen from the table that "Building services upgrade" is the most popular sustainable strategy commonly used by heritage professionals as it was indicated to be adopted by the largest proportion of the respondents (55%). This was closely followed by those who adopt "Improvements to the building fabric to reduce U-value". Among the listed strategies the least popular is the "smart metering" strategy which was identified by the least proportion (17.1%) of the respondents.

6.6.3 Relative significance index

In order to find out if there is any relationship between strategies adopted as the most sustainable options for energy use reduction in the reuse of LCBs and what the respondents perceived as indicators of successful reuse projects, relative significance index (RSI) was employed. The use of relative importance/significance has been widely used and tested extensively in similar types of surveys by many researchers across the globe such as (Olomolaiye *et al.*, 1987; Kometa *et al.*, 1994; Chan and Kumaraswamy, 1997; Chinyio et *al.* 1998b; Adetunji et *al*. 2003; Braimah and Ndekugri, 2009; Henjewele *et al.*, 2012).

According to Chinyio *et al.* (1998b), RSI is recognised as an excellent approach for aggregating the scores of the variables rated on an ordinal scale by respondents and have since been demonstrated to be useful reporting prevalence data. Thus, the relative significance index (RSI) was considered appropriate to use and the values of the strategies

adopted were obtained and compared using Spearman Rank Order correlation. The results are presented in Tables 6.28, 6.29, and 6.30. It can be seen from the result obtained from Table 6.28 that the most popularly identified sustainable option for energy use reduction in reuse of LCBs is "Building services upgrade" with the highest RSI value of 0.785 while the respondents ranked the least "Consideration and application of renewable technologies" with the smallest value of RSI (0.560).

Table 6.28: Relative significance index (RSI) and rank of strategies for energy use reduction in the reuse of LCBs as adopted by respondents

	1	2	3	4	5	NR	RSI	Rank
Upgrading and improvement to building fabric to reduce its U-value	23	29	35	40	28	56	0.627	4
Building services upgrade	4	8	32	63	48	56	0.785	1
Consideration and application of renewable technologies	21	41	51	32	10	56	0.560	5
Incorporation of building energy management system	11	21	50	50	21	58	0.664	3
Users behaviour change	4	11	36	51	48	61	0.771	2

NR = Number of Responses, RSI = Relative Significance Index

A similar treatment was extended to indicators of successful conversion projects and the result is presented in Table 6.29.

Table 6.29: Relative significance index (RSI) and ranks of indicators of successful conversion projects as perceived by respondents

	1	2	3	4	5	NR	RSI	Rank
Perform the functions well for which they are redesigned and/or converted	1	5	28	57	66	54	0.832	2
Respond well to their surroundings and enhance their context	4	6	27	66	54	54	0.804	3
Improved energy performance and carbon emissions reduction after conversion	6	23	50	54	21	57	0.679	6
Conversion is reversible and the building can be reinstated to its former use.	9	23	44	44	35	56	0.694	5
Design interventions are sympathetic with the character of the building	1	3	15	48	86	58	0.881	1
Improve users comfort	6	13	53	54	21	64	0.697	4

NR = Number of Responses, RSI = Relative Significance Index

Table 6.29 presents the relative significance of indicators of successful conversion projects as perceived by respondents. It can be seen from the table that the most popularly identified indicators of successful conversion projects are "Design interventions are sympathetic with the character of the building" with the highest RSI value of 0.881 while the respondents ranked the least "Improved energy performance and carbon emissions reduction after conversion" with the lowest value of RSI (0.679). These two sets of RSI values were then subjected to Spearman Rank Order Correlation and the result is presented in Table 6.30.

Table 6.30: Rank Order relationship between sustainable options for energy use reduction in reuse of LCBs and indicators of successful reuse projects

			RSI (1)	RSI (2)
Spearman's rho	RSI1	Correlation Coefficient	1.000	.500
		Sig. (2-tailed)	.	.391
		N	5	5
	RSI2	Correlation Coefficient	.500	1.000
		Sig. (2-tailed)	.391	.
		N	5	6

From Table 6.30 it can be seen that although there appears to be a moderate relationship between sustainable options for energy use reduction in the reuse of LCBs and indicators of successful reuse projects, the relationship was, however, not significant as the p-value (0.391) was greater than 0.05. The findings obtained from Table 6.28 and 6.29 was combined to determine the respondents' priorities in their approach to addressing energy use reduction and their perception of indicators of successful reuse projects in the reuse of LCBs. Table 6.30 was developed to present the combined findings. It can be seen from the result of the overall RSI and rank of current practice/strategies that the top ranks (i.e. 1-3) still remain design interventions indicating the respondents' top priorities for these projects. Building services upgrade ranked 4th; 'Users behaviour change' ranked the fifth, 'Improve user comfort' ranked the sixth.

It could be concluded from Table 6.31 that the importance given to environmental sustainability by the respondents in practice is very low (i.e. 'Improved energy performance' and 'building energy management system') ranked 7th and 9th respectively. Thus, it could be argued that this consistent lack of making environmental sustainability for heritage building project top priorities discovered from the findings

of this study could be perceived to be responsible for the poor energy performance of many of these buildings. Basically, these strategies or approaches in current practice are interpreted as a moderating factor influencing energy consumption in the reuse of LCBs projects.

Table 6.31: Combined ranking of current practice/strategies (i.e. Moderating factors)

Current practice/strategies	Mean	SD	RSI	Rank
Design interventions are sympathetic with the character of the building	4.405	0.798	77%	1
Perform the functions well for which they are redesigned and/or converted	4.159	0.873	75%	2
Respond well to their surroundings and enhance their context	4.019	0.951	74%	3
Building services upgrade	3.923	0.977	72%	4
Users behaviour change	3.853	1.039	71%	5
Improve users comfort	3.483	0.982	67%	6
Improved energy performance and carbon emissions reduction after conversion	3.396	1.025	65%	7
Conversion is reversible and the building can be reinstated to its former use.	3.471	1.164	65%	7
Incorporation of building energy management system	3.320	1.098	64%	9
Upgrading and improvement to building fabric to reduce its U-value	3.135	1.324	59%	10
Consideration and application of renewable technologies	2.800	1.113	55%	11

Based on the stakeholder theory which forms the theoretical perspective adopted for analysis in this chapter, some proponents of this theory, such as Kaler (2003); Simmons (2004) Steurer (2006) posits that 'an organisation that adopts a more inclusive approach towards the groups it interacted with, could improve its performance and the society would benefit'. Meanwhile, Bryson (2004: p.23) argued that "the inability to attend to information from stakeholders could result in action that too often and too predictably

leads to poor performance, outright failure or even disaster", therefore, the respondents were asked to indicate, suggest and recommend in the survey, strategies they adopted that have achieved success to a significant extent in improving energy performance in their past project.

Table 6.32 presents the stakeholders proposed strategies and recommendations for long term sustainable reuse of LCBs projects. It can be seen from Table 6.32 that the proposed recommendations consist of fourteen (14) strategies with their percentage relative importance (RSI) quantified by the relative importance index method. The ranking of the proposed strategies and recommendations is also demonstrated according to their importance level. It can be seen from Table 6.32 that the three top leading recommendations are energy management (ranked 1st) as the most sustainable strategies for energy use reduction in the reuse LCBs although with a lower (29.9%) of response than calculated RSI. Followed by smart metering (ranked 2nd) and operational energy management awareness and policy (ranked 3rd). Renewable installations (ranked 4t^{h}) before consideration is given to other innovative strategies which may include strategies ranked from 5th – 13th in the table.

Table 6.32: Ranking of strategies and recommendations for long term sustainability

Code	Strategies /recommendations	% of total responses	RSI	Rank
Q18_3	Energy management system	29.9%	62%	1
Q18_5	Smart metering	17.1%	60%	2
Q18_7	Operational energy management policy & awareness	32.2%	59%	3
Q18_6	Renewable installations (e.g. solar, geothermal, biomass)	36.0%	58%	4
Q6_6	Other innovative suggestions	10.4%	56%	5
Q18_2	Building services upgrade	55.5%	56%	5
Q6_3	A framework disseminating effective strategies for conversion projects	33.2%	54%	7
Q18_4	Smart lighting control	35.5%	54%	7
Q18_1	Improvements to building fabric to reduce U-value	54.0%	53%	9
Q6_2	Award schemes to promote and encourage best practice	42.7%	51%	10
Q6_1	Flexibility to building regulation requirements	50.2%	51%	10
Q6_5	Sustainability scheme for heritage buildings	41.2%	50%	12
Q6_4	Local authority supplementary guidance	32.7%	48%	13
Q18_8	Others (careful attention to air leakage; draughtproofing of windows, passive design features, secondary glazing, voltage reduction, etc.)	6.6%	48%	13

According to the findings from Table 6.32 it can be seen that RSI is highly comparable to simple percentages in interpreting prevalence data and a better one as it reduces error and bias commonly evident in ranking prevalence and relative positioning of data. It could, therefore, be argued that the use of RSI is reliable for this result as unbiased prevalent data was needed to be drawn and interpretation is easier and more error-free compared to the use of a simple percentage.

6.7 Factor Analysis

To achieve part of the objective of this study, factor analysis was also employed to analyse the responses from the survey.

Research Objective 3: To determine the critical factors responsible for energy use in the reuse of LCBs arising from stakeholders' perceptions that need to be addressed to improve energy performance.

In order to achieve research objective 3 stated above, items 5, 11 and 12 on the online perception survey were subjected to factor analysis. Factor analysis is a multivariate statistical procedure that has been applied by a number of researchers in many fields of research (Hogarty *et al.,* 2005) as a method of choice for interpreting self-reporting questionnaires (Bryant and Yarnold 1995) with many uses (Hair *et al.,* 1995; Thompson 2004; Tabachnick and Fidell, 2007). This method was used to allow for the investigation of the strongest factors. Starting with the original data matrix and using multiple correlations as the estimates of commonalities, principal factors were extracted after interacting of commonalities. Factors with Eigen value greater than 1 were retained for rotation. From principal component analysis, the procedures yielded two factors and seven component factors and are defined in Table 6.33.

Table 6.33: Rotated Component Matrixa result for factor distributions

	Component						
	1	2	3	4	5	6	7
Adaptation for energy efficiency	.848						
Building modernisation	.831						
Building energy management	.619						
Using technologies	.540					.475	
Minimal consideration		.864					
Energy efficiency priority		.808					
Regulatory measures			.798				
Grade listing			.626				
Energy policy and awareness			.554				
Limited resources and grants				.800			
Lack of adequate framework				.669			
Limitations on sustainable options					.783		
Risks of condensation					.733		
Building complexity	-.429				.510		
Heritage visual impact						.867	
Conflict over fabric U-value							.809
Energy saving payback period							.566

Extraction method: Principal Component Analysis. *Rotation Method*: Varimax with Kaiser normalization

a. Rotation converged in 8 iterations

The variables were ordered and grouped according to the size (Table 6.34) and interpretative labels suggested. According to Table 6.34, the combined factors under the main factor one is labelled *Energy management*. It is associated with adaptation to upgrade building energy efficiency, importance of energy use reduction in conversion projects as modern buildings, the importance of energy monitoring and analysis after conversion to other uses, use of technologies to minimise energy consumption after conversion and listed churches complexity with limiting features on energy efficiency. However, it could be observed that the stakeholders' consensus opinions for all the factors description is 'agree'. Only on one-factor description was the 'neutral'. Therefore, the factors they all agree on will be retained. Meanwhile, the factor in the neutral response

will be discarded. The combined factors under the main factor two is labelled *Design decision*. It is associated with low consideration given to minimising energy consumption and low priority for energy efficiency in conversion projects. However, there is no agreement with these factors description by the stakeholders as they were neutral in their responses. Thus, these factors will not be retained.

The combined factors under the main factor three is labelled *Government regulations*. It is associated with government policies, regulations and requirements (e.g. FiTs, VAT, etc.), influence of grade listing on possible energy efficiency improvements, inadequate operational energy management policy and awareness. The general consensus of the stakeholders on these factors is 'agreed'. Thus, these factors will be retained. The combined factors under the main factor four is labelled *Limited resources and grants.* It is associated with inadequate resources and grants to encourage energy efficiency measures and inadequate energy efficiency framework disseminating effective strategies. The general consensus of the stakeholders on one these factors are 'agreed' while the other is neutral.

The factor which the stakeholders agree with will be retained and the factor with neutral consensus will be discarded. The combined factors under the main factor five is labelled *Risks of condensation and building complexity.* It is associated with most sustainable options in practice are limited in application to heritage buildings, risks of insulation and interstitial condensation in the walls or roof and listed churches are complex buildings with limiting features for energy efficiency. The general consensus of the stakeholders on two of these factors is 'agreed' while one is neutral. Thus, the factor

with which the stakeholders agree with will be retained and the factor with neutral consensus will be discarded. The combined factors under the main factor six is labelled *Heritage visual impact and secondary glazing.* It is associated with the use of technologies to minimise energy consumption after conversion and minimum visual impact along with room for allowance of secondary glazing. The general consensus of the stakeholders on these factors is 'agreed'. Thus, these factors will be retained.

The combined factors under the main factor seven is labelled *Conflict over fabric U-value.* It is associated with significant energy use reduction could only be achieved by reducing the U - value and energy saving measures only makes sense if payback is less than 10 years. The general consensus of the stakeholders on these factors is neutral while the others are disagreeing. Thus, these factors will be discarded. One approach in identifying and developing a framework of critical factors that influence energy use in PHBs as suggested by the SSM-based framework developed in Chapter 4 is to involve stakeholders (i.e. Key influencers) without which the failure to include their perception according to stakeholders' theory may result in the failure of the outcome of the process. Therefore, based on soft systems methodology, Figure 6.6 shows illustrated diagram of critical factors influencing energy consumption in reuse of public heritage buildings as perceived by the stakeholders.

Table 6.34: Identification of factors extracted, ordered and grouped according to size with their degree of acceptance (DoA)

S/N	Size	LFC	Factor Description	DoA
Factor 1: Energy management				
1	0.848	F2	Adaptation to upgrade building energy efficiency	Neutral
2	0.831	F1	Importance of energy use reduction in conversion as modern buildings	Agree
3	0.619	F3	Importance of energy monitoring and analysis after conversion to other uses	Agree
4	0.540	F4	Use of technologies to minimise energy consumption after conversion	Agree
5	-0.429	F22	Listed churches are complex buildings with limiting features on energy efficiency	Agree
Factor 2: Design decision				
1	0.864	F18	Low consideration given to minimising energy consumption	Neutral
2	0.808	F16	Low priority for energy efficiency in conversion projects	Neutral
Factor 3: Government regulations				
1	0.798	F24	Government policies, regulations and requirements (e.g. FiTs, VAT, etc.)	Agree
2	0.626	F23	Influence of grade listing on possible energy efficiency improvements	Agree
3	0.554	F25	Inadequate operational energy management policy and awareness	Agree
Factor 4: Limited resources and grants				
1	0.800	F28	Inadequate resources and grants to encourage energy efficiency measures	Agree
2	0.669	F27	Inadequate energy efficiency framework disseminating effective strategies	Neutral
Factor 5: Risks of condensation and building complexity				
1	0.783	F19	Most sustainable options in practice are limited in application to heritage buildings	Nuetral
2	0.733	F21	Risks of insulation and interstitial condensation in the walls or roof	Agree
3	0.510	F22	Listed churches are complex buildings with limiting features on energy efficiency	Agree
Factor 6: Heritage visual impact & secondary glazing				
1	0.475	F4	Use of technologies to minimise energy consumption after conversion	Agree
2	0.867	F5	With minimum visual impact secondary glazing should be allowed	Agree
Factor 7: Conflict over fabric U-value				
1	0.809	F6	Significant energy use reduction could only be achieved by reducing the U - value	Neutral
2	0.566	F7	Energy saving measures only make sense if payback is less than 10 years	Disagree

S/N = Serial No, LFC = Loaded Factor Code, DoA = Degree of Acceptance

As no prior theory or model exists to explain these factors, the diagram developed and illustrated in Figure 6.6 is based on the factors extracted from the findings of the principal component analysis discussed above. Thus, the factors identified and agreed by the stakeholders influencing energy use in the reuse of LCBs formed the component of the illustrated diagram fully discussed in Chapter 9 in the discussion chapter in this thesis.

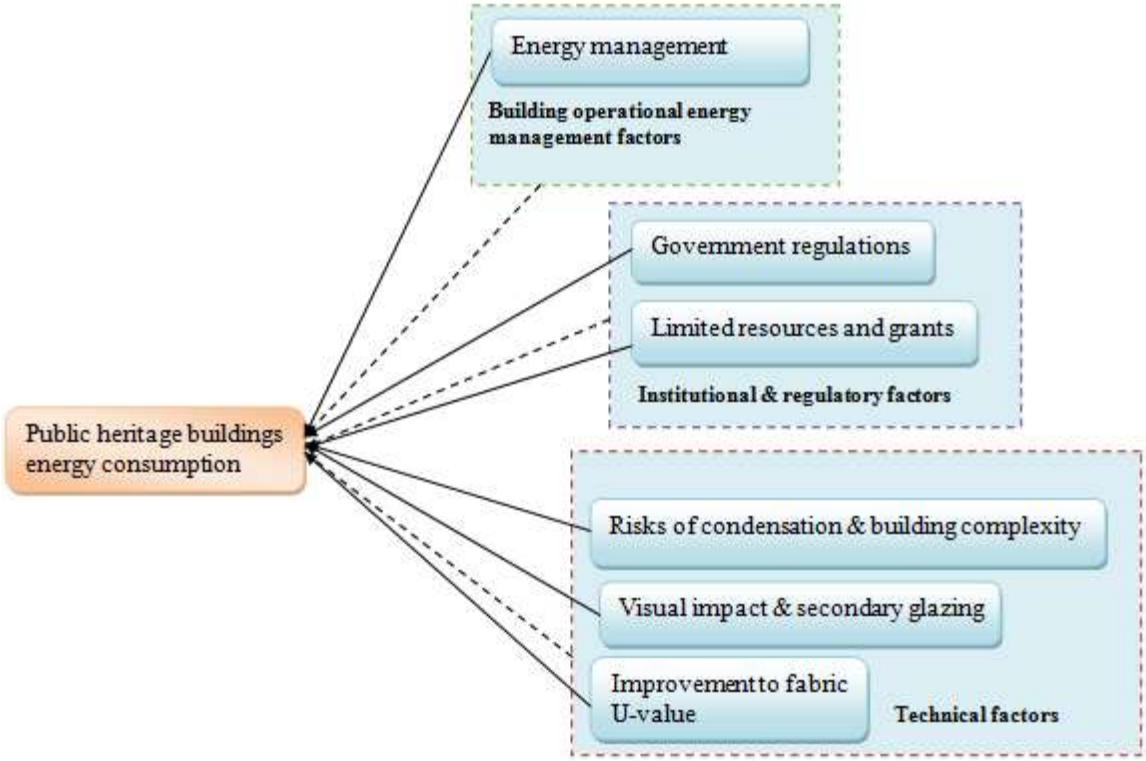


Figure 6.6: Illustrated diagram (A) of critical factors

6.8 Chapter Summary and Conclusion

In this chapter, the critical factors responsible for energy use in LCBs arising from stakeholders' perceptions that need to be addressed to improve energy performance was examined using quantitative analysis methods. The results of the analysis indicate that

there is a significant difference among the respondents as regards their perception on energy use reduction in the reuse of LCBs projects. This difference in perception is perceived to be responsible for the lack of common direction in tackling the problem of energy use in the reuse of LCBs projects. Thus, influences the adoption of strategies in practice that is most sustainable to achieving environmental sustainability of the projects. Meanwhile, top leading recommendations were made by the stakeholders to achieve long-term sustainable reuse of LCBs. These include energy management, smart metering and operational energy management awareness and policy and other innovative strategies. However, to successfully implement these recommendations, six factors that need attention of policy makers emerged, though classified into three as contributing factors to energy use in the reuse of LCBs. The three top leading factors were energy management in operational practices, government regulations and limitations of resources and grants.

Findings from the present study reveal the existence of the gap between what the respondents perceived as important in theory and what they adopt in practice. Results obtained showed the three top strategies adopted in practice are design interventions, functional performance and building surrounding context (Table 6.31). Thus, reveals that the central concern of heritage professionals is mainly inclined towards design interventions with less importance for energy use reduction for reuse of LCB projects. Furthermore, more consideration is given to building services upgrade and improvements to the building fabric to reduce the U-value (Table 6.27) as the most implemented

strategies to reduce energy use in practice rather than energy management. This view is supported by the result obtained from respondents' recommendations and ranking based on RSI analysis. The result indicated strategies that have achieved energy efficiency improvement with a significant and moderate extent are energy management system, smart metering and operational energy policy and awareness (Table 6.32). Meanwhile, these strategies have only been implemented by a few of the respondents. Thus, it is clear from these findings that the cause of failure, in achieving the benefits of the sustainable approach to heritage building projects, is evident in practice. Phase 2 of the analysis for this study provides the findings from building technical and energy use survey in Chapter 7.

CHAPTER 7: RESULTS (BUILDING ENERGY AND TECHNICAL SURVEY)

7.0 CHAPTER OBJECTIVES

- To present the energy consumption and CO_2 emission resulting from building operation
- To evaluate energy performance of existing reuse church projects
- To identify the factors responsible for the differences in energy performance of the buildings
- To catalogue and rank the factors on energy performance of the buildings
- To present and partly discuss the findings from the building energy and technical survey

7.1 Introduction

According to soft systems methodology (SSM) which is the main theoretical orientation guiding this study; one method of dealing with or having a proper perspective energy use problems in public heritage building (LCB) projects as illustrated in the SSM-based conceptual framework developed in Chapter 4 of this thesis is not limited to just involving the stakeholders but also to include technical approaches in order to increase the understanding of the underlying critical factors contributing to the energy use problems. The set of buildings was identified through field observation. The building energy survey assisted in confirming and corroborating information from the other data collection methods: questionnaire survey and interviews. It is important to note that the results presented in this section are deliberately reported primarily on qualitative (rather than

quantitative) basis. This is due to a number factor considered during the analysis in order to be able to identify the factors responsible for differences in energy performance of the buildings surveyed. For instance, it was initially anticipated that the total number of all reused churches (N= 33) found in the study region (East of England) would be investigated in this research study. Furthermore, on commencing the survey discovered that some of the buildings were no longer in use. Apart from the above mentioned reasons, some of the invited participants were not willing to participate in the survey partly due to the sensitive nature of the use of their buildings and the difficulties of getting consent, securing agreement and required approval from higher authority.

Table 7.1: Selection criteria for the surveyed buildings

Location		Reuse projects	No. in rural area	No. in urban area	No. of buildings not in use	Anticipated sample size	No. of accessible building	Actual sample size
1	Cambridge	3	-	3	-	3	2	2
2	Colchester	3	-	3	1	2	2	2
3	Great Yarmouth	2	1	1	-	1	-	-
4	Ipswich	5	-	5	1	4	4	4
5	Norwich	18	-	18	4	14	10	10
6	Peterborough	2	1	1	-	1	1	1
Total		33	2	31	6	25	19	19

7.2 Statistical Assessment of Factor affecting Energy Performance of LCBs

7.2.1 Research objective 4

To assess the energy performance and operational practices of existing reuse of LCBs projects and to determine the factors responsible for their current energy performance. In order to achieve this objective, the energy consumption rating was treated as the energy performance measure and hence a dependent variable. The energy performance of existing reuse projects is presented in Table 7.2. It is viewed from the results obtained that most of the projects (78.9%) exhibited low energy performance ratings while only 21.1% exhibited high energy performance (Table 7.2).

Table: 7.2 Energy performance of existing reuse projects.

Performance	Frequency	Percent
Low performance	15	78.9%
High performance	4	21.1%
Total	19	100.0%

Factors such as building use pattern, year of construction, other sources of energy used in the building, efficiency of heating system, approximate number of visitors using the building weekly, lighting mode, measures taken to improve energy performance, nature of energy management policy, energy management strategies and energy management awareness adopted were considered as independent variables to determine the differences in the energy performance. Statistical analysis was carried out to determine the factors that explain the differences between the high and low energy performance of the investigated buildings. The statistical tool used was Kruskal Wallis *H*-test which is the use of non-parametric one-way ANOVA (test of the difference in means). Non-

parametric test is recommended, particularly when the sample size is less than 30. Table 7.3 depicts the result of the statistical analysis the energy performance of the surveyed buildings.

Observations from results obtained revealed that the differences in energy performance of all the buildings surveyed in this research study could not statistically determine and explain the various factors responsible for the differences in energy performance. This implies none of the factors, which were statistically tested (Table 7.3) could statistically explain the differences in the energy performance as identified by energy consumption rating. The factors tested include: building use pattern (p = .367); year of construction (p = .398); other sources of energy used in the building (p = .792); efficiency of heating system (p = .764); approximate no of visitors using the building weekly (p = .115); lighting mode (p = .172); measures taken to improve energy performance (p = .202); nature of energy management policy (p = .656); energy management strategies (p = .291) and energy management awareness adopted (p = .806). Meanwhile, Wilcoxon-Mann-Whitney rank-sum tests for different means were also performed; similarly, all the outcomes from the surveyed buildings were statistically similar.

Table: 7.3: Statistical tests for factors explaining differences in energy performance

		N	Mean Rank	Kruskal Wallis H-test			Remarks
				Chi-square	df	sig	
What community purpose is building use for?	Arts & Entertainment use	6	9.5	4.296	4	0.367	
	Retail use	5	10.6				
	Multi-purpose use	4	13.75				Not significant
	Museum use	2	8.5				
	Religious and other community use	2	4				
	Total	19					
Year of construction of the building	12 -13th Century	1	10	2.961	3	0.398	Not significant
	14 -15th Century	13	8				
	16 -17th century	1	16				
	18 - 19th Century	2	11.5				
	Total	17					
Other sources of energy used in the building	Solar Photovoltaic	2	6	0.467	2	0.792	
	Air Source heat pump	1	8				Not significant
	None	12	8.33				
	Total	15					
Efficiency of the heating system	60-70%	4	6.5	1.846	4	0.764	Not significant
	71-80%	1	9				
	81-90	2	8				
	91-100	4	6				
	Inefficient	1	3				
	Total	12					
Approximate number of visitors using the building weekly	1000 or less	3	6.67	7.425	4	0.115	Not significant
	1001 to 5000	3	4				
	5001 to 10000	2	6.5				
	10001 to 15000	1	10				
	More than 15000	8	12.25				
	Total	17					

Table: 7.3 (Contd.): Statistical tests for factors explaining differences in energy performance

Lighting mode	Artificial only	8	10.13	1.864*	1	0.172*	Not significant
	Natural only	0	0				
	Combination of natural & artificial	8	6.88				
	Total	16					
Measures taken to improve energy performance of the building	replacing entire lighting system with a more efficient light source	1	5	3.2	2	0.202	Not significant
	others	1	4				
	none	3	2				
	Total	5					
Nature of energy management policy	unwritten	4	7.75	0.843	2	0.656	Not significant
	written but partially implemented	1	11				
	None	9	7				
	Total	14					
Energy management strategies adopted	monitor trends in energy consumption	1	2	4.961	4	0.291	Not significant
	Consumption records adjusted for weather conditions	1	7				
	Energy use made known to workers to check habits	1	9				
	others	1	1				
	none	7	6.71				
	Total	11					
energy management awareness adopted	no promotion of energy management awareness	4	5.25	.060*	1	0.806*	Not significant
	informal awareness to workers of energy use reduction	5	4.8				
	Total	9					

* = the same values were obtained for Mann-Whitney U-test.

7.3 Evaluation of Factors Explaining Differences in Energy Performance

This section presents a further evaluation of data obtained from the nineteen (19) existing buildings surveyed. The qualitative explanatory approach was chosen to identify the factors that explained the differences in energy performance of the buildings surveyed. The rationale for adopting this approach is to complement and provide further explanation for the findings. Furthermore, this approach would also enable the researcher to identify lessons to be learned from both high and low energy performing buildings.

The term the *lessons learned* refers to positive and negative aspects of the projects that have clear messages and might be helpful to subsequent low performing building projects. The lessons learned are also intended as observations that can help identify best practices, either for improvements to the investigated buildings or concepts that worked and should be applied to future buildings. These lessons and best practices would be considered together with the goals of reducing energy use and CO_2 emissions in reuse of public heritage buildings. They are meant to identify where the process of delivering heritage building projects, needs to be changed to promote and realize low energy use for heritage building projects. Table 7.4 presents the evaluation criteria used to determine the building operational practices and energy performance.

Table 7.4: Building operational performance evaluation criteria

Conceptual Definition	Dependent & Independent Variables	Description
Building energy perfomance		
	Annual Energy Consumption CO_2 Emissions	Monthly energy bills Fuel types (Gas or Electricity) Yes: 1 No: 2
Building use		
	Activity/function	Category of use Arts & Entertainment use: 1 Retail use: 2 Multipurpose use: 3 Museum use: 4 Religious & Community use:5
	Intensity of use	Primary :1 Secondary : 2
Building Characteristics		
	Age	Year Built
	Building size	Floor area in square meter Small (< 250m2) :1 Medium (251 - 400m2): 2 Large (> 400m2): 3
	Building conversion	Year Converted
Operational energy reduction strategies		
	Energy management strategies	Monitor trends in energy consumption:1 Consumption records adjusted for weather conditions:2 Monitoring and targeting scheme employed :3 Energy use compared to targets for other buildings: 4 Energy performance advised to users:5
	User behavior control	By turning off electric appliances when not in use: 1 Turn lights out when not in use: 2 Use full loads with dish washer: 3 Use energy saving light bulbs: 4 Buy energy efficient appliances: 5 6=Other
	Energy management policy	Unwritten:1 written but not implemented: 2 written but partially implemented: 3 written and extensively implemented:4
	Energy management awareness	No promotion of energy efficiency: 1 Informal awareness used: 2 Some ad hoc staff awareness:3 Program of staff awareness & regular publicity:4
Operations and maintenance		
	Building maintenance quality	Very poor: 1 Poor: 2 Fair: 3 Good: 4 Excellent: 5
	Heating & Lighting system	Efficiency
Renewable technologies		
	Micro generation Technologies	Ground source heat pump Solar panel Air source heat pump
Historic Value		
	Architectural Style	If it was built in the style of either Medieval: 1 or Victorian: 2
	Grade Listing	Grade I: 1 Grade II*: 2 Grade II: 3

7.4 Building Description and Uses

A summary of key building features is shown in Table 7.5. The building varies in sizes with a total gross floor ranging from 101m^2 to 866m^2. The buildings were classified according to their size. The smallest size buildings were classified as buildings up to 250m^2, medium size buildings are classified buildings ranging from 250 - 450m^2 while the largest was classified as building greater than 450m^2. Most of the buildings were built between 12th – 19th centuries and were mainly medieval and Victorian in architectural style. The churches surveyed were also classified according to their main use (Figure7.1). Arts and entertainment uses dominate the data set; 32% of the total buildings/churches have been reused as theatre, cultural performance and dance, music and training purposes. Meanwhile, 26% of the churches were reused as retail comprising of bookshop, rental centre and food service (café). It could be observed that 20% of the total churches were reused for multipurpose activities; 10% were used for museum properties and 16% for religious and community uses.

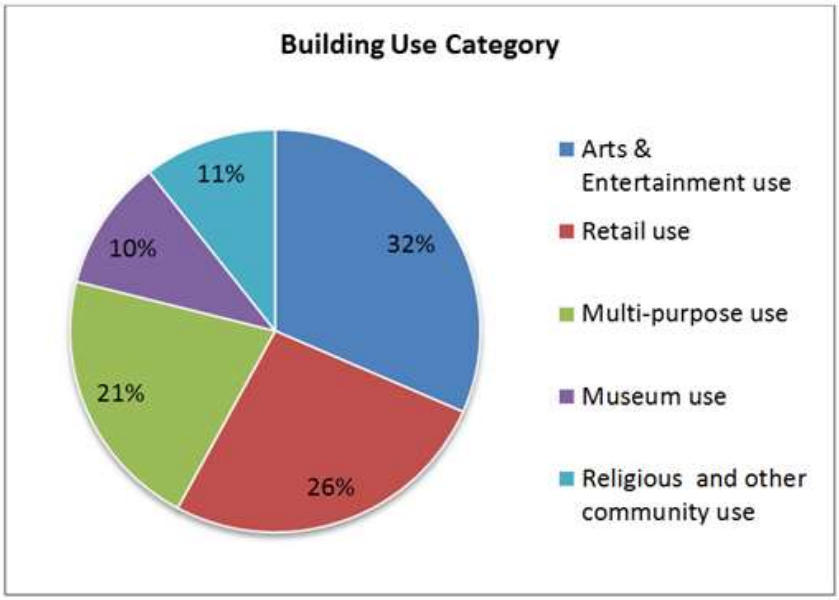


Figure 7.1: Building use category

Table 7.5: Key building features and energy use by the buildings surveyed

Building Code	Year Built	Floor Area (m^2)	Grade Listing	Building Conversion year	Main Activity	Arch. Period	Electricity (kWh)	Gas (kWh)	Total Energy use (kWh)
B1	C15	429	I	1980	Theatre	Medieval	23,248	133, 580	156,828
B2	C15	269	I	1975	Bookshop	Medieval	4, 437	0	4,437
B3	C14	280	I	2004	Bookshop	Medieval	52, 453	58, 808	111,261
B4	C14	173	I	-	Educational Art	Medieval	5, 222	28, 547	33,769
B5	C14	228	I	1980	Concerts	Medieval	84, 000	204, 000	288,000
B6	C15	349	I	1980	Community Café	Medieval	0	76, 170	76,170
B7	C14	383	II*	2005	Community Café	Medieval	50000	195, 194	245,194
B8	C12	350	II*	1958	Museum	Medieval	0	91, 158	91,158
B9	C14	830	I	1990	Worship	Medieval	13, 672	5, 162	18,834
B10	C19	201	II	1980	Concerts	Victorian	59, 200	43, 361	102,561
B11	C15	327	I	1991	Prayer group	Medieval	3, 317	45, 378	48,695
B12	C17	101	II	2008	Community Café	Medieval	5, 474	68, 238	73,712
B13	C12	392	II*	2008	Concert	Medieval	0	111, 184	111,184
B14	C15	545	I	2002	Community café	Medieval	74, 783	160, 044	234,827
B15	C19	866	II	1996	Community Centre	Victorian	35, 913	205, 840	241,753
B16	C14	262	I	1969	Cultural Performance	Medieval	12507	0	12,507
B17	C14	181	I	2009	Medieaval art /museum	Medieval	4852	35846	40,698
B18	C15	327	I	-	Music school	Medieval	5286	0	5,286
B19	C15	200	II*	1994	Visitor's attraction	Medieval	27722	121785	149,507

7.5 Energy Performance Indicator (EPI)

A building's energy performance indicator or PI essentially refers to a specific quantity of energy use per unit of floor area. According to CIBSE (1991), the total energy use of a building can be used to determine the measure of energy performance known as the Normalised Performance Indicators (NPI). NPI is basically the energy use per unit floor area and also known as the energy use index (BRECSU, 2000). In order to normalise the consumption data, energy use data was applied to a heated floor area based on the data provided by respondents to derive kWh/m^2. This was done in two parts, firstly in terms of electricity and secondly for fossil fuel (gas). The rationale and the benefit of this is that if building energy use can be reduced to a single value in terms of kWh per square meter per year, it could be possible to compare different buildings with each other along with other external standards or benchmarks. Thus, the use of benchmarking and performance indicators is fundamental to any improvement strategy.

According Jefferson *et al.* (2007), an indicator system should provide a measure of current performance. In order to allow for comparison between individual buildings, all energy used discussed in this study is the energy delivered to the building and is reported in kWh/m^2/year and CO_2 emissions as kgCO_2/m^2/year. The figures obtained for individual buildings were then used to compare the performance of individual buildings with other buildings in the league of table drawn to the surveyed buildings. The best and the worst performing buildings were identified and the areas to be addressed in the worst performing buildings were highlighted.

Examination of the resultant data revealed a number of extreme values within the data. However, it was observed that a number of the extreme values obtained in this research study might have been due to be the result of buildings with extension designed for them and the pattern of use of that extension to the buildings. The energy performance indicator (EPI) for the investigated buildings is depicted in Table 7.6. It can be seen that the total annual energy use per heated floor area ranges from 16 kWh/m^2/year to 1263 kWh/m^2/year with a mean of 357.84kWh/m^2/year. Building 'B18' was found to have a lower EPI of 16kWh/m^2 while building 'B5' was found to have the largest EPI of 1263kWh/m^2/year (Figure 7.2).

Table 7.6: Energy performance indicator (EPI) for the investigated buildings

	EPIELEC (kWh/m^2)	EPIGAS (kWh/m^2)	Total Energy use per floor area (kWh/m^2)	Overall Performance Ranking	Performance Level
B18	16	0	16	1	HPB
B2	17	0	17	2	HPB
B9	16	6	24	3	HPB
B16	48	0	48	4	HPB
B11	10	139	149	5	LPB
B4	30	165	195	6	LPB
B6	0	218	218	7	LPB
B17	27	198	225	8	LPB
B8	0	260	260	9	LPB
B15	41	238	279	10	LPB
B13	0	284	284	11	LPB
B1	0	311	366	12	LPB
B3	187	210	397	13	LPB
B14	137	294	431	14	LPB
B10	295	216	510	15	LPB
B7	131	510	640	16	LPB
B12	54	676	730	17	LPB
B19	139	609	748	18	LPB
B5	368	895	1263	19	LPB

EPIELEC: Energy performance indicator by electricity use
EPIGAS: Energy performance indicator by gas use
HPB: High performance building
LPB: Low performance building

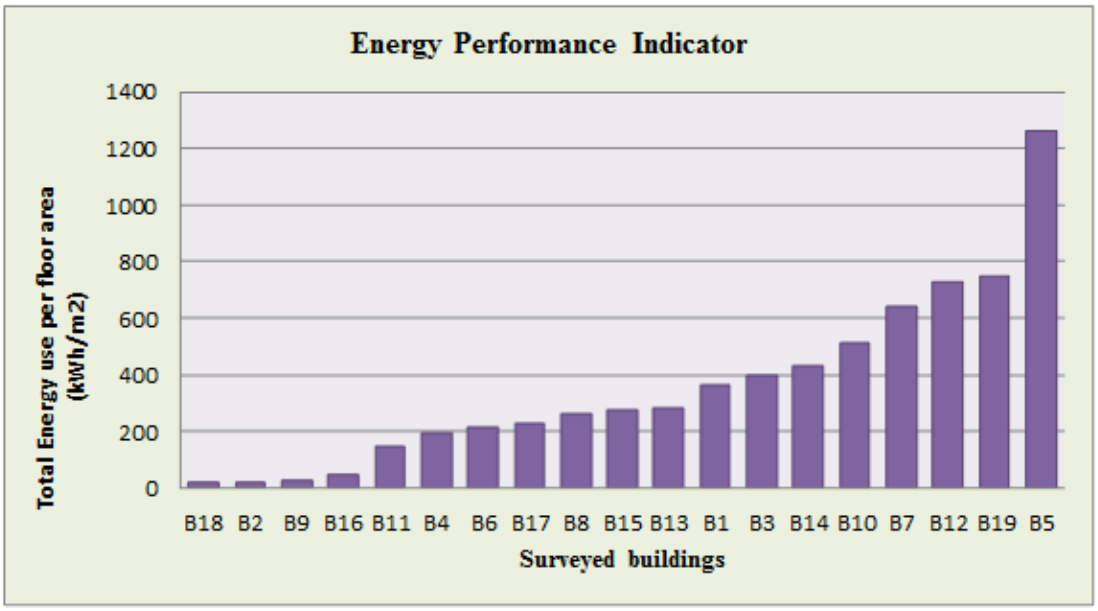


Figure 7.2: Energy performance indicator of surveyed buildings

7.6 Comparison of Annual Energy Consumption of Surveyed Buildings with Benchmarks

Benchmarking is an important initiative in the drive for improvement in energy efficiency and is a mandatory requirement of the European Union (EU) Directive on Energy Performance of Buildings. It is a method of comparing a building's utility consumption with typical or best practice figures. DETR (1998) defined benchmarking as the comparison of the performance of one organisation against another and then using the lessons from the best organisations to make improvements. Thus, comparisons at a more detailed level with benchmarks are important for annual energy end-use per square metre of floor area. Comparison with benchmarks allows the standard of energy efficiency to be assessed and enable remedial action to be taken. For this reason, energy consumption for gas, electricity, and both gas and electricity were compared with energy benchmarks. Table 7.7 shows the benchmarks taken from CIBSE TM46 (2008); the benchmark covers

public buildings with light use to include churches. Churches are considered to be public buildings, according to CIBSE guidelines. Although churches are not categorised by type, age, size or construction, according to these guidelines, it was necessary to use this as only a rough comparator.

Table 7.7: Annual utility benchmarking

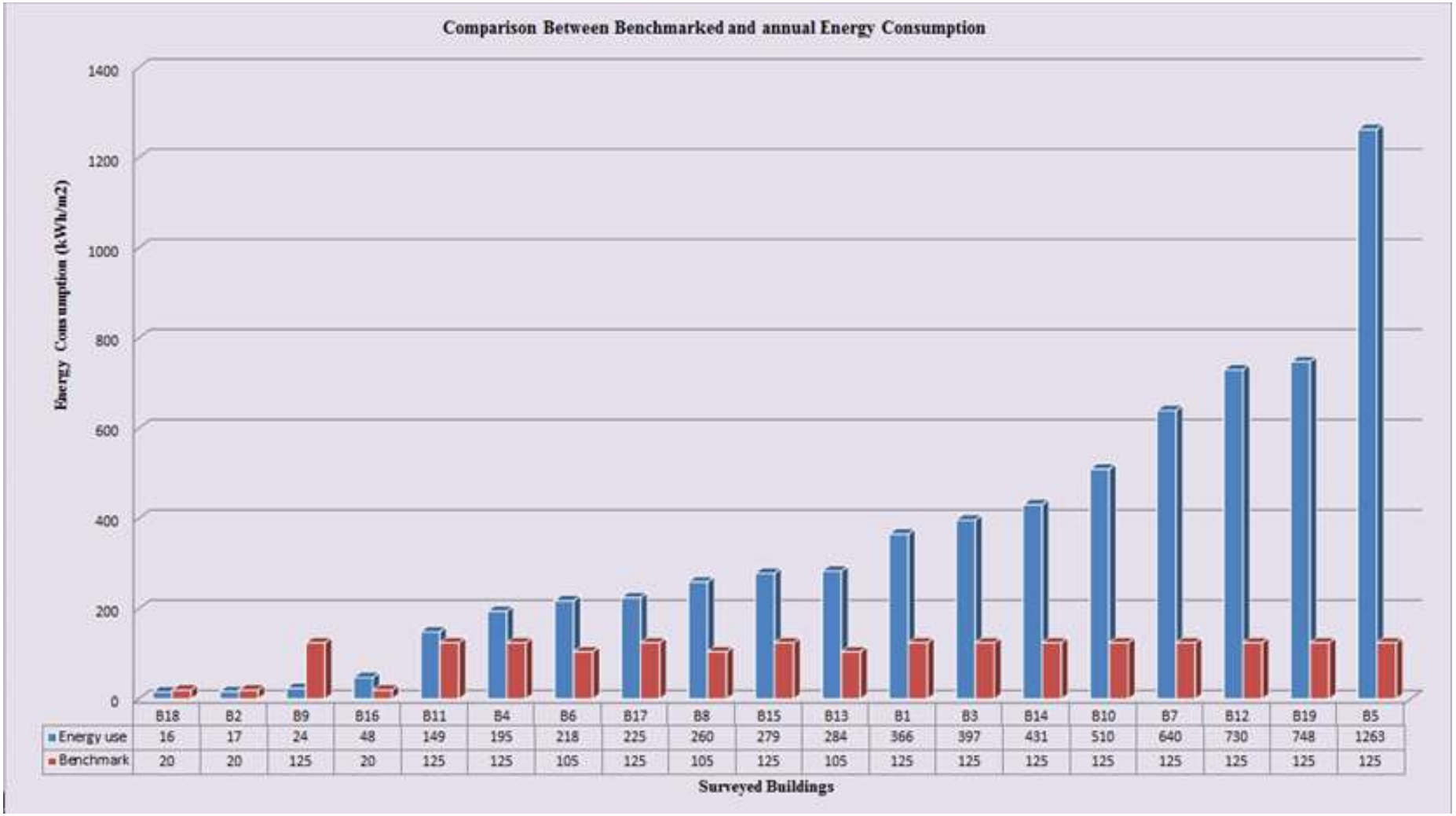
	Benchmarks	Units	Benchmarked Annual Utility Consumption
Gas	105kWh/m²	390m²	40,950kWh
Electricity	20kWh/m²	390m²	7,800kWh

Source: CIBSE TM46:2008 Energy Benchmarks

Figure 7.3 shows the comparison between the benchmark and annual energy consumption for nineteen (19) buildings surveyed. It could be observed three buildings (B18, B2 and B9) use less energy than the expected benchmarked annual utility consumption. Two buildings (B18 and B2) use less electric energy while one building (B9) use less electricity and gas energy compared to the benchmark. It could also be observed that while building 'B16' appears to have low energy consumption, its annual energy usage is more than twice compared to the benchmarked annual utility consumption.

It is worth nothing that the energy consumption of most buildings surveyed was substantially higher and simultaneously higher and plateaued than the benchmarked utility consumption. Few, of the buildings, however, had lower energy consumption (i.e. better than the benchmarked utility consumption). For instance, the energy use of building 'B5' is ten times higher than required. These buildings are considered appropriate for reviewing operational practices, equipment in use, hours of operation etc. compared to

the high performing buildings. Figure 7.3 shows that the total current annual electricity consumption for building 'B16' approximately doubles the best practice benchmarks. However, for building 'B18' and 'B2' it can be seen that the total current annual electricity consumption is less than the benchmarked figure.



	B18	B2	B9	B16	B11	B4	B6	B17	B8	B15	B13	B1	B3	B14	B10	B7	B12	B19	B5
Energy use	16	17	24	48	149	195	218	225	260	279	284	366	397	431	510	640	730	748	1263
Benchmark	20	20	125	20	125	125	105	125	105	125	105	125	125	125	125	125	125	125	125

Figure 7.3: Comparison between benchmark and annual energy consumption of the surveyed buildings

Figures 7.4, 7.5, and 7.6 below compares benchmarks for churches with the current annual utility consumption of the building surveyed.

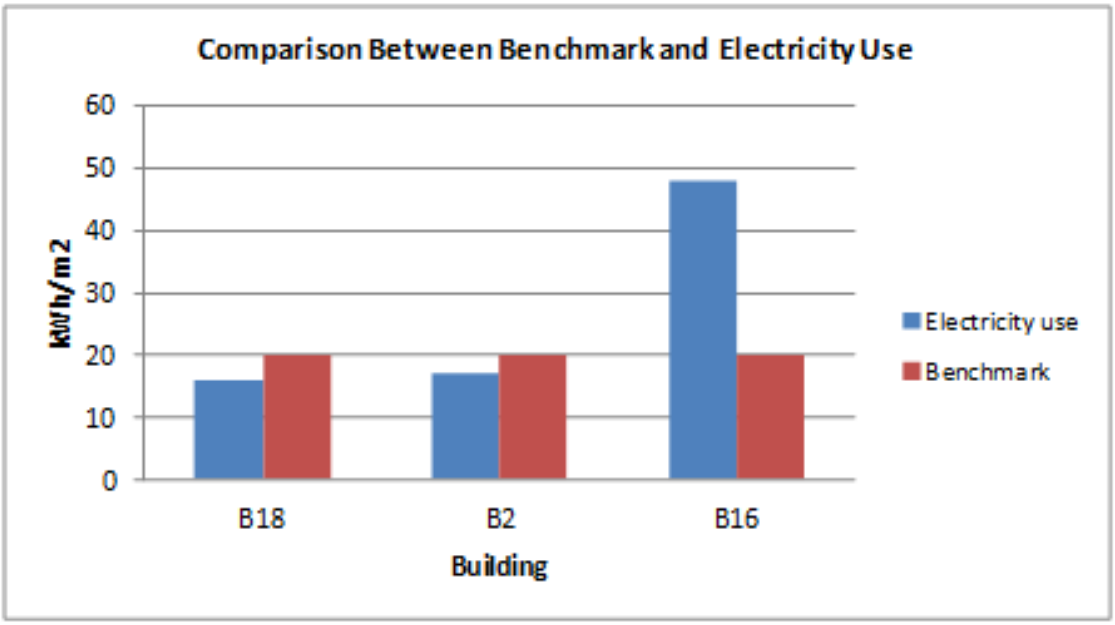


Figure 7.4: Comparison between benchmarked and electricity consumption

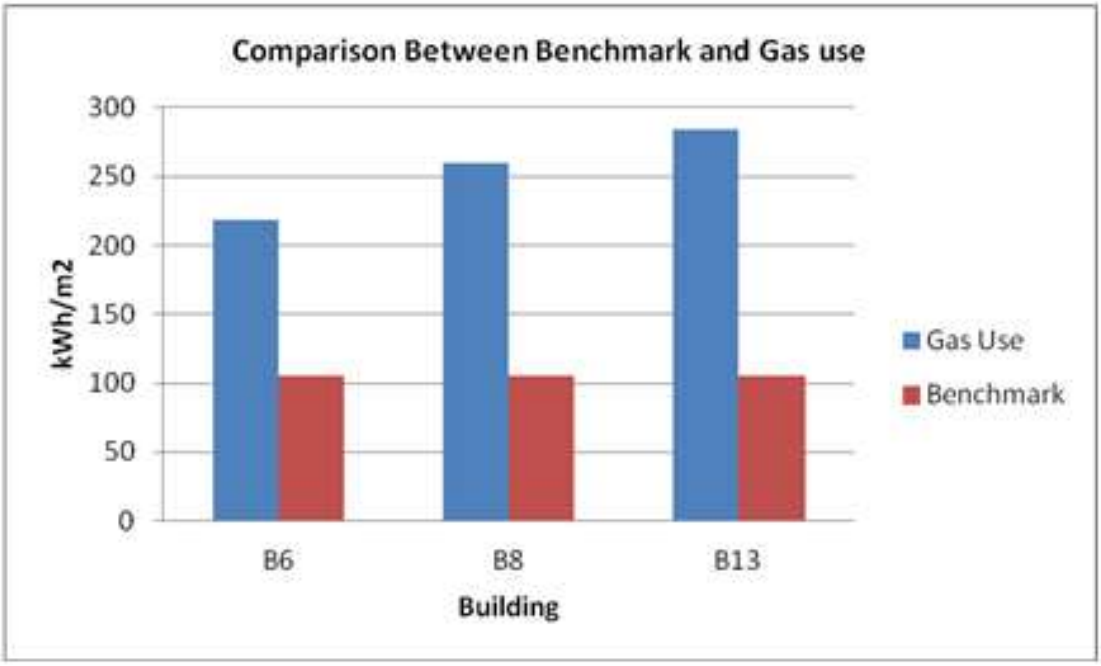


Figure 7.5: Comparison between benchmarked and gas consumption

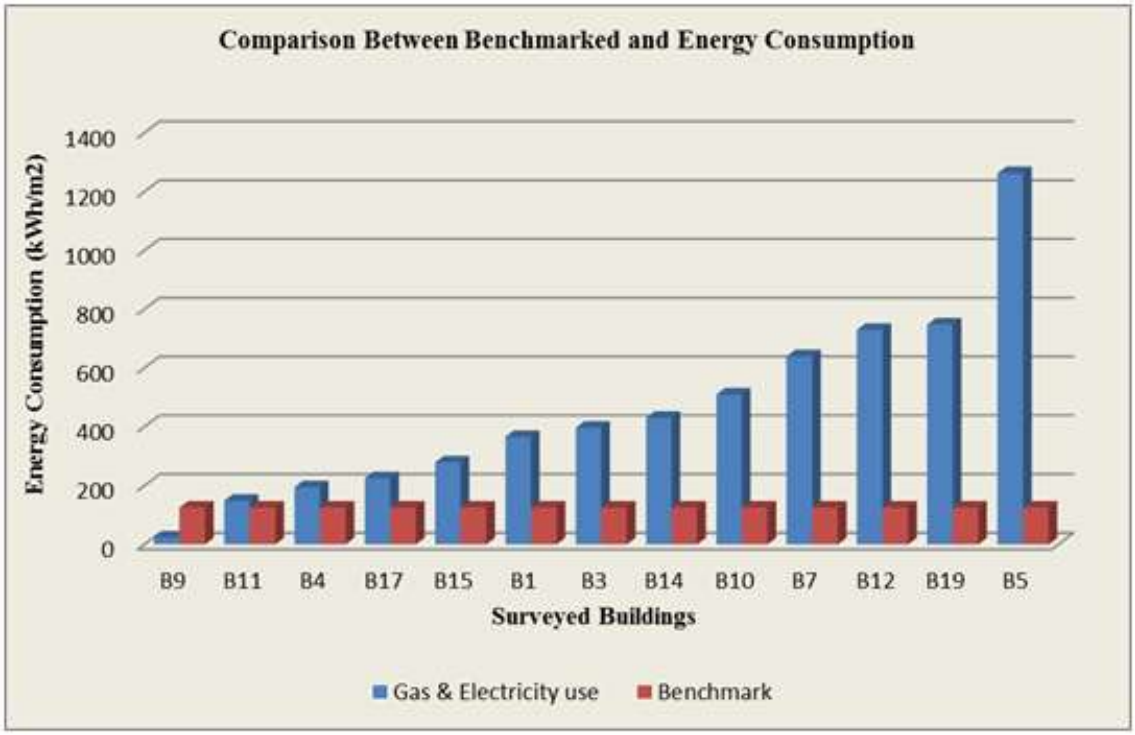


Figure 7.6: Comparison between benchmarked and electricity and gas consumption

7.7 Energy Use of Listed Churches Surveyed

The survey instrument was sent to 25 managers in charge of reused listed churches within East of England region (Appendice B). A total of 19 responses was obtained representing 76% of the survey population. Energy was converted into CO_2 emission using DEFRA (2009) CO_2 emission conversion factors. The energy consumption data of the surveyed buildings assumes CO_2 emission factors of 0.184kg of CO_2/kWh for gas and 0.542kg of CO_2/kWh for electricity. Carbon emissions can be reported in both 'absolute' and 'relative' terms. Absolute emissions mean the total footprint while relative emissions refer to the absolute figure indexed to a unit of this per m^2 per performance which can also be referred to as 'intensity indicators'. For the purpose of this present research, carbon emissions of all the buildings surveyed were partly reported in absolute and

relative emissions. 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. Table 7.8 shows energy use of the buildings with complete data in terms of absolute emissions. The total electricity and gas consumption for the surveyed buildings is shown in kWh/m^2 of the total area in order of their emissions to allow comparisons.

Table 7.8: Energy use of the buildings with complete data in order of absolute emissions

	ELECTRICITY (kWh/m^2)	GAS (kWh/m^2)	Total Energy use (kWk/m^2)	Absolute emissions (kgCO_2)	Emissions per floor area (kgCO_2/m^2)
B5	368	895	1263	83,064.00	364
B14	137	294	431	69,980.50	128
B7	131	510	640	63,015.00	165
B15	41	238	279	57,339.41	66
B10	295	216	510	40,064.82	199
B3	187	210	397	39,250.40	140
B19	139	609	748	37,433.76	187
B1	0	311	366	37,179.14	57
B13	0	284	284	20,457.86	52
B8	0	260	260	16,773.07	50
B12	54	676	730	15,522.70	154
B6	0	218	218	14,015.28	40
B11	10	139	149	10,147.37	31
B17	27	198	225	9,225.44	51
B9	16	6	24	8,912.33	10
B4	30	165	195	8,082.97	47
B16	48	0	48	6,779.11	26
B18	16	0	16	2,865.01	9
B2	17	0	17	2,405.26	9

7.8 Qualitative Analysis and Findings on Surveyed Buildings

The qualitative analyses of surveyed buildings carried out in this research study are divided into three namely;

(a) Building use typology: analysis of category of building use pattern identified in the survey

(b) Fuel type: analysis of different energy use (i.e. Gas, electricity and combined gas and electricity use)

(c) Building operational energy performance and practices: analysis of the difference in energy performance of the building surveyed (i.e. High and low energy performance of the buildings)

7.8.1 The operational energy performance of the buildings, according to the use pattern

Table 7.9 presents the categories of building use typology, activity and/or function of individual buildings within the category, building characteristics, energy performance indicator and performance ranking of churches surveyed. Table 7.9 shows there is a large variation in the energy use, according to building use typology, activity and/or function of individual buildings within each building category. Basically, the building type was categorised into five (5) according to their activity or functions, namely: Arts and Entertainment, Retail, Multipurpose, Museum and Religious with other Community use. A range of energy use intensity according to building use pattern is anticipated from these categories as some, such as building 'B10', 'B14' & 'B12' have lots of energy intensive equipment while other buildings ('B5' and 'B7') have extension facilities attached to them. Intensity observations were made from the results obtained in Table 7.9. On one

hand, it was noted that buildings with extension facilities (B5 and B7) and building with large catering services (B10, B12 and B14) recorded high energy usage in terms of energy use per floor area; while on the other hand, building carrying out retail services (B2) and another for religious use (B9) were among the buildings that recorded low energy usage per floor area. Apart from the differences in energy use by building activity pattern observed from Table 7.9 further differences arising from these findings can be observed from the results presented in Tables 7.16 - 7.35 on the energy performance by building operational practices.

Table 7.9: Operational energy performance and ranking of surveyed buildings, according to their category of use

		Building Characteristics				Energy Performance Indicator		Performance Ranking		
Building typology	Activity/function	No. of Building	Building Code	Year Built	Grade listing	Energy Use (kWh/m²)	CO_2 Emissions (kgCO2/m²)	High/Low	Rank	Overall Rank
Arts & Entertainment Use	Training (educational art/music)	1	B18	C15	I	16	9	High*	1	5
	Cultural performance & dance	1	B16	C14	I	48	26	High*	2	
	Training (educational art/music)	1	B4	C14	I	195	47	Low	3	
	Theatre,	1	B1	C15	I	366	57	Low	4	
	Music concerts	**1**	**B10**	**C19**	**II**	**510**	**199**	**Low**	**5**	
	Music concerts	**1**	**B5**	**C14**	**I**	**1263**	**364**	**Low**	**6**	
Retail use	Rental center	1	B2	C15	I	17	9	High*	1	4
	Food Service use	1	B6	C15	I	218	40	Low	2	
	Food Service/Worship	**1**	**B14**	**C15**	**I**	**431**	**128**	**Low**	**3**	
	Bookshop/Food service	1	B3	C14	I	397	140	Low	4	
	Food Service	**1**	**B12**	**C17**	**II**	**730**	**154**	**Low**	**5**	
	Total	**5**				**1558**	**423**			
Multipurpose Use	Other Community uses	1	B11	C15	I	149	31	Low	1	3
	Music concerts	1	B13	C12	II*	284	52	Low	2	
	Food Service use, conference & office	**1**	**B7**	**C14**	**II***	**640**	**165**	**Low**	**3**	
	Visitors' attraction	1	B19	C15	II*	748	187	Low	4	
Museum Use	Church Art studio and/ or gallery	1	B17	C14	I	225	51	Low	1	2
	Museum	1	B8	C12	II*	260	50	Low	2	
Religious & Other Community Use	Religious use/community/religious	1	B9	C14	I	24	10	High*	1	1
	Community/religious	1	B15	C19	II	279	66	Low	2	
	Grand Total	**19**				**6132**	**1654**			

C = Century, * = High performing buildings, Rank (1 = best performing building, 6 = least performing building)

The significance of categorising energy use, by building use, can further be seen in figure 7.7. The total estimated annual energy consumption per floor area for all the buildings surveyed is 6132kWh/m^2 with approximately total CO_2 emission of 1654kgCO_2/m^2.

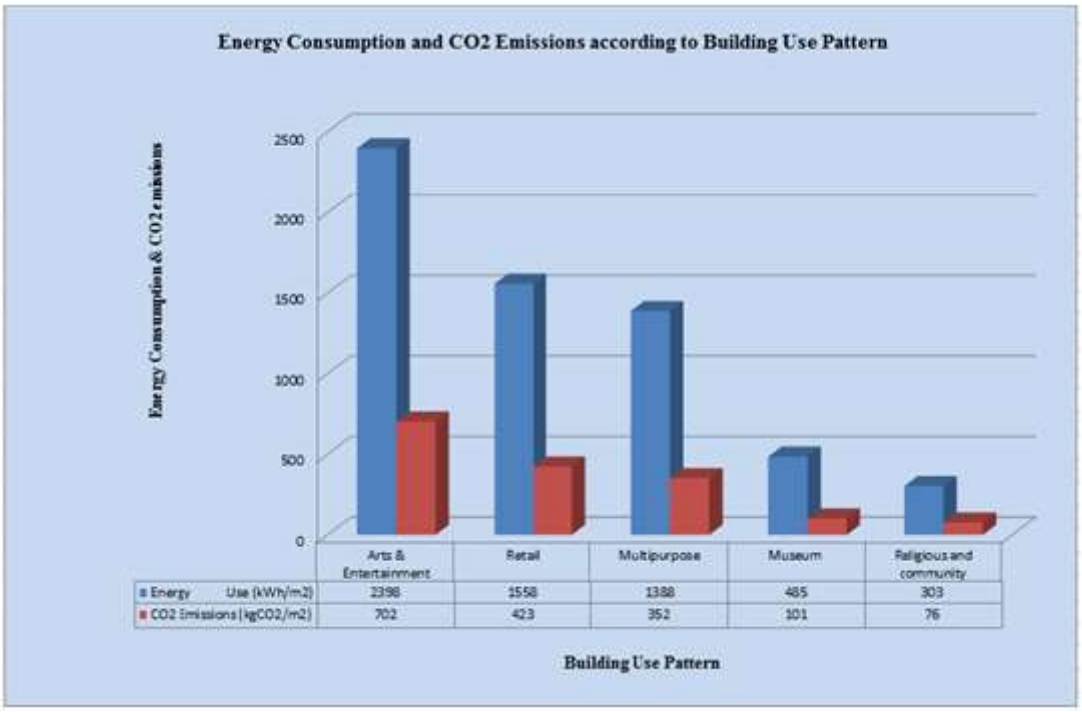


Figure 7.7: Energy consumption and CO_2, according to the building use pattern

To facilitate comparison of energy use among the building use typology or pattern of use, total energy use in each category was determined and given overall rank according to their performance ranges (1=High performance, 5=low performance). Buildings use for religious and other community purposes use the lowest amount of energy 303kWh/m^2 (5%) ranked first and best performing according to building use pattern. This was closely followed by buildings use for museum purpose ranked second with energy use of 485kWh/m^2 (8%). The energy use became tripled with buildings for multipurpose use 1388kWh/m^2 (22.6%) ranked third, followed by buildings use for retail purposes

1558kWh/m^2 (25.4%) ranked 4th. Meanwhile, buildings use for arts and entertainment use the largest amount of energy 2398 kWh/m^2 (39%) ranked 5th as the lowest performing building use type. Furthermore, to facilitate comparison between buildings in each category of building typology and/or pattern of use, total energy use for individual building activity and/or function in each building use pattern category were ranked according to their performance (1=High performance, 6=low performance) (Table 7.9). The 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.

According to Table 7.9, high performing buildings were found in three (3) of the building typology and categories except for buildings use for multipurpose and museum. The category of buildings uses for arts and entertainment comprises of buildings use for educational training in arts and music, theatre and music concerts. In this category, buildings 'B18' (educational art/music) and 'B16' (cultural performance/dance) ranked 1st and 2nd as the only high performing buildings with low energy use of 16kWh/m^2 (0.7%) and 48kWh/m^2 (2%) respectively of the total energy use in the building use typology. Although building 'B4' (educational art/music) has a smaller floor area (173m^2) is ranked 3rd with higher energy use of 195kWh/m^2 (8.3%) much higher than its counterparts 'B18' (327m^2) with the same building activity and/or function. The difference in energy use for these two buildings could partly be explained as a result of other factors which would further be explained in subsequent sections. Furthermore, in this category building 'B1' is which is used for theatre and ranked 4th with energy use of 366 kWh/m^2 (15.3%).

Meanwhile, buildings 'B10' and 'B5' both use for musical concerts ranked 5th and 6th as the highest energy consuming building activity and/or function with energy use of 510 kWh/m^2 (21.3%) and 1263kWh/m^2 (53%) respectively.

The category of buildings uses for retail purposes comprise of buildings for activity and/or function such as retail centre, food service, food service with worship, book shop with food service and food service only. In this category, only one building ('B2') use as retail centre is found to be high performing ranked 1st with the energy use of 16kWh/m^2 while other buildings ('B6', 'B14', 'B3' and 'B12') were low performing. In the multipurpose use category, all the buildings were low performing and they comprise of buildings for an activity or function such as other community uses, music concerts, food service use, conference and offices and visitors attraction. Similarly, buildings in the museum category use as church art studio/gallery ('B17') and museum ('B8') is all low performing. Among the religious use and other community category, building ('B9') with the primary use as worship performs better (higher performing) than building ('B15') whose primary use is for the community.

The approach of analysing based on high and low performance of the surveyed buildings compared to others within the same geographical region (East England), implies that opportunities exist within this portfolio of buildings to reducing energy use and operating costs. Furthermore, the performance range and ranking for the surveyed buildings could be valuable information and a tool for the owners and facilities managers of these buildings. This would enable them to compare the energy performance of their building within the same building portfolio and geographical region. Likewise, they could

get more informed on the actions to be taken to boost the performance of their buildings. In addition, the result of this finding could also serve as valuable information that can be used as a decision point when leasing, buying or financing any of these buildings or similar buildings.

7.8.2 Energy use by fuel type

In order to determine the factors responsible for the difference in energy performance of the surveyed buildings, energy performance of the buildings was categorised into high and low performance and compared according to their fuel type and their energy usage. Subsections 7.11.1, 7.11.2 and 7.11.3 present the findings from the buildings using electricity only, gas only or both gas and electricity respectively.

7.8.2.1 Electricity energy use

Both Tables 7.10 and 7.11 presents the energy performance characteristics of reuse listed churches using electrical energy only. The respondents were asked to indicate the activity in the building that constitute the main (75%) and secondary (25%) use of their building. It could be observed that this group of buildings demonstrated better energy performance when compared with the results of the energy consumption ratings of other surveyed buildings.

Table 7.10: Energy performance and building use characteristics of surveyed buildings using electricity

Building Code	Main Use	Secondary Use	Floor Area (m^2)	Electricity (kWh/m^2)	Rating	Rank
B18	Music school	Music school	327	16	A	1
B2	Bookshop	Bookshop	269	17	A	2
B16	Cultural performance and dance	Cultural performance and dance	262	48	B	3

Table 7.11: Annual energy use and CO2 emissions per floor area of the surveyed buildings (electricity only)

	B18	B2	B16
Electricity			
kWh/year	5286	4438	12508
$kW/m^2/year$	16	17	48
CO_2 emissions			
$kgCO_2/m2/year$	9	9	26
Delivered energy carbon factor ($kgCO_2/kWh$): 0.542			

For comparison between the buildings in this category, it can be seen from Table 7.10 that as the building size decreases, energy consumption increases. This finding is quite surprising because building 'B16' appears to be the smallest in size in this category. However, Figure 7.8 shows that B16 consumes more than half (59%) of energy use within the group. This helps explain why 'B16' used more than twice energy compared to CISBE benchmarked for energy use. This high consumption recorded by B16 may possibly be due to the intensity of energy use of buildings. Additionally, it could also be observed that the smaller buildings are put to more use or patronized than the bigger ones (intensive use or multi-purpose usage). This shows the preference in the use of smaller buildings,

this preference in usage may have consequently resulted in the over-use, which leads to (high energy consumption) low energy performance.

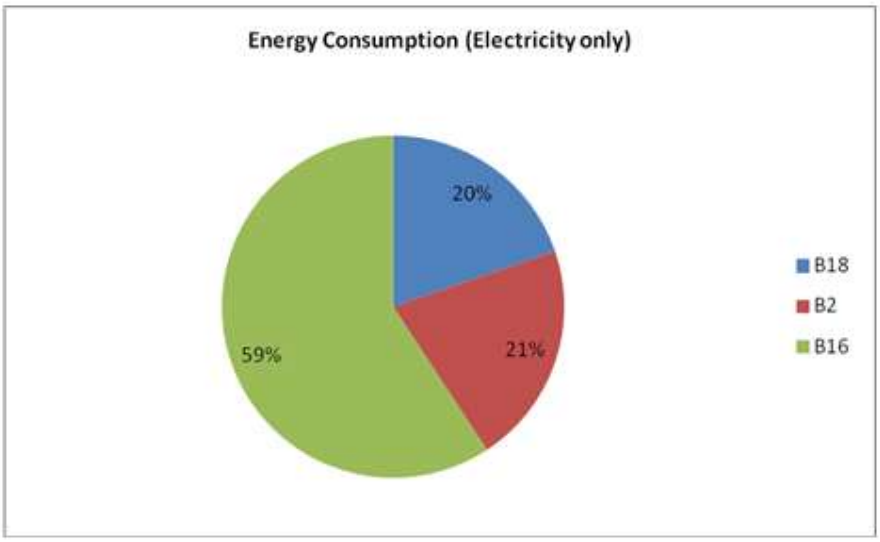


Figure 7.8: Percentage of electricity consumption by building fuel type

7.8.2.2 Gas energy use

The operational energy performance of the surveyed buildings using only gas energy is presented in Table 7.12 and 7.13. The energy performance of these buildings is quite poor compared to the buildings using electricity only given that the properties of the buildings have similar construction. As expected, as the floor area of these buildings increases, the energy consumption increases. However, a noticeable difference that was observed among this group of building compared to buildings in Table 7.10 is the dual usage of the buildings except building 'B8' used only for the museum.

Table 7.12: Energy performance and building use characteristics of the surveyed buildings (gas only)

Building code	Main Use	Secondary Use	Floor area	Gas (kWh/m²)	Rating	Rank
B6	Foodservice/community café	Prayer chapel	349	218	G	1
B8	Museum	Museum	350	260	G	2
B13	Concert and rehearsal	Community centre (arts & crafts)	392	284	G	3

Table 7.13: Annual energy use and CO2 emissions per floor area of the surveyed buildings using gas

		B6	B8	B13
Gas				
	kWh/year	76,170	91,158	111,184
	kWh/m²/year	218	260	284
CO_2	emissions kgCO_2/m²/year	40	50	52
Delivered energy carbon factor (kgCO_2/kWh): 0.184				

In the league of the final ranking on energy performance level (Table 7.6) for all the buildings surveyed; 'B6' ranked 7th; 'B8' ranked 9th and 'B13' ranked 11th. Buildings used for museum are perceived to be higher consuming in nature, however, contrary to this perception; Building 'B8' consumed lower energy in comparison with other buildings, a closer observation shows that building 'B8' uses an air source heat pump to meet its energy demand. The energy use data obtained from these buildings show the actual energy use of these buildings is way off (i.e. More than twice) compared to CISBE benchmarked for energy use.

The high energy use of buildings in this group is perceived to be as a result of multiple factors arising from energy end uses such as process plant (e.g. Freezers) and other

equipments (e.g. Catering), user's behaviour and attitude, efficiency of heating equipments etc. which would further be highlighted in the latter part of this analysis. Figure 7.9 shows the building use as food/catering service constitute the lowest energy usage (29%); Museum, 34%; and Concert and Rehearsal (37%).

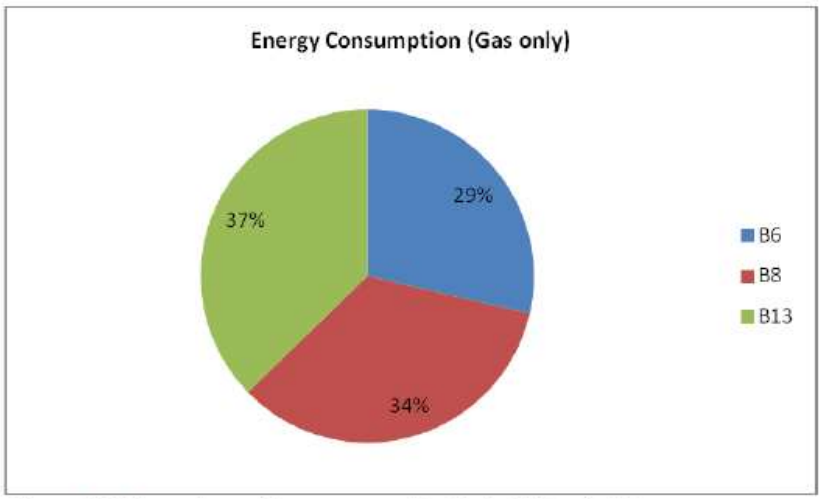


Figure 7.9: Percentage of gas consumption by building fuel type

7.8.2.3 Gas and electricity use

The characteristics of the buildings using the combination of gas and electricity are presented in Tables 7.14 and 7.15. The buildings in this category constitute 68% of the buildings surveyed. It could be observed that only building 'B9' out of thirteen other buildings within this category had the lowest energy use and consequently a better energy performance, especially when compared to other buildings in this category with similar size and use, such as building 'B15'. Data obtained from building 'B9' shows significant reasons why this building tops the list as the highest-performing building in this category. Building 'B9' is partly used for religious worship, for 2 -3 services on Sundays and 2-3 services during the week.

The building is also partly used for varieties of community-based activities such as music festival. Firstly, the building operators had a good approach to monitoring energy use of the building on monthly and yearly basis. Secondly, the old boiler dating from the 1950s, which originally runs on coke, but converted to gas in the 1960s has just been replaced by new gas boilers. Thirdly, the building operators reported '*we try to ensure that full heating is only on when there are actual activities occurring'* (Email communication with 'B9' operator, 2012). Interestingly, a notable feature which had also enhanced the energy performance of building 'B9' is the installation of photovoltaic system in 2012 generating 5955kWh electricity and saving 3394 tonnes of CO_2 and does not affect the visual appearance of the building. These factors all contribute to the high performance of the building.

An important factor could be observed from the data in Table 7.14 and Table 7.15 which may partially be responsible for high energy consumption is that building 'B12' and 'B14' is observed to be used for food and catering operations. This is a notable observation as catering operations use a variety of high energy intensive equipment to provide food for customers and the energy consumed by this equipment alone varies considerably according to how it is used and how it is regularly maintained. 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.

In addition, it is common in catering operations for equipment to be switched on at the beginning of a shift and left running throughout the day hence, these factors may largely be responsible for the high energy use in these buildings apart from heating the building during the cold season. Energy consumption in these buildings could also become aggravated if users' energy consumption reduction awareness and behaviour are very poor and the kitchen equipment such as hobs and ovens is used to warm the kitchen area. For comparison between the similar buildings, field data obtained for building 'B5' and 'B7' shows these buildings had extended facility attached to them for other multi-function community uses such as conference, musical concerts. This could partly explain why their energy consumption is quite huge compared to other buildings using the same fuel type.

Table 7.14: Energy performance and building use characteristics of buildings using electricity and gas

	Main Use	Secondary Use	Floor Area (m^2)	Elec & Gas (kWh/m^2)	Rating	Rank
B9	Church Service	Community Centre (Arts & Crafts, Music Festival Etc)	830	24	A	1
B4	Educational Art	Educational Art	173	195	G	3
B17	Museum of Religious Art	Museum of Religious Art	181	225	G	4
B11	Prayer group	Other community uses	327	149	F	2
B12	Food Service/Community Café	Food Service/Community Café	101	730	G	11
B10	Musical Concerts	Theatre, Cultural Performance & Dance	201	510	G	9
B3	Bookshop	Food Service/Community Café	280	397	G	7
B19	Visitor's Attraction/Exhibitions	Visitor's Attraction/Exhibitions	200	748	G	12
B1	Theatre	Cultural Performance & Music Concert	429	366	G	6
B14	Food Service/Community Café	Church Service	545	431	G	8
B15	Community Centre	Church Service (Sundays Only)	866	279	G	5
B7	**Food Service/Community Café**	**Conference**	**383**	**640**	**G**	**10**
B5	**Musical Concerts**	**Art Studio, Photography & Theatre**	**228**	**1263**	**G**	**13**

Table 7.15: Annual energy use and CO_2 emissions per floor area of buildings using electricity and gas

	B9	B11	B4	B17	B15	B1	B3	B14	B10	B7	B12	B19	B5
Gas & Electricity													
kWh/year	19,853	48,695	33,769	40,698	241,753	156,828	111,261	234,827	102,561	245,194	73,712	149,507	288,000
$kWh/m^2/year$	24	149	195	225	279	366	397	431	510	640	730	748	1263
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13
CO_2 emissions													
$kgCO_2/m^2/year$	10	31	47	51	66	57	140	128	199	165	154	187	364
Delivered energy carbon factor ($kgCO_2/kWh$)			Electricity = 0.542			Gas = 0.184							

7.9 Analysis and Ranking of Energy Performance by Building Operational Practices

Building operational energy consumption has been increasing for several reasons such as changing use patterns (i.e. More intensive use and longer hours) and greater use of electrical equipment and appliance within the building. The following presents the findings from the analysis of the building operational practices. The result of the survey is summarised in the following sections. In some cases, the results are presented as the percentage of valid response/replies to each question, where a non-valid reply means that no answer was given. A mean response for responses in each group was computed to indicate the significance of each group using equation 1.

Mean response for responses in each group = $(\Sigma R \times n) \div N$..... (1)

Where:

R = Number responses in each group

n = Frequency of responses

N = Total number of responses

The overall mean of the energy consumption rating was determined to enable the ranking in each group as shown in equation 2.

Overall mean (OM) for each group of responses = $[\Sigma M/Gn]$..... (2)

Where:

M = Mean of each group of responses

Gn = Number in the group

SD = Standard Deviation

7.9.1 Users behaviour and energy use

The user behaviour and energy consumption are presented in Table 7.16. The results obtained show that 31 percent of the respondents had good user behaviour towards equipment and appliance usage in managing energy. It could be observed that the greater percentage (21%) of the best user behaviour were buildings with high performance while 10% were buildings with low performance. On a general note, users' behaviour was poor with regards to energy management with results obtained show that the lowest performing buildings recorded 37% of the respondents turned off equipment and appliances only after closing hours. While 32% never turned off at all. The minority in this group (10%) turned off their appliances and equipment when not in use. Thus, these observations partly reveal why these buildings are low performing in terms of energy use.

7.9.2 The energy management awareness strategy adopted

The energy management awareness strategy adopted is presented in Table 7.17. Results showed that 28 percent of the respondents with low-performing buildings had no form of promotion of energy management awareness. Meanwhile, across the entire survey, over half (55%) of all the respondents only use a form of informal awareness as their strategy. In comparison to other low-performing buildings, only a few (11%) of the low-performing buildings adopted some ad hoc staff awareness while others (6%) adopted a programme of staff awareness and regular publicity. In the overall, the mean consumption rating (Mean = 90.5; SD=39.7) for the energy management awareness strategy was ranked 14th on the factor identification table (Table 7.36).

Table 7.16: User behaviour and energy consumption rating

How frequent is equipment/appliance turned off?	High Performance		Low Performance		Total Respondents		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Always turned off when not in use	4	21%	2	10%	6	31%	51	34.4	1	88.0
Only turned off after closing hours	-	0%	7	37%	7	37%	94		2	
Never turned off at all	-	0%	6	32%	6	32%	119		3	
Total (N)	4	21%	15	79%	19	100%	264			

Table 7.17: Energy management awareness strategy and energy consumption rating

Energy management awareness strategy adopted	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall Mean
No promotion of energy management awareness	-	0%	5	28%	5	28%	96		3	
Informal awareness used	4	22%	6	33%	10	55%	73		2	
Some ad hoc staff awareness	-	0%	2	11%	2	11%	143	39.7	4	90.5
Program of staff awareness & regular publicity	-	0%	1	6%	1	5%	50		1	
Total (N)	4	22%	14	78	18	100%	362			

7.9.3 Measures to improve energy performance

An important feature of the survey is the understanding of the measures that has been taken to improve the energy performance of all the buildings. As can be seen from an observation made from the results and summarised in Table 7.18, about one third (33%) of the buildings had under-floor heating system and another one third (33%) are unsure of measures to improve energy performance of the building. Results obtained also showed that just 5% of the high performing building and 11% of the lowest performing buildings installed new boilers as a measure to improve the energy performance of the buildings.

Further observation from the Table revealed that a minority (17%) of the respondents indicated that their lighting system had been replaced by a more efficient light source. It is worth noting from the table that in terms of simple measures of improving energy performance, such as; draught proofing doors and windows and fitting closers, none of the buildings surveyed had adopted any of these measures. Yet these measures are non-intrusive, non-invasive and low-cost measures to reducing energy consumption in heritage buildings. On the overall, the mean consumption rating (Mean = 92.25; SD=24.9) was obtained for measures taken to improve energy performance and was ranked 13th in the factor identification table (Table 7. 36).

7.9.4 Energy management policy

In this study, it was necessary to explore the possibilities of having energy management policy from the respondents using the result presented in Table 7.19 of listed church buildings surveyed for the purpose of this present research work. From the result in Table 7.19 although two-thirds (62.5%) of the respondents had an energy management policy

in place, however, contrary to expectation, the remaining 37.5 percent responded that they had no energy management policy in place. Thus, indicating that they were not employing any strategy or policy necessary for improving energy performances therefore had higher mean of the energy consumption rating. On the overall, the mean consumption rating (Mean = 86.5; SD=6.0) was obtained for energy management policy and was ranked 17th in the factor identification table (Table 7. 36).

Table 7.18: Measures taken to improve energy performance and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
Measures taken to improve energy performance?	n	%	n	%	n	%	Mean	SD	Rank	Overall Mean
Under floor heating	-	0%	6	33%	6	33%	103		2	
Fitting door closers to external doors	-	0%	-	0%	-	0%	0		5	
Draughtproofing of windows & doors	-	0%	-	0%	-	0%	0	24.9	5	
Installation of new boiler	1	5%	2	11%	3	17%	105		3	
Replaced lighting system with more efficient light source	-	0%	3	17%	3	17%	106		4	92.25
None	3	17%	3	17%	6	33%	55		1	
Total	4	22%	14	78%	18	100%	369			

Table 7.19: Energy management policy and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
Do you have any energy management policy?	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Yes	4	25%	6	37.5%	10	62.5%	82		1	
No	-	0%	6	37.5%	6	37.5%	91	6.0	2	86.5
Total	4	25%	12	75%	16	100%	173			

7.9.5 Nature of energy management policy

The results of the energy management policy are summarised in the Table 7.20. It could be observed from the Table that only two buildings out of sixteen had some form of written energy management policy. One respondent reported to have a written but partially implemented an energy management policy while another respondent proportionately reported to have written and extensively implemented energy management policy. Surprisingly, the difference is not statistically significant, as the respondents' buildings still fell under the low performing buildings category. As elsewhere, the limitations of small sample size must be borne in mind while interpreting these results.

It's important to note that the evidence from Table 7.21 revealed that integration of energy management policy was observed to be poor as half of (50%) of the respondents stated they had an unwritten energy management policy. However, it was observed to be much poorer at 38 percent of the respondents considering no form of energy management policy in their operations. Clearly, 'integration' here is a subjective concept and the effectiveness of such is dependent on the strategies adopted to manage energy use by the building operators. The most striking result emerging from the data shows that 25% of the respondents with higher performing buildings appear to have had an indicative of a stronger commitment to energy management policy even though they have unwritten policy. On the overall, the mean consumption rating of (Mean = 90.0; SD=37.5) was obtained from the nature of energy management policy adopted and was ranked 15th in the factor identification table (Table 7.36). This underscored the importance of

commitment to energy management policy in reducing energy consumption most especially if written and adopted.

Table 7.20: Nature of energy management policy and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall Mean
Nature of your energy management policy										
Unwritten	4	25%	4	25%	8	50%	79		2	
Written but not implemented	-	0%	-	0%	-	0%	0			
Written but partially implemented	-	0%	1	6%	1	6%	140		4	
Written and extensively implemented	-	0%	1	6%	1	6%	50	37.5	1	90.0
None	-	0%	6	38%	6	38%	91		3	
Total	4	25%	12	75%	16	100	360			

Table 7.21: Energy management strategies and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
What are your energy management strategies?	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Monitor trends in energy consumption	4	21%	3	16%	7	37%	58		1	
Consumption records adjusted for the weather	-	0%	4	21%	4	21%	134		4	
Monitoring and targeting scheme employed	-	0%	1	5%	1	5%	140	33.0	5	108.2
Energy use compared to targets for other buildings	-	0%	-	0%	-	0%	0			
Energy use made known to workers to check habits	-	0%	2	11%	2	11%	113		3	
none	-	0%	5	26%	5	26%	96		2	
Total	4	21%	15	79%	19	100%	541			

7.9.6 Energy management strategies adopted

Energy management strategies adopted for the building is presented in Table 7.21. In response to the question of energy management strategies adopted, (37%) respondents expressed that they monitor consumption trends of their energy use; majority (21%) of them were buildings under the high performance category. Meanwhile, others (21%) adjusted figures for weather conditions through consumption records. It was observed that, out of the 19 participants who completed the survey, only a small number (5%) indicated they adopted energy use compared to targets for other buildings. A notable feature of the survey is the extent to which strategies for energy management is adopted by majority (74%) of the respondents. It can be observed from Table 7.21 that only a small number (5%) of the respondents employed monitoring and targeting scheme; just a few (11%) above that employed strategies of making energy use known to workers to check habits.

It is surprising that the majority (74%) of the respondents that adopted energy management strategies belonged to the low performing category and only a minority (26%) of the total respondents had no form of strategies adopted. For a comparison of these findings with the resulting findings presented in Table 7.20 on nature the nature of energy management policy adopted; it could be argued that most likely the 21 percent of the respondents with high performing buildings could have taken responsibilities to manage energy use of their building as the building managers. Nevertheless, the overall mean energy consumption rating (Mean = 108.2; SD=33.0) obtained for energy management strategies adopted was ranked 5th on the factor identification table (Table7.36). This implies that a more pro-active approach and adopting combinations of

energy management strategies in operational practice of these buildings could have had more positive outcomes in reducing their energy consumption.

7.9.7 Building operation hours

Table 7.22 summarises the typical hours of operation hours in a week for the buildings covered in the survey to determine how it influences energy use and the extent to which energy used can be gauged from the reported hours of operation of the building. Significant variations in hours of operation by the use pattern of the buildings were observed. For example, 47 percent of the total respondents stated that they operated the building for less than 60hours per week, of which 12% of them constitute respondents with high performing and 35% were of low-performing buildings. A very small proportion (6%) from the high performing buildings also reported operating their buildings between 60-79 hours and greater than 160 hours per week, meanwhile, respondents with low performing buildings reported 60-79 hours (12%); 100-119 hours (17%), and 120-139 hours (12%) respectively. On the overall, the mean consumption rating (Mean = 99.4; SD=71.8) was obtained for building operation hours and was ranked 10th in the factor identification table (Table 7.36).

Table 7.22: Building operation hours and energy consumption rating

Building operation hours/week	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
<60	2	12%	6	35%	8	47%	67		2	
60 - 79	1	6%	2	12%	3	18%	181		5	
80 - 99	-	0%	-	0%	-	0%	0	71.8		99.4
100 - 119	-	0%	3	17%	3	17%	164		4	
120 - 139	-	0%	2	12%	2	12%	76		3	
>160	1	6%	-	0%	1	6%	09		1	
Total	4	24%	13	76%	17	100%	497			

7.9.8 Heating equipment used for the building

Respondents were asked what heating equipment they used for heating the building. The results (Table 7.23) show that 52% of the buildings were operated on gas boiler. 5% and 16% of high performing buildings had their buildings operated by a boiler and electric radiant heater for individual space heating respectively. Meanwhile, among the low performing buildings, 16% operated their buildings on gas boiler with under-floor heating; 11% on a suspended gas radiant heater. On the overall, the mean consumption rating (Mean = 132.25; SD=36.8) was obtained for building heating equipment and was ranked 2nd in the factor identification table (Table 7. 36). It is apparent from this table that building heating equipment plays a significant role among the factors responsible for energy consumption in public heritage buildings.

7.9.9 Age of current heating system

Table 7.24 sets out the results of the data on the age of the current heating system used for building operation. Approximately one-third of the respondents (33%) reported that the age of their current heating system ranges between 1-5years old. Other

respondents (28%) reported age of their heating system to a range between 6-10 years while two respondents stated the age of their current heating system to be between 11-15 and 31-35 years old respectively. It was noted that only a few (17%) of the respondents reported not to have an idea of the age of their current heating system. On the overall, the mean consumption rating (Mean = 101.17; SD=66.7) was obtained for age of heating system and was ranked 8th in the factor identification table (Table 7. 36).

Table 7.23: Heating equipment and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
Heating equipment used for the building	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Gas boiler with radiator	1	5%	9	47%	10	52%	114		2	
Gas boiler with fan convector	-	0%	-	0%	-	0%	0			
Suspended gas radiant heater	-	0%	2	11%	2	11%	170		4	
Gas boiler with underfloor heating	-	0%	3	16%	3	16%	155	36.	3	132.25
Electric radiant heater for individual space heating	3	16%	1	5%	4	21%	90	8	1	
Total	4	21%	15	79%	19	100%	529			

Table 7.24: Heating System age and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
How old is the current heating system?	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
1 - 5yrs	1	5%	5	28%	6	33%	44		2	
6 - 10yrs	-	0%	5	28%	5	28%	135		5	
11 - 15yrs	-	0%	1	5.5%	1	5.5%	199		6	
16 - 20yrs	-	0%	2	11%	2	11%	127	66.7	4	101.17
21 - 25yrs	-	0%	-	0%	-	0%	0			
31 - 35	-	0%	1	5.5%	1	5.5%	87		3	
Don't know	3	17%	-	0%	3	17%	15		1	
Total	4	22%	14	78%	18	100%	607			

7.9.10 Efficiency of the heating system

Respondents were asked what the efficiency of their heating system for operating the building (Table 7.25). Almost one-third (32%) of the building operators have no idea of the efficiency of their heating system. A lower percentage (26%) of the building operators indicated that the efficiency of their heating system ranges between 60-70% efficiency of which high performing buildings constitute a smaller (5%). It was observed that out of the 19 respondents, 21% reported 91-100% heating efficiency; 16% stated 81-90% heating efficiency and 5% reported 71-80% heating efficiency. On the overall, the mean consumption rating (Mean = 103.8; SD=29.4) was obtained for heating system efficiency and was ranked 6th in the factor identification table (Table 7.36) showing the significant impact that this factor can make on energy consumption.

Table 7.25: Heating system efficiency and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
What is the efficiency of the heating system?	n	%	n	%	n	%	Mean	SD	Rank	Overal mean
60 - 70%	1	5%	4	21%	5	26%	95		3	
71 - 80%	-	0%	1	5%	1	5%	140		5	
81 - 90%	-	0%	3	16%	3	16%	129	29.4	4	103.8
91 - 100%	1	5%	3	16%	4	21%	73		1	
Don't know	2	11%	4	21%	6	32%	82		2	
Total	4	21%	15	79	19	100%	519			

7.9.11 Quality of building maintenance

Table 7.26 summarises the respondent's evaluation of the quality of maintenance of the building. The quality of maintenance of the building was assigned numbers from 1 (poor) to 4 (excellent) to determine if the maintenance of the building has a significant

impact on energy use. The result from Table 7.26 showed that half (50%) of the buildings was fairly maintained. 12.5% reported the quality of maintenance was poor; while, just above one-third (25% and 12.5%) indicated their building was in good and excellent condition. However, contrary to expectation, the quality of maintenance was reported to be poor for 2 buildings among the highest performing buildings. On the overall, the mean consumption rating (Mean = 75.5.8; SD=39.0) was obtained for building maintenance, quality and was ranked 18th in the factor identification table (Table 7.36) showing the significant impact that this factor on energy consumption is less compared to other factors identified.

Table 7.26: Building Maintenance quality and energy consumption rating

Quality of maintenance of the building?	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Poor	2	12.5%	-	0%	2	12.5%	17	39.0	1	75.5
Fair	-	0%	8	50%	8	50%	97		4	
Good	1	6%	3	19%	4	25%	93		2	
Excellent	-	0%	2	12.5%	2	12.5%	95		3	
Total	3	18.5	13	81.5%	16	100%	302			

7.9.12 Lighting system

Lighting is a principal electrical load in church buildings. Building operators in the churches surveyed were asked about the artificial lighting system used in the buildings. Table 7.27 presents the results of artificial lighting used in the buildings. The majority (78%) of the respondents (22% of low performing; and 56% of high performing buildings) had the use of fluorescent tube for artificial lighting in common. It is apparent from this result that very few (11%) used the most efficient lighting source (i.e. Light emitting diode) while a few (11%) still make use of incandescent light source for their

building. Comparing this result with the findings obtained from Table 7.18; it could be argued that those who indicated they have replaced their lighting system with more efficient light source might not have considered the most efficient lighting source which could be responsible for higher energy consumption rating obtained for the buildings. On the overall, the mean consumption rating (Mean = 96.67; SD=26.3) was obtained for type of lighting system used and ranked 11th in the factor identification table (Table 7.36).

Table 7.27: Type of lighting system and energy consumption rating

Lighting system used in the building	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Ovreall mean
Fluorescent tube	4	22%	10	56%	14	78%	81	26.3	1	96.67
Incandescent	-	0%	2	11%	2	11%	82		2	
Light emitting diode (LED)	-	0%	2	11%	2	11%	127		3	
Total	4	22%	14	78%	18	100%	290			

7.9.13 Heating strategy adoption

Participants were asked to indicate the form of heating strategy adopted in operating their building. The result from Table 7.28 shows that a minority (20%) of the respondents used continuous heating as a form of heating strategy. Among the 15 building operators who responded to this question, 80% of them reported that they operate their building through intermittent heating. On the overall, the mean consumption rating (Mean = 102.5; SD=57.3) was obtained for type of lighting system used and ranked 7th on the factor identification table (Table 7. 36).

Table 7.28: Heating Strategy and energy consumption rating

Heating strategy adopted for the building?	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Intermittent heating	4	27%	8	53%	12	80%	62	57.3	1	102.5
Continuous heating	-	0%	3	20%	3	20%	143		2	
Total	4	27%	11	73%	15	100%	205			

7.9.14 Fabric improvement

The building operators were asked if there was any application of insulation to the building. It can be seen from Table 7.29 that 63% of the buildings had no form of insulation applied to the building including higher performing buildings. Meanwhile, 25% of the lowest performing buildings had made some improvement of the fabric in the form of adding insulation to the floor and 6 percent had some improvement of the fabric in the form of wall insulation and roof insulation respectively. One unanticipated finding was that buildings with some form of fabric improvement seem to be performing lower than buildings without fabric improvement. Furthermore, it could be observed from the findings that the mean energy consumption rating is incredibly higher for buildings with some form of fabric improvement. While the reason for this is not clear, a possible explanation may be due to a number different factors yet unknown. However, on the overall, the mean consumption rating (Mean = 113.25; SD=38.8) was obtained for fabric improvement and ranked 4th in the factor identification table (Table 7. 36) indicating that this factor plays a significant role in the factors that explains the difference in energy consumption between the high and the low performing buildings.

Table 7.29 Fabric improvement and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
Application of insulation to the building	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Floor	-	0%	4	25%	4	25%	109	38.8	4	113.25
Wall	-	0%	1	6%	1	6%	154		3	
Roof	-	0%	1	6%	1	6%	128		2	
No insulation	4	25%	6	38%	10	63%	62		1	
Total	4	25%	12	75%	16	100%	453			

Table 7.30: Building cooling strategy and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
Cooling equipment used in the building?	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Central system air-conditioners	-	0%	2	12.5%	2	12.5%	147	39.7	3	114
Other cooling equipment e.g. fans	-	0%	2	12.5%	2	12.5%	125		2	
No cooling equipment (natural air cooling)	4	25%	8	50%	12	75%	70		1	
Total	4	25%	12	75%	16	100%	342			

7.9.15 Building cooling strategy

Table 7.30 presents the findings on the type of cooling strategy employed by surveyed buildings. A total of 75% of the respondents reported that their building had no form of artificial cooling system used in the building. It could be observed from the table that the remaining 25% of the respondents indicated that they use air-conditioning system and other forms of cooling equipment in their building. A striking result obtained from this finding is that though only four (4) out of sixteen (16) of the total respondents to this question uses some form of cooling equipments in their building, the mean energy consumption rating of these four (4) buildings nearly doubles those of other twelve (12) buildings who indicated no form of cooling for the buildings. The possible explanation for this could be partly due to user's attitude to saving energy such as leaving the air conditioning on overnight or not switching off fans when not needed. This may be as a result of the common assumption that switching off an extractor fan will not have much of an effect on energy savings.

It could, however, be argued that a single fan may only signify a small power load, yet could bring about a significant loss of heat from a building if not adequately controlled. The heating system would then have to compensate which could typically increase boiler fuel consumption by around 5%. These findings may disprove the myths that leaving the air conditioning on overnight reduces energy costs as the system stays at the required temperature. This result shows a much higher energy consumption using air conditioning and fans than necessary. In the overall, the mean consumption rating (Mean = 114; SD=39.7) obtained for building cooling strategy and ranked 3rd on the factor identification table (Table 7.36) indicating that this factor plays a significant role in the

factors that explains the difference in energy consumption between the high and the low performing buildings.

7.9.16 Renewable technology adoption

Building operators were asked if there was any form of renewable technologies adopted and/or used for the building. Table 7.31 summarises the results for renewable technology implemented for the buildings investigated. On the average, 13% of the building adopted solar photovoltaic for electricity generation. Among them, 6.5% were high performing and low performing buildings respectively. One building (7%) had air source heat pumps; while greater number (80%) had no form of renewable technologies for the building. On the overall, the mean consumption rating (Mean = 59; SD=25.7) was obtained from renewable technology adoption and was ranked the least (20th) on the factor identification table (Table 7.36) indicating that this factor plays a significant role by clearly making a significant improvement in the energy performance of heritage buildings.

7.9.17 Building age

The year of the buildings surveyed was constructed is presented in Table 7.32. Generally, buildings constructed before 19th century constituted mainly the high performing buildings. These constituted majorly (67%) buildings constructed between the 14th – 15th centuries. Similarly, a greater percentage (40%) of low-performing buildings was also between 14th-15th centuries. Buildings built in the 12th-13th centuries; 16th-17th centuries; 18th-19th centuries, all constituted low performing buildings respectively. What is interesting in this result is that all the high performing buildings (27%) in those

surveyed could be observed to be buildings built prior to 19th centuries. This result is contrary to the myth that older buildings are less energy efficient. Similarly, statistical findings as indicated earlier in this study corroborate these results by showing that there is no significant difference between building age and energy consumption rating.

On the other hand, why it could also be argued that not all older buildings are energy efficient, observations from this result show that the age of the building is an important factor that could explain the difference in energy performance of the surveyed buildings. This argument stems from the results presented in Table 7.32 showing far more than half (60%) of the low performing buildings are buildings built prior to 19th centuries. Although, other possible explanations for this could be as a result of other unknown aggravating factors responsible for energy consumption within these buildings. However, on the overall, the mean consumption rating (Mean =101.0; SD = 50.2) obtained for building age factor shows it ranked 8th in the factor identification table (Table 7.36) indicating that this factor plays a significant role when considering energy use of heritage buildings.

Table 7.31: Renewable Technology Adoption and energy consumption rating

Renewable technologies used for the building?	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Solar Photovoltaic	1	6.5%	1	6.5%	2	13%	39	25.7	1	59
Air Source Heat Pumps	1	7%	-	0%	1	7%	50		2	
None	3	20%	9	60%	12	80%	88		3	
Total	5	33.5%	10	66.5	15	100%	177			

Table 7.32: Building age and energy consumption rating

What is Year of Construction of the building?	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
12th - 13th Century	-	0%	2	13%	2	13%	51	50.2	1	101.0
14th -15th Century	4	27%	6	40%	10	67%	66		2	
16th - 17th Century	-	0%	1	7%	1	7%	154		4	
18th - 19th Century	-	0%	2	13%	2	13%	133		3	
Total	4	27%	11	73%	15%	100%	404			

7.9.18 Building conversion year

Table 7.33 shows the year of conversion of the surveyed churches to other uses. Nearly half (54%) of the churches were reported to have been converted to another use between 2002-2012, of these categories, 7% were high performing buildings and 47% were low performing buildings, 20% of the buildings were reported to have been converted between 1969-1979 while 13% of high performing buildings formed the greater part of the buildings. On the other hand, 27% of the buildings were converted between the years 1980-1990; 7% of these categories to be high-performing buildings between the years 1991-2001 only 7% were converted to other uses. On the overall, the mean consumption rating (Mean = 67.5; SD = 28.5) obtained for building conversion year factor shows it ranked 19th on the factor identification table (Table 7.36) indicating that this factor is not a significant factor when considering energy use in reuse of heritage buildings.

7.9.19 Building heritage status

Table 7.34 shows the grade listed status of the churches shared. The majority (60%) of the buildings were grade listed churches with 27% of them to be high performing buildings. Grade II and Grade II buildings were 20% each respectively, and were of low performing buildings. On the overall, the mean consumption rating (Mean = 97.4; SD = 42.8) obtained for building heritage status factor shows it ranked 12th in the factor identification table (Table 7. 36) indicating that this factor plays some significant role when considering energy use in reuse of heritage buildings. However, based on a theory of value which takes priority over other factors when considering an energy use reduction

in reuse of heritage buildings, caution needs to be taken when considering some level of compromise to be introducing energy efficiency measures.

Table 7.33: Building conversion year and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
Year of building Conversion to another use	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
1969 - 1979	2	13%	1	6%	3	19%	28	28.5	1	67.5
1980 - 1990	1	6%	3	19%	4	25%	84		3	
1991 - 2001	-	0%	1	6%	1	6%	66		2	
2002 - 2012	1	6%	7	44%	8	50%	92		4	
Total	4	25%	12	75%	16	100%	270			

Table 7.34: Building heritage status and energy consumption rating

	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
Grade Listing of the building?	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Grade I	4	27%	5	33%	9	60%	55	42.8	1	97.4
Grade II*	-	0%	3	20%	3	20%	89		2	
Grade II	-	0%	3	20%	3	20%	140		3	
Total	4	27%	11	73%	15	100%	284			

7.9.20 Building use pattern

Table 7.35 shows the results of other issues related to energy use in reused churches. The result shows that 26% of the lowest performing buildings are used for food preparation and large restaurant; 16% used for a drink and snack bar and 5% for a small restaurant. On the overall, the mean consumption rating (Mean = 133; SD = 74.3) obtained for building Use pattern factor shows it ranked 1st in the factor identification table (Table 7.36) indicating that this is a significant factor when considering energy use in reuse of heritage buildings.

Table 7.35: Building use pattern and energy consumption rating

Commercial food preparation/serving in the building?	High Performance		Low Performance		Total Respondent		Descriptive Statistics			
	n	%	n	%	n	%	Mean	SD	Rank	Overall mean
Drink & Snack bar	-	0%	3	16%	3	16%	216	74.3	4	133
Food preparation area/Small restaurant	-	0%	1	5%	1	5%	165		3	
Food preparation area & Large restaurant	-	0%	5	26%	5	26%	106		2	
Not applicable	4	21%	6	32%	10	53%	44		1	
Total	4	21	15	79%	19	100%	531			

7.10 Ranking of Factors Responsible for Difference in the Buildings' Energy Performance

Table 7.36 illustrates the ranking results of factors responsible for the difference in energy performance of investigated buildings based on mean of the energy consumption rating while Figure 7.10 shows the graphical representation of the factors. In the table, the factor code, factor category, factor description, the overall mean and the ranking are presented.

Table 7.36: Ranking of factors responsible for difference in energy performance

Factor	Factor Category	Factor Description	Overall Mean	Overall Rank	
F20	building use pattern	Commercial food preparation/serving in the building?	133	1	Low performing indicators
F8	heating equipment	Heating equipment used for the building	131	2	
F15	cooling equipment	Cooling equipment used in the building?	114	3	
F14	Fabric improvement	Application of insulation to the building	113	4	
F4	energy management strategy	what are your energy management strategies?	108	5	
F10	efficiency of heating system	What is the efficiency of the heating system?	104	6	
F13	heating strategy	Heating strategy adopted for the building?	103	7	
F9	Heating system age	How old is the current heating system?	101	8	
F17	Building age	What is Year of Construction of the building?	101	8	
F7	operation hours	Building operation hours/week	99	10	High performance indicators
F12	lighting	Lighting system used in the building	97	11	
F19	heritage value	Grade Listing of the building?	95	12	
F3	energy performance improvement	Measures taken to improve energy performance?	92	13	
F2	energy awareness	Energy management awareness strategy adopted	91	14	
F6	nature of energy mgt policy	Nature of your energy management policy	90	15	
F1	user's behavior	How frequent is equipment/appliance turned off?	88	16	
F5	energy management policy	Do you have any energy management policy?	87	17	
F11	maintenance	Quality of maintenance of the building?	76	18	
F18	conversion year	Year of building Conversion to another use	68	19	
F16	renewable technology	Renewable technologies used for the building?	59	20	

Scoring 1-8: responsible from worst to the lowest performing indicators
Scoring 10-20: responsible from best to the highest performing indicators

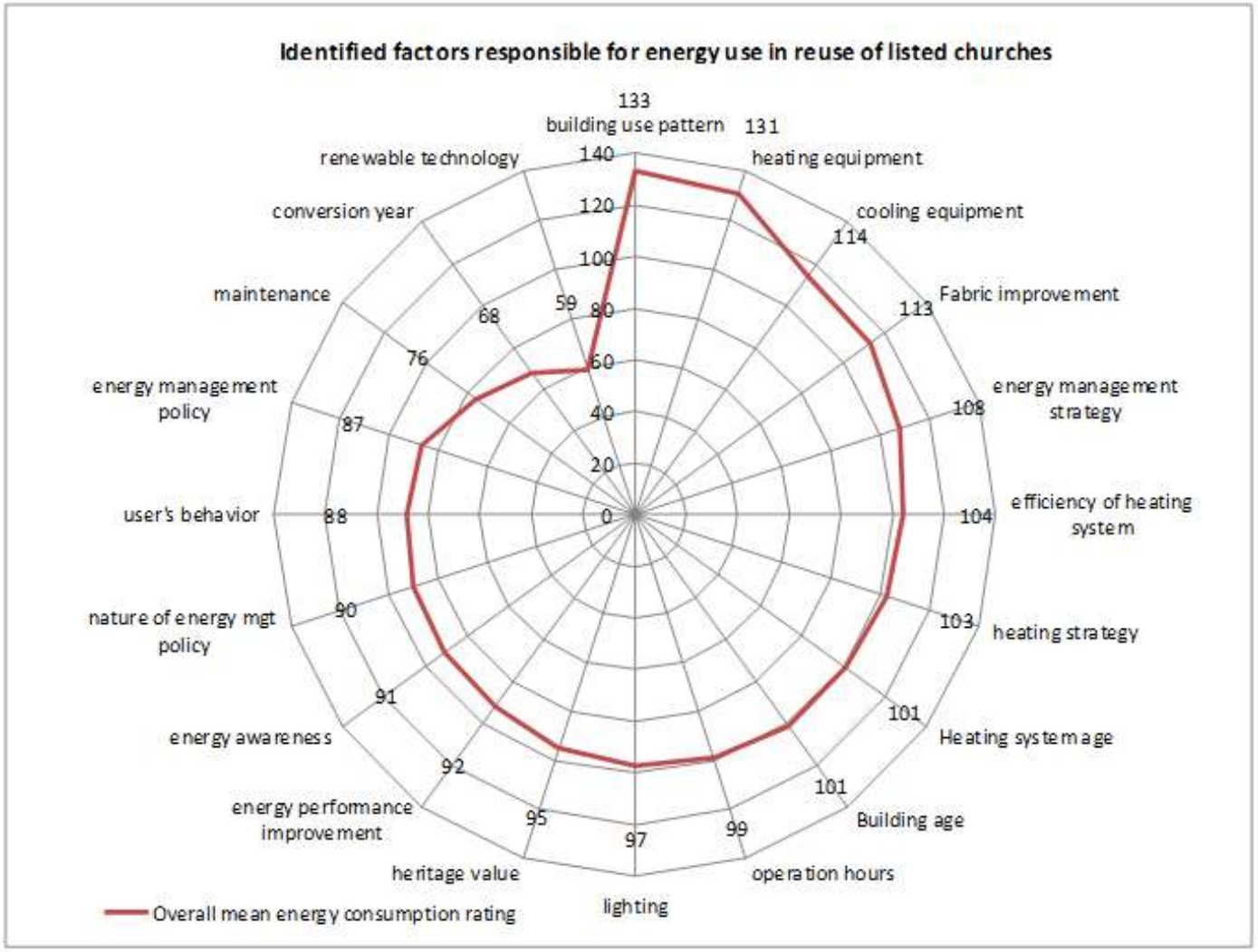


Figure: 7.10 Graphical representation of operational factors responsible for difference in energy performance

7.10.1 Factor groupings, ranking and identification of operational best practice

In order to identify the best practice in the analysis of the energy performance of the surveyed buildings based on the building operational practices, the twenty (20) factors presented and ranked in Table 7.36 and graphically illustrated in Figure 7.10 above were grouped to reflect the building operational performance evaluation criteria presented in Table 7.4 in this chapter. This was done by identifying and grouping similar factors together and ranked based on their overall mean (Table 7.37). The group energy consumption factor rating and performance are also presented to identify and show best practices identified in the result of the analysis.

According to Table 7.37, factor group A – D is identified as the factors responsible for the highest energy consuming factors explaining the difference in energy performance of the surveyed buildings. These factors are the factors to be integrated in the framework illustrating critical factors influencing energy consumption in reuse public heritage building projects to be fully discussed in Chapter 9 of this thesis. While factor group E – I were factors demonstrating best operational practice and will be considered in the development of final operational energy management framework in Chapter 10 of this thesis.

The findings from the building technical and energy use survey of the nineteen (19) buildings surveyed in this study shows there is a range of building typology and activity/function of these buildings which consume a significant amount of energy as indicated in the analysis. While many of these buildings have very long lives, however,

the equipment that heats, cools and provide lighting lasts for a few decades depending on the equipment. Thus, energy efficiency and conservation in these building results

Table 7.37: Factor groupings, ranking and identification of operational best practices

Factor Group	Factor Category	Factor Code	Factor Description	Overall Mean	Rank	Group factor Rating	Factor performance group
A	Building use pattern	F20	Buildings built with extension for other facilities	133	1	F	Low performance factor group
			Buildings used for commercial food preparation				
			Buildings used for arts & entertainment				
			Buildings used for retail				
			Buildings used for multipurpose functions				
B	Services	F8,	Heating equipment	113	2	E	
		F15,	Cooling equipment				
		F10	Efficiency of heating system				
		F13	Heating strategy				
		F9	Heating system age				
C	Fabric improvement	F14	Wall insulation	113	2	E	
D	Lighting	F12	Type of lighting system	102	4	E	
		F3	Efficiency of lighting system				
E	Energy management	F2	Energy management awareness	99	5	D	Medium performance factor group
		F6	Nature of energy mgt policy				
		F5	Energy management policy				
F	Building characteristics	F17	Building age	98	6	D	
		F19	Heritage value				
G	User's behavior	F1	Frequency of turning off equipment/appliance	88	7	D	
H	Building maintenance	F11	Quality of maintenance	76	8	D	
I	Micro regeneration	F16	Renewable technologies	59	9	C	High performance factor group

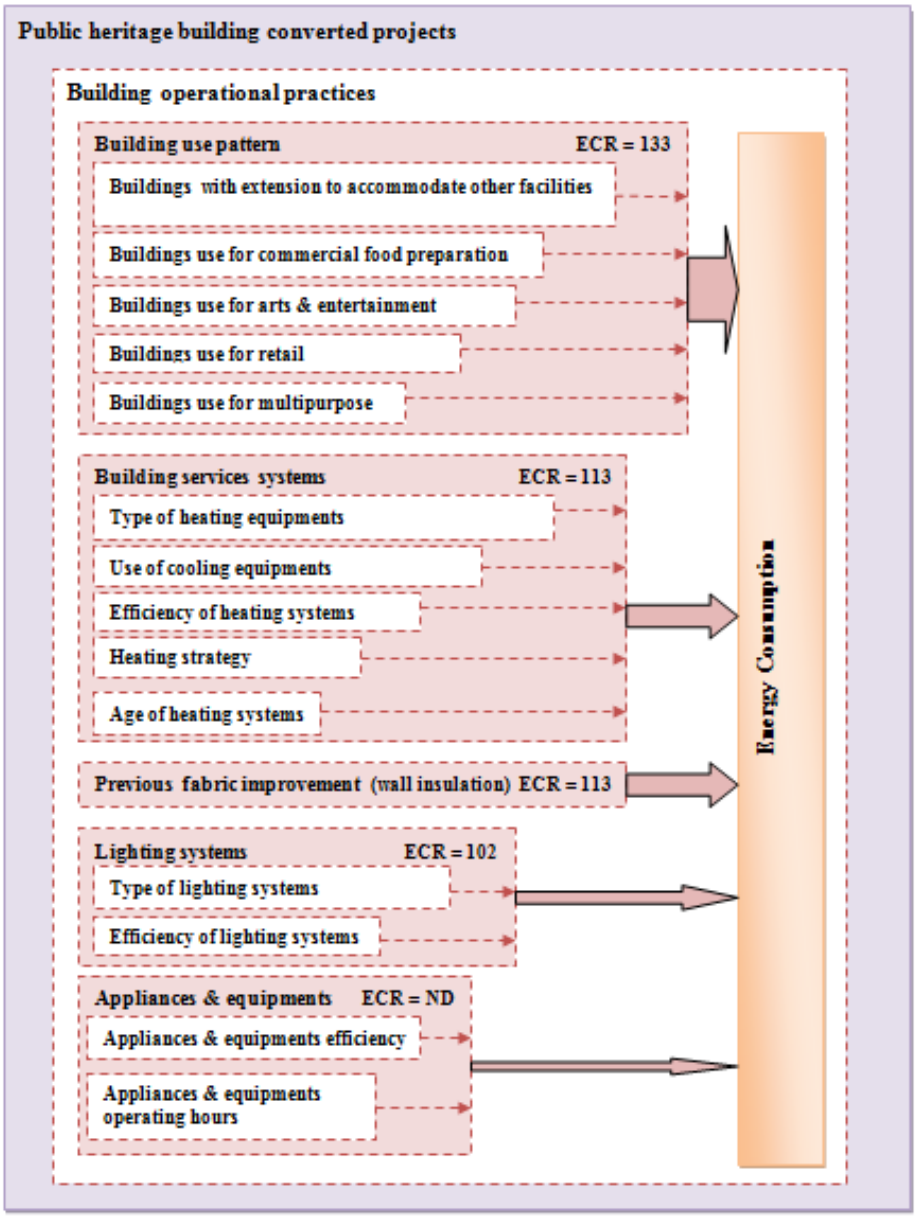
1 – 4 = factor responsible for high energy consumption requiring urgent attention and interventions;
5 – 9 = factors responsible for low energy consumption demonstrating best practice and lessons

from a combination of best practices identified in this study such as efficient equipment selection, periodic replacement of heating and cooling systems, efficient operating practices, caution in fabric improvement, preventive maintenance, changes in users' behaviour, conscious and planned efforts to integrating energy management policy, awareness and strategies to heritage buildings day to day operational practices. It is important to note that the combinations of individual and collective decisions, actions and efforts to reduce energy consumption of these heritage assets could result in significant energy savings. The findings from this analysis also indicate that if attention is given to implementing the lessons learnt from operational best practice that distinguished the higher performing buildings from the least performing one, the decision can reduce public heritage buildings' energy consumption by significant amount that could contribute to UK overall target for reduction of CO_2 emissions by 2020.

7.11 Development of Framework of Building Operational Practices

Figure 7.11 presents the developed framework from the findings of building operational practices influencing energy consumption in the reuse of LCBs. Using a soft systems methodology approach to articulate the factors responsible for differences in energy performance of the surveyed buildings; it was considered appropriate to provide a graphical illustration in the form of a framework to describe the exploration of dysfunctions in energy consumption of public heritage buildings. The essence and/or importance of this framework is to enable the necessary changes or interventions that are technically required to suggest possible solutions. To achieve this, SSM approach was employed to develop the diagram in Figure 7.11 in order to graphically clarify and sharpen the understanding of the reader about the factors identified from the analysis of

the technical and energy use survey conducted for this study. This clearly defines the technical areas that need to be concentrated upon and addressed to deal with the problems identified. However, the technical approaches will be complemented with other approaches in order to provide a holistic solution to the problem.



ECR = Energy Consumption Rating, ND = Not Determined

Figure 7.11: Illustrative diagram (B) from building operational practices' factors

7.12 Chapter Summary and Conclusion

High-energy consumption has been identified in 78.9% of reuse of listed churches surveyed in this study. Thus, the analysis in this chapter proves that many heritage buildings are low-performing buildings, though with potential and identifiable prospects for efficiency improvements and cost savings. Less than one-third (21%) of the buildings in this analysis were found to be above C based on their energy consumption ratings which create major concerns for project performance. Energy use in the surveyed buildings is found to be exacerbated by the combination and interplay of several factors. This chapter has shown that building use pattern, type, age and efficiency of services and lighting constitute major factors responsible for high energy consumption in the surveyed buildings. Energy consumption ratings of the buildings identified to be greater than 100 (C) could save as much energy as those starting with above average energy efficiency. Therefore, the surveyed buildings with energy consumption ratings below C ratings characterize possible opportunities for energy savings.

Part of the objective of this study is to identify those factors responsible for the difference in energy performance of the surveyed buildings, analyse the factors and rank them accordingly. To achieve this objective, twenty (20) different factors were identified, categorized and ranked into nine major groups. In addition, to further achieve the stated objective, SSM approach was employed to develop a framework, which would incorporate the identified critical factors. This is to graphically clarify and sharpen the understanding of the reader about the factors, which clearly define the technical areas that needs urgent attention so as to deal with the problems identified. Thus, if all buildings

with low-performing ratings reduced their energy consumption by way of addressing the identified factors, total annual energy consumption could be decreased significantly. Furthermore, annual bill savings for building owners could also amount to several savings of money as well as the reduction in the environmental footprint of the buildings. The factors and groups responsible for higher energy consumption (those needing attention) are discussed in details in Chapter 9.

CHAPTER 8: RESULTS (PRACTICING PROFESSIONALS' PERCEPTION)

8.0 CHAPTER OBJECTIVES

- To present the findings from a series of semi-structured interviews conducted for this study
- To serve as a further test of validity/reliability through comparison of the online survey results with the interview findings

8.1 Introduction

Semi-structured interview was selected because it provided the opportunity to have a guiding framework and still make room for respondents to elaborate and expand on their responses, which was more detailed than the responses from the online stakeholders' perception survey. Nine (9) semi-structured interviews were conducted between 2nd February 2014 and 2nd April 2014. All interviews were audio recorded and transcribed verbatim. The transcribed data were analysed using content analysis proposed by Gillham (2000). This is a procedure whereby substantive statements from the transcripts were highlighted and used to create narratives in the interviewees' own words.

According to Gillham (2000, p.74) 'the key feature of writing up interview data is to weave a narrative which is interpolated with illustrative quotes'. The illustrative quotes assists the researcher in the analyses to represent vividly the interviewees' responses in their own word as well as allow a balanced representation of the interviewees. Thus, the approach used for this analysis satisfy the three tenets of qualitative study: describing,

understanding and explaining. Participants who completed the online survey were asked to provide their contact information for a follow-up interview and the professionals who gave consent to participate in a follow-up interview were contacted.

A total of twelve (12) heritage building practicing professionals were contacted out of which only nine (9) were able to grant their final consent. The interviewees were professional's with diverse experience and occupations that directly interfaced with heritage building projects; with years of experience ranging from 5-35years in the industry. Thus, this gives a good representation of reuse of listed church projects across the North, South, East and West of England. Table 8.1 presents the details of those that granted final consent to be interviewed. In order to anonymize the interviewees, the use of representative descriptors was adopted to represent each interviewee. These are referred to as heritage practising professionals (HPP) which were nine in number and given identification as HPP1 - HPP9 in the text. Table 8.2 shows the framework of the interview schedule adopted for the study and how it is connected to the research objectives.

8.2 Interview Data Analysis, Procedure and Presentation

The data analysis of the interview commenced manually through verbatim transcriptions of the audio recordings. Each transcript was further manually processed based on the suggestion of Yin (2003) and Krippendorff (2004) hierarchical content analysis procedure

as summarised in Table 8.3. Responses were grouped according to the themes of the objectives of the study, namely: i) key factors underlying energy use (objective 1); ii) perceptions and priorities towards energy use reduction (objective 2); iii) practices and performance (objective 3); iv) strategies and challenges in practice (objective 4); and v) guidelines for professionals and operators (objective 5). They were further categorised under 'lead questions' and 'supplementary questions'.

Table 8.1: Presentation of information on interviews conducted

Location of Interviewee		Region	Interviewee's Profession	Interviewee's Position in the Organisation	Years of Experience	Date Interviewed	Interviewee's ID
1	Surrey	South	Architect/Conservation Specialist	Partner	35	January 2014	HPP7
2	Cornwall	South West	Architect/ Historic Buildings Specialist	Director	30	January 2014	HPP8
3	Gateshead	North East	Architect	Principal Architect	32	February 2014	HPP1
4	Derby	Midlands	Architect	Partner	34	February 2014	HPP2
5	London	Greater London	Architect	Project Running Architect	5	February 2014	HPP3
6	Plymouth	South West	Heating Engineer	Director	25	February 2014	HPP9
7	Canterbury	South East	Sustainability Consultant	Architectural Technician	11	February 2014	HPP4
8	Plymouth	South West	Electrical Designer	Director	20	March 2014	HPP5
9	Norwich	East	Building Service Engineer	Senior Engineer	29	March 2014	HPP6

Table 8.2: Framework for interview schedule

Objectives	Themes	Foccus of Questions	Supplementary Questions
To establish knowledge about key factors underlying energy use in reuse of public heritage building projects	Key factors influencing energy use	Determination of environmental sustainability of the project	1. How the project budget was determined? 2. What your capital budgeting process is, and how does it take into account life cycle analysis? 3. How sustainable considerations and/or decisions were integrated into the budget? 4. How budgets affect your decisions on environmental sustainability of the projects?
To investigate the perceptions, priorities and values of stakeholders about energy use reduction in reuse of public heritage buildings	Perceptions and Priorities	Determination of project requirement and goals	5. Could you please describe how the needs and/or the requirements of the project were identified? 6. What were the top goals and/or priorities for the project? 7. What specific target for low energy performance was included in the goal? 8. At what point were the energy consultants and/or contractors involved in the project?
To evaluate energy consumption and operational practices of existing reuse of public heritage buildings projects	Practices and Performance	Determination of project performance and operational management	9. What level of assessment and/or analysis was carried out to determine previous energy consumption and to improve energy performance of the building? 10. What strategies were adopted to reduce energy demand of the building and to enhance its sustainability? 11. Please could you comment on how your choice of fuel formed part of your low energy strategy?
To assess the strategies adopted in practice and to determine the factors preventing energy use reduction of public heritage buildings projects	Strategies and Challenges	Determination of low energy strategy for the project	12. What would you consider to be the most and least effective strategies adopted to reduce energy demand and why? 13. How were the ideas for the most effective strategies developed and how were they introduced? 14. How effective were the strategies adopted? 15. What indicators are used to judge the effectiveness? 16. What were your main frustrations in implementing the strategies and how were you able to overcome them?
To propose an operational energy management framework for public heritage buildings	Guidelines for Professionals and Operators	Development of framework	17. Since occupancy, what provision was made to obtain feedback from building operators on current energy performance of the building? 18. What provision was made to monitor and to more effectively manage the building energy use during the operational phase? 19. What provision was made to educate the building operators and/or users on how energy could be managed in the building? 20. What other circumstances do you consider might be contributing to higher or lower energy use than anticipated in your project? 21. What would you suggest to more effectively manage energy use in future similar projects?

In order to ensure the validity and reliability of the transcribing and analysis of the data, triangulation approach was adopted. Creswell (2007) and Patton (1990) described triangulation as a qualitative validity approach that makes use of multiple and different sources, methods, investigators and theories to provide corroborating evidence to shed light on a theme or perspective. After transcribing all interviews, member checking was carried out on all the interviews and the interviewees confirm the accuracy of the transcripts. Based on the suggestion of Creswell (1998), the researcher and another independent researcher were involved in the content analysis. During the process of analysis the interview transcripts, efforts were made to establish the abstract concepts found in the texts. Table 8.3 summarises the procedure of the content analysis of the interviews.

Table 8.3: Procedure of content analysis of interviews

Stage		Description
1	Coding	Transcribed responses were carefully examined for keywords in connection with the themes of the objectives of the study and were coded accordingly.
2	Collating	Responses coded were collated and grouped into specific code tables.
3	Reducing	Each response contained within specific code tables was reduced in content to short paraphrase. Meanwhile significant sentences in the responses were identified for possible use as verbatim examples. At this stage internal consistency of data was checked.
4	Comparing	Cross comparison was made from the data tabulated at stage 3 between all the interviews while searches for occurences, similarities, pattern and differences were also conducted.

According to Richards and Richards (1998) and Fetterman (1997), the ability to process analysed data in the form of frequencies is not uncommon for ethnographic research as this allows the preparation of graphic and/or visual representations of the verbal data. The use of visual representation in research is important because it allows complex

information to be conveyed quickly and coherently. In this study, some of the findings of the interviews are presented through the use of visualisation and tables. This method of presentation will go a long way in relating the interview findings to the essence of the study, which is fundamental in phenomenological inspired research (Tattersall *et al.*, 2007). Thus, by visualising the findings, the intention of the research study will further provide the multidimensional perspective of the connotations the interviewees considered to be part of contributing factors relating to the problem under investigation.

8.3 Findings from the Interviews

8.3.1 Key factors underlying energy use

Could you briefly tell about the success of your project based on environmental sustainability in terms of reduction in CO_2 emission?

Some of the interviewees acknowledged that it was difficult to predict the CO_2 performance moreover; there was no *figure* for the CO_2 emissions because they could not establish it. Meanwhile, some claimed not to have data on environmental sustainability, but made use of strategies which may promote the sustainability of the building. Specifically, HPP1 responded by indicating,

"*....We try to improve the sustainability from the point of view that we use about 99.8% of the existing fabric of the building so we try to retain as much as possible of the existing fabric so that we minimize the amount of materials we bring".*

In contrast to other interviewees who acknowledged the difficulties of establishing the environmental performance of their project, some others asserted that they were able to achieve some reduction in CO_2 emission in their project. For instance, HPP2 indicated,

"*...A 100% reduction in CO_2 emissions when comparing the building in its previous form; assuming present day occupation level's."*; (HPP2)

Other interviewees could confidently affirm,

> *".....we manage to get some predictions and from the predictions, we achieved 36% reduction in CO_2 by adapting heating system, I am not sure of the overall reductions but I think is something like about 50% reduction in CO_2."*(HPP4).

Meanwhile, some other interviewees rather indicated other means by which they consider their project successful such as adopting ground source heat pump (GSHP), insulating the roof, refurbishment of the glazing systems and achievement in significant reduction of electricity use to achieve a reduction in CO_2 emission of their project. HPP5 (2014) emphatically stated how this was achieved in their project,

> "*...There was a new extension so a ground source heat pump (GSHP) to service the new extension which is the café. So that brought the building to modern building standard.....We did improve the building fabric; we insulated the roof and try to improve the infiltration so we refurbish the glazing systems".*

The views expressed by the interviewees on achieving sustainable reductions of CO_2 emissions from heritage building projects go beyond a shadow doubt that divers opportunities exist to improve environmental performance of heritage buildings; as such it would be practical to pursue such opportunities in future heritage building projects.

Please could you shed some light on how the project budget was determined?

Although some interviewees did not state the worth of their projects, in other cases, budget ranged from £250,000 - £1.15million. The interviewee gave a number of ways on how the budget was determined. Some were determined by the end user either on the

basis of their business case study and/or business plan or the sufficient amount they are able to generate to sustain the building in the long term. HPP1 (2014) specifically noted,

> *"...There was like the end user...they made their own business case to see how is going to work and they approach.....various funding bodies in order to see....what sort of fund might be available*".

This involves two stages; firstly, the conservation and accessibility plan and secondly, the design team to work in conjunction with the end users in converting their business plan into design proposals. Other interviewees alleged that the client decided what the budget is going to be which only borders on areas of the client major concern. This ranges from the building's structural condition, the provision of new facilities and more space for the community to use. Meanwhile, the designer is to come up with a design to fit the requirements and to see how much it will cost to meet these requirements. Although, some of the interviewees argued that the primary driver behind the project was the fact that there was no effective heating for the building which dictated budget that was given to the designer; however, other interviewees acknowledged that they determined the budget themselves within the limits allowed from the grant. HPP2 (2014) clearly articulated this by asserting,

> "*...The budget really was determined by ourselves as an architect when we got the job and we had to give an estimate of what we felt the cost might be and the target was to keep it within the quarter of a million pounds that was the maximum cost allowed from the big lottery".*

It is interesting to note the response from one of the interviewees of how energy savings feature inculcated into the budget made securing funding possible for the project most especially the role of the local council played. The interviewee pointed,

> " *....Because the idea was to make the building a community building, and the local council fund it a little bit through the scheme called the government growth area funding. So a lot of the funding came from there and that determines the budget..... We applied for a lot of grants so there was initial budget determined and then for lots of the energy saving features, we manage to get funding through grants*" (HPP4, 2014).

In contrast to other responses above, other interviewees claimed not to know how the budget was determined. Some of such excerpts included:

> *....."Nothing to do with us, we were given the budget to work with"* (HPP5); *...."It was funded by insurance after a major fire at the church, the payment was negotiated, but essentially it was assessed on the complete rebuilding….."*(HPP7); *"the budget was determined from what is possible to achieve"* (HPP8).

It could be observed from the views expressed by the interviewees that the major determinants of the budget for reuse of heritage building projects are varied and strongly influenced majorly by the requirements of the end user. Notwithstanding, most of these views are related to prime factors such as cost effectiveness, available grant, the client's own limited resources and insurance and most importantly, the inculcation of energy saving features in the budget. Meanwhile, it is evident from these views that there is very little or no clear consideration for the requirements of environmental sustainability of the projects from the user's perspective. However, it could be argued that where energy saving features was included in one of the project's budget, it attracted funding. Therefore, this could be perceived to be a critical factor for lack of funding in many heritage building projects and could be an important indicator to limiting the environmental performance of reused listed church projects.

What is your capital budgeting process, and how does it take into account life cycle analysis?

A few number of the interviewees mentioned that they do not carry out full life cycle analysis, but rather took into consideration factors like what is being specified, how long is going to last and what will be the likely maintenance cycle. Such responses included:

> ...*"I 'd like to say we did not take into account life cycle analysis;"*(HPP4) *"we would expect any item of central plant to have life cycle analysis of 25 years anything less than that wouldn't consider because it means you are spending money on something that isn't going to last;"*(HPP6) *"Life cycle analysis was not undertaken because it is such a restricted situation"*(HPP8)

Other interviewees adopted a different approach to their budgeting process and life cycle analysis. Precisely, one interviewee explained that

> "*...firstly getting the budget estimate from a sketch scheme of the basic essentials... subject to approval of the big lottery and the village hall management committee, full details from the full working drawings were turned over to quantity surveyors to set the detailed budget....we didn't have electrical and mechanical engineer at all. We were very much reliant on Carbon Zero as a professional organisation and their commission was limited to initial advice.... even though they were the cheapest, their budget came up to £69,000 for the boreholes, the water system and heating systems, including the laying down the heating pipes so they were advisers in terms of life cycle costing and from my own professional point of view"* (HPP2, 2014).

Reflecting upon the above comments obtained from the interviewees, it is evident that only few of the interviewees took advantage of Life Cycle Cost Analysis (LCCA). This could be perceived to be as a result of limited knowledge on the part of the practitioners. LCCA could be a vital tool for providing evidence in support of the argument that energy saving features has a positive economic trade-off whenever put into consideration in a project. This implies that higher up-front capital costs become counteracted by lower future operating costs. This understanding to projects application with the aim of saving

energy can be useful to combat the traditional approach of considering only the lower upfront capital costs.

***How were sustainable considerations and/or decisions integrated into the budget*?**

A number of interviewees acknowledged that it is difficult to integrate sustainable considerations into the project's budget. The reasons given were: lack of the supplementary budget, inadequate funds on the part of the clients and the priority of the clients in wanting to make the building fit into their requirements. In a few cases, other interviewees pointed to the alternative approach they adopted through design in such a way to incorporate sustainable features within the budget envelope. For HPP3 (2014), the strategy adopted for sustainable consideration was rather based on the design strategy adopted for the interior by way of zoning the internal areas for under-floor heating system so that the building can be heated based on the zone that is needed rather heating the entire area they are not using. One of the interviewees clearly expressed,

> *....."This was a very difficult thing to do… essentially what we need to do is like trying to design the building in such a way that will incorporate as much as sustainable features within the budget envelope that is given to us...because at the time the building was built there were no as far as I can recall there were no supplementary funding for improving on the sustainability of the energy efficiency of the building.... So you try also as a design team to.. manage the best thing you can have because there is no separate budget for sustainability unfortunately"* (HPP1, 2014)

Another interviewee rather argued further stating,

> *....."again I'm going to keep going back to money... purely finance… if they go with the high efficiency gas boiler, they will have to pay for it themselves because they wouldn't have got any money"* (HPP2, 2014).

On the other hand, it is worth noting that others claimed to have some sustainability consideration at the beginning of the project, pointing to the fact that though the primary focus of the project was not for environmental reduction they took initiatives to look into environmental improvement of the project and did some energy strategy review right from the beginning of the scheme. This was exemplified in the following statements from the some of the interviewees

> .....*"We did a sustainability review at the beginning of the project, which was discussed with the project managers and cost consultants…. and the preferred elements based on the cost basis were appropriated into the scheme"* (HPP5); *"they were discussed with the PCC at an early stage and they welcomed the opportunity to use alternative sources of heat generation"* (HPP7).

Interviewee HPP4 (2014) reasserted their approach,

> "*….with the original budget including the sustainability features.... We applied for some other grants as well and they paid for major amounts of sustainability features.... but as we are installing heat pumps and others....They were included within the budget... Because we were going to get this funding for the heat pumps so we took an overview of the project on how sustainable we can make the church...."*

Across the group of the interviewees, it is clearly evident that there exists a multiplicity of perception and approach to integrating sustainable considerations into the project's budget. While some claimed it was difficult to achieve for several reasons identified above, others took the step further to overcome this challenge by bringing it into the requirements and/or introducing it to the client for sustainable delivery of the project even though it was not initially anticipated by the client. This suggests that though

environmental sustainability considerations may not have been driven by the client, however, they could then be pushed forward by the design team.

How budgets affect your decisions on environmental sustainability of the projects?

Generally, the interviewees indicated that the budgets for their projects were unfavourable to integrating environmental sustainability; however; only minimal pressures were experienced in decision making. Most of the interviewees expressed their concern about how a budget handicaps them apart from other restrictions to employ energy saving features into their projects. What appear to be excerpts from the interaction with them include the following:

> *".....The budget was not comfortable.. I have to say that...We have to tailor our decision.....to complete the building within the available budget…… we could have let say improve the energy efficiency of the building by putting double glazing because it's just not acceptable. Equally, we couldn't improve the insulation of the walls because again, it won't be acceptable from a conservation point of view so we did what we could so ....."* (HPP1);

Interviewee HPP2 strongly advanced his opinion and the role government need to play to encourage energy saving and renewable energy production for heritage buildings. He argued,

> "*....Conservation buildings should be paramount in terms of government thinking, but it is not paramount I'm afraid..., and there is a current discussion between the Green deal, which is a failed government initiative..... The construction industry is now campaigning as it has done for a very long time for a reduction in VAT to 5%. This would be paid for by abandoning the Green Deal programme. The building regulations relating to existing buildings would have to be strengthened at the same time to encourage energy saving and renewable energy production.*

Another interviewee expressed similar barriers the limitations on funding conservation projects has posed on enhancing sustainability of heritage projects. For instance, HPP3 (2014) drew attention to how their tender was returned because of the unexpected rise in prices, which exceeded their expectation for the amount to complete their project. The respondent expressed that this would have influenced decisions on what to retain and what to remove from the project. Meanwhile, HPP5 (2014) posited that if the client have not got the capital to invest in environmental systems they cannot go ahead. He argued that,

> *….on this one, we had a photovoltaic array, but they could not afford it".*

HPP6 as well expressed his opinion stating,

> *…"Obviously the more money you have the more sustainable you can be. Because of money had been the object, not only could we have provided the biomass boiler, we could have looked possibly to solar panels as well as to generate electricity".*

On a similar note, HPP8 also advanced other interviewees' position on the issue,

> *…."In scenarios where the client is very short of funds……there is a practical need to heat the building with the lowest capital outlay."*

A different perspective from other's claim was that the budget had an enhancing influence on their decision on environmental sustainability. According to (HPP4, 2014),

> *…"It (the budget) enhanced it (the practitioner's decision on environmental sustainability) because we got this extra grant, it really made us to be able to push projects forward."*

8.3.2 Perceptions and priorities towards energy use reduction

Could you please describe how the needs and/or the requirements of the project were identified?

The interviewee's understandings of how the needs of the projects were identified are diverse. In some cases project requirements were done by the end users, although were explained to the interviewers. In other cases, they were suggested to the users by the interviewees. Meanwhile, others claimed that they do not know how the project requirements were defined. HPP1 (2014) expressed how the needs of the project were determined without the design team involvement. According to him,

> *"..... this was done before we were involved in the projects and this was done by the end user by their business case but is also part of the wider consideration.....one of the objectives is to sort of promote heritage as part of the council's business development plan ..... so this is more of operational level planning at the highest council level and then going down to policy to operational implementation to project".*

HPP8, 2, 9 and 4 described how the needs of the projects were determined by the end user,

> *"In this case the parish asked for the best possible heating, but bearing in mind that the church interior is special and so could not be altered"*
>
> *".....Well, the actual parish council and the management committee all determined that they wanted to have a village hall that they can use and they were using the building, but it was damp, it was cold, mouldy and almost like a health hazard, they did have functions there sometimes they had skittles there in the summer but it was completely unusable in the winter.... So that determined their main fundamental requirement....* (HPP2)
>
> *"The client.……approached the architect...who enlisted my assistance with the heating design….the heating requirements were then broadly outlined by the client at a meeting……..."*(HPP9)
>
> *".....the need for the project were based on the fact that ……..does not have a community building of its own and the council did not have the budget to build a*

> *brand new community building…….likewise for the church, the congregation was getting smaller and smaller and the building is being used less and less……..the council looked at how the church could be converted…..”*(HPP4)

Some were suggested to the users by the practitioners:

> *“.....we suggested what needed to be done to the church ....For instance, if the roof was to be repaired and other things so they have an idea of the priorities ..... so we develop a report on the building to give them an idea of the priorities. The client knows that the floor issue was a top priority because there are areas in the church that they could not use because the floor is so uneven, and some of the areas have different of 100mm so it was a real trip hazard. So that became the number one priority.....”* (HPP3)

Others claimed that they do not know how the project requirements were defined,

> *“.....we are mechanical and electrical consultants so we do not know how the project requirements were defined. That was set by the client and the architect”* (HPP5)

To link the above responses of the interviewees and further details on the content of the responses of the interviewees, it could be perceived that energy use reduction does not appear to be a priority in any of the project needs. Notwithstanding, the range of determination of the needs of the projects varies from redesigning for community uses, replacement and redesigning heating system and best possible heating. Thus, generates emerging themes identified as repair, replace and redesign. Therefore, it could be argued that these themes appertains to critical factors to be considered when taking a decision to address the issues of energy use reduction in reused of listed church projects.

What were the top goals and/or priorities for the project?

Interviewees were asked about their awareness of the top goals and/or priorities for their projects. Again, key themes emerged from the responses: (1) the lack of perceived

priority of energy use reduction over other goals of the project; and (2) priority of building use functionality and developing the local economy and employment. One interviewee reiterated that the target of the project was focused on developing the local economy and employment:

> *".....now, as part of economic restructuring the area is moving towards more service industry, cultural heritage……..to attract more people to come to visit the more, spend more money.....and develop the local economy and employment"*(HPP1)

Another aspect of the goals that resonated among the others interviewees was the target functionality as mentioned by the interviewees:

> *".....They couldn't afford to run it because nobody will use it because it didn't have functions like toilet and things like that…….with all those three requirements fulfilled, then the building could be reused again."*(HPP2)

> *".....to provide the …….council with a community space….and to have somewhere in the centre……..where things are happening, and to make more use of the great building……."* (HPP4)

> *"It was to improve....the building and provide a building that is more of use to the community and all round use for the community so by incorporating to the space"* (HPP3)

> *"The primary reason was that the building was too cold and they have got to do something……..The top goal was to make the building more comfortable because it was not a nice place to be"* (HPP6)

> *"To rebuild the church to the highest possible standards incorporating new design, To provide a light, warm, welcoming interior for services and community events and To provide new facilities: kitchen and WC"*(HPP7)

> *"…….to re-use the old LPG tank……to achieve a median temperature of 10 ° C with a boost on Sundays; to minimise running costs"*(HPP9)

It could be concluded that observations from the above responses revealed that none of the interviewees mentioned the importance that low energy strategies could synergistically play with other goals and priorities for the projects. It might be argued that considerations for energy use reduction could provide as much significant economic benefit as local economy, employment and functionality considerations for the project.

What specific target for low energy performance was included in the goal?

Some of the interviewees unanimously indicated that no specific targets for low energy performance were intended. The views expressed included:

> *".....There was no specific target, but it is written in the council policies that we always like to aim and promote sustainability, energy efficiency, etc."*(HPP1), *".....To be honest, we didn't have specific target for energy performance, we just sort of work to try to fulfil the client brief……..In this project, it wasn't an option*" (HPP3), *".None...*" (HPP8).

Meanwhile, a few interviewees mentioned that their clients wanted low energy performance and/or reduction in CO_2 emissions conversely, only one interviewee (HPP6) indicated a specific target:

> "…..they wanted a building that was deemed eco or low energy use, low water use, sustainability..." (HPP2)
>
> *".....Well, because it (the building) was going to be used more often, we were looking into how we can reduce the CO_2 emissions, so we looked at boilers, we looked at other different things in the church that use a lot of energy, we make sure we include them in the end goal to make the church use less energy as much as possible considering that it was going to be used more and more..."* (HPP5)
>
> *"The specific target was that they were looking for a reduction; I think 25% in their carbon emissions, but with the biomass boiler we knew we would be well over that"* (HPP6)

In some cases the target was moderated by cost:

> *"The target was to provide heating and hot water at an affordable cost*"... (HPP7)

> *"Just to minimize running costs, no set target was given, although projected running costs were requested"* (HPP9)

The development and the advocate for low energy targets could play a prominent role in encouraging reuse of listed churches as indicated in the case of interviewee 'HPP6'. However, whether these targets could be as aggressive as they could have been seeming to be an open question. It could be argued that in the case where the request for low energy use is tied to the requirement of the clients, it demanded a variety of feasible strategies from the designer to integrate the most sustainable option and/or features for the project. This was exemplified in the project of interviewee 'HPP4'.

At what point were the energy consultants and/or contractors involved in the project?

The focus on involving energy consultants and/or contractors was relevant for the many of the interviewees who saw the significant role these could play in sustainable delivery of their projects. On the other hand, only a few interviewees who did could involve energy consultants felt it could affect the feasibility of the projects. Most of the interviewees indicated that in most cases the energy consultants were involved from the beginning. Their responses included:

> *"They were involved at the beginning", "..Because of the M&E council mechanical engineer is placed within our service...they were involved essentially from the very beginning from 2005, the moment we were appointed", "..At the very beginning the consultancy has produced in the initial report...", "An M & E engineer was appointed at the outset of the project", "As a potential contractor, I was involved at a very early stage of the scheme", "..The energy consultants were brought in right at the very beginning during planning stage….The conservation officers and other people that give consent to the development of historic buildings will need to have an idea of how far you are going to touch the*

building and the depth you are going, so we kind of got everyone involved at the beginning."

Others did not involve energy consultants at all:

".....we haven't had any energy consultant involved in a way to keep cost down…if we involve every consultants then the clients wouldn't be able to execute the project because everyone's fees will take all the money we had" (HPP3)

8.3.3 Practices and performance

What level of assessment and/or analysis was carried out to determine previous energy consumption and to improve energy performance of the building?

The remarks of some of the interviewees indicate that more than fifty per cent of the interviewees acknowledged they had no idea of previous energy consumption of their projects before the commencement of their projects. Meanwhile, others found the practice of analysing previous energy consumption important as a means to identify potential area to improve the energy performance of the building. The following indicates the responses of those who had no idea of previous energy use of their projects:

".....I'm not 100% sure if there was already a BMS system in place when we sort of commence work or not….I think they were looking into…….energy consumption based on previous bills .... The system that has been already in

place was old fashion gas fired Combi boilers and even old fashion sort of warm air gas fired heating system that were not particularly energy efficient...."(HPP1)

"....The client will have the records of the past energy bills and of what it costs to heat and maintain the building...." (HPP3)

"...None other than the basic experience of the people those that manage and run the village hall..." (HPP2)

"We had no idea of what the previous energy consumption was purely because none of the building systems were working….no gas bills and no electricity bills.

> *We did modelling of the building to prove what we needed to do to heat the building. But as the building was in effect unheated, we had no idea of what previous energy consumption was."....* (HPP6)
>
> *"None"* (HPP9).

A number of other interviewees who referred to one form of analyses conducted before the commencement of the projects asserted what they did. Nonetheless, while some expressed the usefulness of the assessment, on the other hand, others felt the usefulness of such practice was rather limited. Interviewee HPP4 alleged a detailed energy model was useful to identify or verify a variety of strategies considered for low energy performance and to assist in decision making and explained,

> *".....It's quite difficult to model churches, there is a program called SBEM (Simplified Building Energy Model) and another program called IES similar to it. You can do with SBEM and IES as in any model of the building in 3D and you can assume the heat loss value for the walls, floors and roofs and the efficiency of the heating system.... then we estimated the heat loss.....we did not do it ourselves; We had another company's engineer did the calculations for us using the software. And that is what gave us our predictions of the energy consumption of the building as it was.*

A similar approach used by HPP4 was also considered and adopted by HPP5 confirming,

> *"We did a thermal model of the existing building"*

In contrast to other interviewee's approach, interviewee HPP7 and 8 admitted the limitation of the other interviewee's procedure claiming;

> *"....We had previous energy bills, but they were for a very limited use of the building"* (HPP7)
>
> *"....Heat loss calculations were undertaken, but the volume/height of the building meant that the results will always be sub-optimal."* (HPP8)

What strategies were adopted to reduce energy demand of the building and to enhance its sustainability?

Seventy eight per cent of the interviewees referred to the strategies adopted to reduce energy demand of the building and to enhance its sustainability. On the other hand, few of the interviewees expressed that they could do nothing to reduce due to the listed nature of the buildings. In some cases, some adopted the use of high efficient gas fired boiler and low energy lightings while others use zoning strategies to avoid energy wastage in the building. The adopted strategies were varied from one project to another project, although many some have some strategies in common. For instance, HPP1 mentioned the strategies of combination of high efficiency gas fired boiler and low energy lighting systems:

> *"…..We considered and implemented…..high efficient gas fired boiler that replaced the existing low efficient system and ...low energy lighting…..as they are programmable……depending on what is going on in the building you can dim the light, can provide background lighting, direct lighting, etc. "*

HPP2 rather advanced the strategies of applying heritage friendly construction materials and components:

> *"….The specific strategy was to dry the building out…..the natural hydraulic lime and components inside which is the ….. insulated plaster with chosen hemp…"*

Interestingly, HPP3 articulated how he used a form of design strategy of incorporating heating zoning system within the entire church:

> *"….The heating system being on different zones….they don't have to heat the entire church; they can just heat one meeting room and the kitchen that's all they need for that particular evening or on a Sunday when the church is full the client can heat everywhere, but then during the week when most of the main body of the church, the nave isn't used they can lock it off if they need to and not heat it at all. And also if its late evening activities and the users forget to put the heating off, then the client can configure the heating to go off so there is no wastage."*

HPP4 explained how the strategies were adopted by addressing the problem of very inefficient old heating system with renewable technology along with the installation of low energy lighting system:

> *"....We got another heating system which is the GSHP.... Originally, it was gas boiler of about 20 years old which was reaching the end of its life. It was really inefficient and.....And then because the building is going to be used as theatre, concerts etc. we installed low energy LED lighting system which includes base lighting and all the types of lighting required for different events"*

HPP5 highlighted adopting more controversial strategies on fabric improvement by adding insulation he claimed,

> *"We refurbished the glazing systems and insulated the roof and....added insulation to the floor"*

In contrast to other strategies adopted by other interviewees, HPP6 advanced his argument for adopting biomass boiler. He argued,

> *....In terms of reducing the building energy usage, it was purely limited to improving the energy efficiency of the heating system by using the biomass boiler instead of using the electric and gas fired heating there wasn't any physical improvement to the building structure because we just weren't allowed to do it."*

Similar to strategies of fabric improvement adopted by 'HPP5' another alternative, unconventional and innovative strategies of locating renewable technologies (Air Source Heat Pump) in heritage building was adopted and pointed out by HPP7 stating,

> *"We were able to redesign the roof to incorporate insulation, install a small bank of solar panels on the tower roof, and an air source heat pump in the tower"* (HPP7)

In a few cases, other interviewees expressed their limitations why nothing could be done:

"None – we have had to place the heat emitters in locations dictated by the previous Victorian installation" (HPP8)

"None, as the church was a listed building, no meaningful chances could be made to its structure or appearance."(HPP9)

Following the above responses on the above strategies adopted by the interviewees and from a conservation point of view, it would appear that not all the strategies adopted are valid strategies for addressing the issues of energy use in heritage buildings for sustainability purposes. Notwithstanding, these strategies do indicate the diverse range of approaches that could be applied to heritage buildings on a case by case basis. This strongly supports the views that there is no one fit for all approach or strategies for improving environmental sustainability of heritage buildings. Furthermore, it's noteworthy to exercise some high level of caution when considering some of these strategies in any future projects (Table 8.4 and Figure 8.1).

Table 8.4: Relative importance and ranking of strategies adopted by the interviewees

Strategies adopted	Relative importance	rank
under floor heating	5	1
floor insulation	4	2
roof replacement/redesign & insulation	4	2
high efficiency gas boiler	3	3
replacement of floor	3	3
ground source heat pump	3	3
high efficiency luminaries	2	7
repointing of wall	2	7
refurbishment /repair of glazing	2	7
low energy programmable lighting	1	10
zoning of floor for controlled heating	1	10
roof repair	1	10
installation of solar panels	1	10
air source heat pump	1	10
biomass boiler	1	10

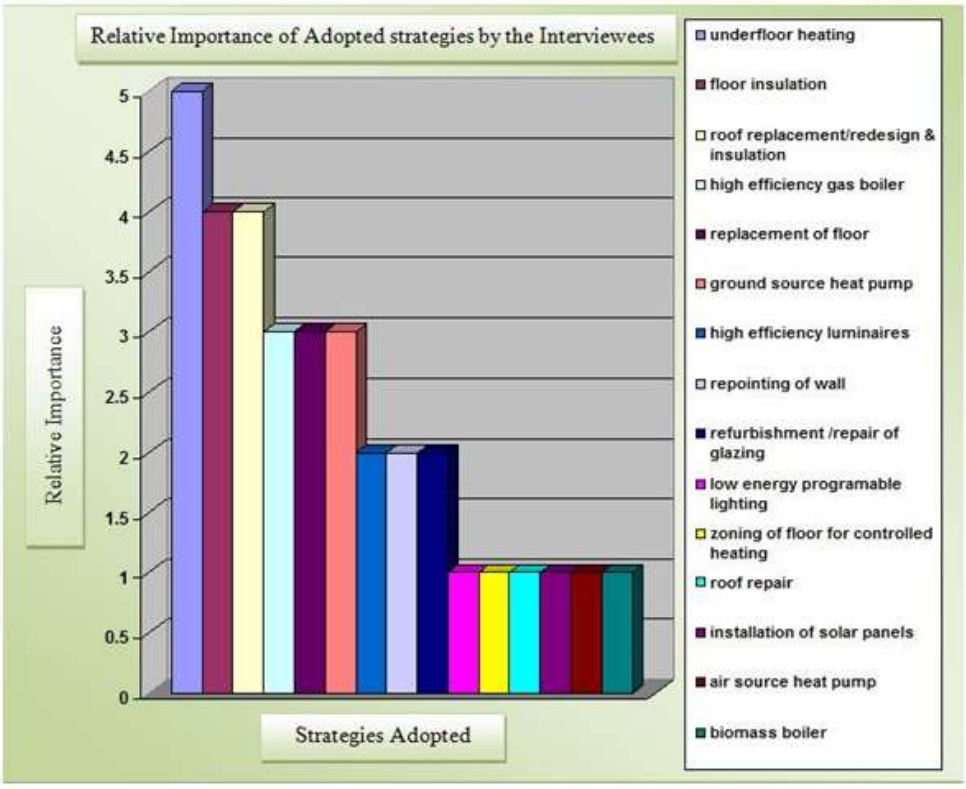


Figure 8.1: Relative importance of strategies adopted by the interviewees

Please could you comment on how your choice of fuel formed part of your low energy strategy?

Interviewees acknowledged that the choice of fuel formed part of the low energy strategy they considered in their projects and was mostly based on sustainability. According to HPP1,

> *".....to avoid using sort of electrical energy……..on sustainability ground, the only option we had was to go for gas because of the limitations for other options of renewable energy……under floor heating is probably the best option because…….all the water doesn't need to be heated to the same level as radiators, heating….most of the heat is ……as it comes from the ground in the first few meters……..."*(HPP1, 2014)

Interviewee HPP2 rather draws attention to the rationale for his choice of renewable technology and specifically mentioned that the only fuel choice they had was electricity but he affirmed:

> *".....We know we could not afford electricity to run an uninsulated building....Everybody, locally and I are aware of the volatile cost of fuel and liquid LPG. There is no gas main…….wind generator will not provide sufficient energy or be acceptable within that particular location and we didn't have enough land to place it within the ground and the local land wasn't friendly… So we quickly came to conclusion that we require some form of ground source heating (GSH)....* (HPP2, 2014)

Interviewee HPP3 clearly stated his choice and limitations and described,

> *".....It's a very basic boiler for heating the building....if one breaks down the other one could operate the system and that would be the under floor heating. I think we looked into other options and this seems to be the appropriate because of the size of the building…….we have lots of experience using all those things in other projects, but for this particular project, we didn't find another solution that will fit the building parameters."*(HPP3, 2014)

Interviewee HPP4 argued the basis of his final choice after giving several considerations to other alternatives and difficulties associated to selecting them he expressed,

> *"We wanted to use a low carbon renewable energy technology in the church. We looked…….at solar thermal,....photovoltaic (PV) and because of the location and historic nature of the church, they would not let us put anything like that on the roof, We looked at……..biomass boiler, but due to the central location of the town,*
>
> *it's really difficult to get in the delivery.....so the only option we ended up…….were air source heat pump (ASHP) and GSHP. ASHPs looked really unsightly placing them in the church did not really go down very well with the conservation guys so we were really left with one option which was GSHP…….the least controversial of them."*(HPP4, 2014)

Interviewee 'HPP5' gave similar consideration of choice of fuel to that of 'HPP4'he claimed available resources was a determining factor of his final selection,

> *"...The first thing…was to look at the available resources on the site…..a lower CO_2 emission is something that works well with the heat loss and the parameters of the building itself. We incorporated the ground source heat pump……."* (HPP5, 2014)

According to 'HPP6' available grant from the central government dictated best choice of fuel, making the project feasible to achieve. He admitted,

> *"..Again the grant available from the central government for a biomass boiler; if it was gas fired I don't know what they would have done….it was purely down to cost and the fact that money was available from the central government for a biomass boiler..."*(HPP6, 2014)

Interviewee 'HPP8' and 'HPP9' indicated the impossibility of the most sustainable choice and refer to the cause of the limitation alleging,

> *"We could only place the boiler in one location and gas was not feasible – it would have been LPG Therefore oil was the only solution, though biomass was considered, but the logistics have proved impossible"* (HPP8, 2014)*; "….I went along with the PCC's request to re-use the existing LPG tank, but then realised that this was incompatible with the desire to site the boiler in the basement as this in turn would conflict with the gas safety regulations. Next we looked at oil……..having ruled out Air source Heat Pumps – lack of capacity – and*
>
> *Ground Source Heat Pumps – capital cost. Further suggestions of biomass were also considered....."* (HPP9, 2014)

8.3.4 Strategies and challenges

What would you consider to be the most and least effective strategies adopted to reduce energy demand and why?

Responses of the interviewees to this question are quite diverse, revealing and instructive. The interviewee's consideration of the most effective strategies is summarised and presented in Table 8.5. According to interviewee 'HPP2' reusing building itself in the

first instance is considered the most effective strategies he further advanced his argument that,

> **"**……. *in terms of the reuse of the building, the carbon footprint is only one third that of a new building….We could have considered Air Source Heat Pump (ASHP) but that would have been environmentally probably not acceptable….on a scheduled monument because the units are quite big and they have to be outside.....The least effective strategies would have been to rely on electricity as the main source and not to go for the more expensive borehole system"* (HPP2, 2014)

Interviewee 'HPP4' on the other hand, posits the combination of certain strategies rather provides the effectiveness according to him,

> *"....I think the most effective strategy is probably the GSHP…I think the overall heating system with the under floor heating, the insulation, the heat pump combined is probably the most effective strategy…… Because it enhances the building, made it more comfortable to inhabit .....and just really encourage the use of the building. I think if we had not done it, people would be less inclined to book it for events… (The least effective strategy) I think it would probably be the rain water harvesting because it breaks down quite often because the pump fails…."* (HPP4, 2014).

For other interviewee, such as 'HPP5' the most effective strategies were rather more of fabric improvement. He argued that

> *"....(the most effective strategy is) Improving the fabric u-value and reducing infiltration, refurbishing the glazing systems, insulating the roof and floor...."* (HPP5, 2014)

However, conflicting view of this is expressed by HPP6 (2014), who in his opinion rather stressed on restrictions imposed to fabric improvements. According to him,

> *".....The problem is you can't do anything to the building fabric…because you've got vaulting which is underneath the main roof construction so you can't insulate the roof. But as it is now you are limited to reducing electrical consumption, which would be by high efficiency lighting and overall heating demand. On a project like this, you are very limited on such measures because*

> *you are not allowed to interfere with the building very much because you can't touch the windows, there is nothing you can do with the floors or the walls……. The least effective strategies is if you were trying to replace the existing boiler plant with new and you are not doing anything to change the type of heating emitter,"* (HPP6, 2014)

Meanwhile, other interviewees concur with the view on the combinations of fabric improvement along renewable technology. Specifically, interviewee 'HPP7' takes the stance on the combinations of

> *"....the insulation, solar panels and air source heat pump because they provide hot water and heating throughout the year"* (HPP7, 2014).

According to interviewee HPP8's proposition, *"...Draughts around doors could be reduced by means of thermally lined curtains.* She further also draws attention to the fact that *"...Some churches have looked at high level fans to circulate the warm air, but I have not witnessed this working very well to date."* (HPP8, 2014).

Again, as initially observed above it is self-evident that there exists a multiplicity of views on the most effective strategies from heritage practitioner's perspective. Table 8.6 shows the various strategies as identified from the interviewees' responses and ranked

accordingly. It can be seen from Figure 8.2 that the most reccurring themes and/or strategies revolves around building services constituting 34% and ranked 1st among the strategies mainly considered for energy use reduction (Table 8.6). This is followed by maintenance approach (24%) and fabric improvement (24%) ranked 2nd and in the 4th rank the application of renewable technologies (18%) (Table 8.6). The adoption of these strategies could be perceived to be exacerbated by various factors connected to the buildings the interviewees had worked on.

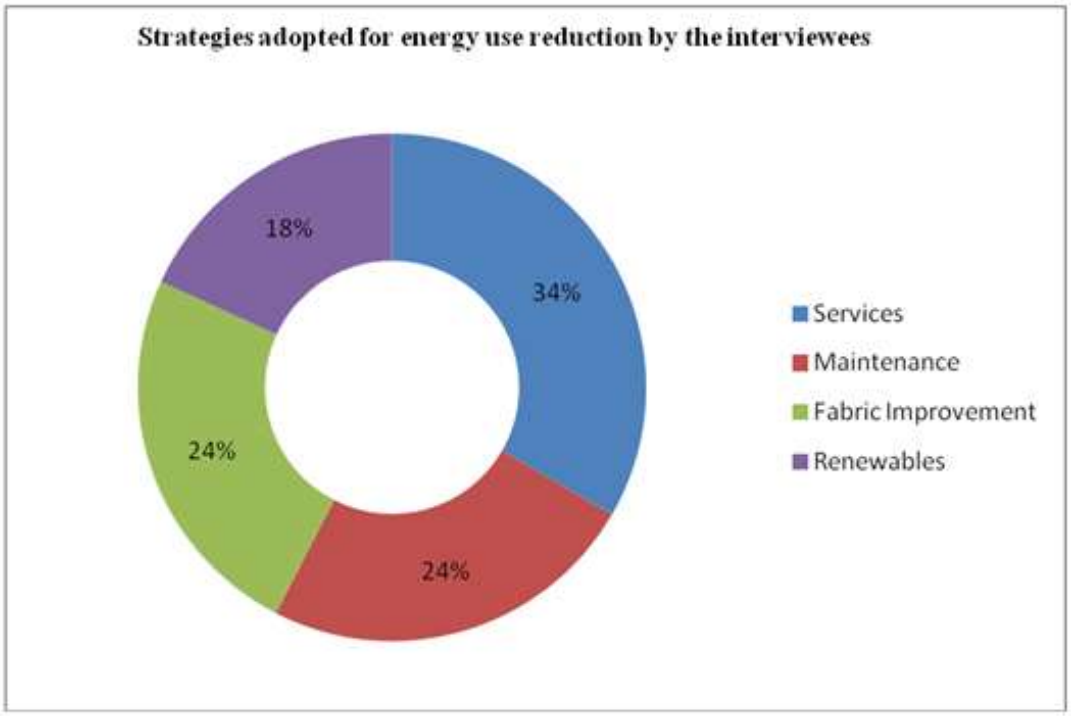


Figure 8.1: Interviewees most effective strategies for energy use reduction

Table 8.5: Data matrix from respondents' perception of energy use reduction strategies for reuse of LCBs

Strategies Adopted		Which Most Effective	Reasons For The Most Effective
HPP1	• replacement of heating system with high efficiency gas boiler • low energy programmable lighting • replacement of lighting system • replacement of floor • repointing of wall • roof redesign/replacement • roof insulation • under floor heating	Under floor heating	All the water does not need to be heated to the same level as radiators heating because its at a lower temperature Because of the volume of the building as most of the heat is remains within the few meters above the ground
HPP2	• replacement of floor • repointing of wall • roof repair • roof insulation (Partly) • refurbishment /repair of glazing • under floor heating • floor insulation • replacement of heating system with ground source heat pump	Reusing the building	It minimises CO_2 emissions
HPP3	• replacement of floor • internal zoning of floor for control heating • under floor heating	Under floor heating	Because of the volume of the building as most of the heat is remains within the few meters above the ground
HPP4	• under floor heating • floor insulation • replacement of heating system with ground source heat pump	Ground source heat pump	Provided the needed comfort
HPP5	• roof insulation • refurbishment /repair of glazing • floor insulation • replacement of heating system with ground source heat pump	Fabric improvement	-
HPP6	• under floor heating • replacement of heating system using biomass boiler	Replacement of heating system	
HPP7	• roof redesign/replacement • roof insulation • installation of solar panels • air source heat pump	Combination of insulation, solar panel and Air source heat pump	Because they provide hot water and heating throughout the year
HPP8	• replacement of heating system with high efficiency gas boiler	Replacement of heating system	Improved comfort of the indoor environment
HPP9	• replacement of heating system with high efficiency gas boiler	Replacement of heating system	Improved comfort of the indoor environment

Table 8.6: Strategies adopted for energy use reduction by the interviewees

	Strategies adopted	HPP1	HPP2	HPP3	HPP4	HPP5	HPP6	HPP7	HPP8	HPP9	Total	Grand Total	Rank
Services	High efficiency gas boiler	√							√	√	3		
	Low energy programmable lighting	√									1		
	High efficiency luminaries	√				√					2		
	Under floor heating	√	√	√	√		√				5		
	Zoning of floor for controlled heating			√							1	11	1
Maintenance	Replacement of floor	√	√	√							3		
	Repointing of wall	√	√								2		
	Roof repair		√								1		
	Refurbishment /repair of glazing		√			√					2	8	2
Fabric Improvement	Roof replacement/redesign & insulation	√	√		√	√		√			4		
	Floor insulation	√	√			√		√			4	8	2
Renewables	Installation of solar panels							√			1		
	Air Source heat pump							√			1		
	Ground source heat pump		√		√	√					3		
	Biomass boiler						√				1	6	4

How were the ideas for the most effective strategies developed and how were they introduced?

The responses from the interviewees suggested a number of ways ideas could be developed when considering the most effective strategies for heritage building projects. These responses are quite informative and they included: local knowledge; sustainability and cost; design development; the building itself; local fuel sources; money; design team; and collaboration. The interviewees expressed their views as follows;

> *".....as design team....I've tried to explore options ....in our case we could try to do gas or electricity and you know the choice was fairly obvious for heating we need to use the gas because is considered to be more environmentally friendly than electricity..."* (HPP1)

Interviewee 'HPP2' argued that the building should make the decision before the designer's experience and the client's requirement. He stated,

> *".....the strategy revolves around local knowledge, how much it will cost .....to run the building effectively with the electricity we needed to dry the building that did require intervention that scheduled monument commission wouldn't allow and we need a low cost solution and to provide water and heat and the low cost solution, though not so low but it is low cost because I think we've worked out 15 years payback for GSHS..."* (HPP2, 2014)

According to interviewee ' HPP3' and 'HPP4', the idea for most effective strategies was attributed to more of design exploration of various options in collaboration with other design team such as the engineers and other allied professionals outside the design team before they came up with the most suitable options for the project. This underscores the importance of collaboration across the design team to achieve sustainable project delivery pertaining to heritage buildings. Both interviewees stated,

> *"....We looked into all the options and this seems to be the best way. We spoke to different companies and tried finding what the options were for sustainability and cost and we explained to the client the most suitable options."* (HPP3, 2014); "*.....Is kind of based on the design development… talking with the engineers and looking at the best options with the engineers... we looked at all the different possible options like carbon renewable technologies we could and we went through it."* (HPP4, 2014)

Similarly, these responses were supported by other interviewees, who also responded,

> "*.....By collaboration."* (HPP8, 2014) and "*.....Within the design team and then discussed and explained to the client"* (HPP7, 2014).

Other interviewees were rather of the opinion that the building itself and the available local fuel resources put together informs the ideas, whereas, the others felt that it was the money. These views were brought to the fore by interviewee 'HPP5' and 'HPP6' according to their views;

> *".....you look at the building itself and look at what suitable technology applied to that building you look at the availability of local fuel sources and then undertake the calculation to determine which provides the best solution in terms of a number of options"* (HPP5, 2014); *".....the money was there for a biomass boiler, so we were told what to do. They gave us their guidelines, but for us, we were limited to how we actually got the heat out into the building"* (HPP6, 2014). However, according to interviewee 'HPP9', "*....Sometimes the only option left when all others are ruled out is the most effective option, if not perfect.....*" (HPP9, 2014)

How effective were the strategies adopted? What indicators are used to judge the effectiveness?

In response to this question, some interviewees clearly acknowledged that since they have no specific target set for energy performance of their projects, it was rather difficult for them to measure the effectiveness of their strategies. Others could confidently say that their strategies were effective arguing this from the point of responses and feedback obtained from the building users who now found the building much more useable and

comfortable compared to previous use of the building. Although there was no evidence of post occupancy evaluation conducted to ascertain this claim. Interviewee 'HHP2' was confident of this on his project when he stated,

> *"...Very effective because basically, they got a building that they are proud of, they do like the building so they retain the building, and it's a warm building, one that is continuously warmed no matter when they go, evening or daytime even if the heating is not on fully its always warm, dry and airy and light and spacious..... A lot of people coming in now don't feel threatened by the indoor environment…… The most effective thing is that the building is used and for what it wasn't used for."* (HPP2, 2014)

According to interviewee 'HPP4' the strategies adopted have actually proved quite accurate. His argument was supported by post occupancy evaluation data collected on the project after it was completed. He advanced his argument about how they were able to get the predicted energy use against the actual energy use stating,

> "*.....Obviously we have been monitoring the church... for a full year now we have the data.... we have the predicted CO_2 and actual CO_2 use. And to us there are some thing that are quite working properly and you know you kind of get this sort of things in the first year of completion of the projects. You have certain things that still need to be dealt with. But...after a year, the strategies that we adopted have been effective in terms of what we set out to achieve at the beginning of the project* (HPP4, 2014)

A similar stance on the effectiveness of the strategies was also taken by interviewee HPP6 (2014) who affirmed to 100% effectiveness and according to him,

> *".....The client is incredibly happy with the building.....now, before a large service they just turn the heating up an hour or two beforehand and it would raise the temperature within the building to a comfortable level enough to make the users really comfortable…. (The indicators) The happiness and satisfaction of the users; religious congregation is quite often long serving and talking to the…. management, they said the people who had spoken to them after the refurbishment was completed all commented on how nice….. Now was to be able to sit in and*

also a lot of the users were taking their coats off, whereas beforehand they never did because they were just too cold."

What were your main frustrations in implementing the strategies and how were you able to overcome them?

In response to this question, one of the interviewees (HPP1) emphasised that there are other factors limiting the design team apart from the issue of sufficient funding. The interviewee expressed his view by emphasising

'*.....I think the biggest problem is that there is never sufficient fund to implement all of the things the client wants to be implemented or you know as architect want to do..."*
He further argued that the design team would not have been able to do much and that's mainly because of the nature of the building. While drawing attention to the building, he referred to the fact that the whole idea is to originally be able to interpret the history of the building. According to him,

> *".... It's always trying to want what is more important and from a conservation point of view we see that it's more important to show the history of the building than to sort of slightly improve the energy efficiency".*

Some interviewees indicated they had no limitation of any sort. For instance, interviewee 'HPP2' claimed that there was

> "*..None really, because……. as a conservation architect, my goal was to get the building repaired, and use it at a low cost so in this respect there is nothing. If this was a non-listed building or non-scheduled building and was solid brick of the same size and they want to have it in use and I couldn't insulate it, dry line it, and improve glazing and then that would have been the frustration".*

Similarly interviewee HPP3, HPP5 and HPP8 stated that

> "*.....we don't have any frustrations. It's quite straightforward*."; "*No, we follow our clients brief ....*"; *"The project was not frustrating, it was a normal situation for work on a precious historic building"*

Other interviewees expressed their opinion and their limitations. For instance, HPP4 (2014) stressed the fact that

> *"....it was a listed building, and we would love to have insulated the building and make it as airtight as possible, however, this is not possible with listed buildings……if you are installing heat pumps, you need to make the building efficient first.....before you look at renewable technologies. But we could not really make the building any more efficient except for the floor so that is quite frustrating. And obviously some limitations would have been designated historic remains under the floor not to be able to insulate the whole floor with under floor heating the whole church so those are the main limitations".*

According to interviewee HPP6 (2014), it was a case of other factors such as

> *"....space, in that we were limited to where the plant could go. Noise, because we have to try and keep it as quiet as possible....The fact that we can't interfere with any of the building structure and the limitation of improving the thermal performance of the existing building structure."*

Interviewee HPP7 (2014) on the other hand, refers to the limitation from government scheme. She stated,

> "*We got a grant for installation of the ASHP but the government scheme meant that we could only use some approved contractors, and the main M and E sub contractor didn't get on with them and we couldn't get a joined up service*" Conversely, interviewee HPP9 rather of the expression that *"Dealing with committees is never easy especially when there is a lack of technical understanding.*

8.3.5 Guidelines for obtaining feedbacks on building energy performance

Since occupancy, what provision was made to obtain feedback from building operators on the current energy performance of the building?

Most interviewees indicated the means of obtaining feedback from the building operator following project completion. One of the interviewees (HPP1) stated that the building is filled with remote control linked to the council's building management system (BMS)

under the control of the council's energy team in order to constantly monitor the performance of the building. However, the interviewee claimed not to be aware of the current energy performance. Interviewee 'HPP2' on the other hand, affirmed to have been receiving user satisfaction on the cost of running the building. He exclaimed,

"*...Within the 1st six months I have talked to the client and they will say they were thrilled really and basically it was in full use and the energy bills were not great and you know they were happy……the cost of running are easily within revenues. I mean the cost of running it and so those are the report back.…"* (HPP2, 2014)

Interestingly, Interviewee 'HPP4' claimed the design team had rather been responsible for the monitoring of the building energy performance. He stated,

> *".....We have been doing that ourselves rather than getting information from the building operators and or users. We have been going to the church once a month, recording all the information that we need and compiling all together to be able to take on the next stage of the project, which is reported back to the funding body on how the building is performing compared to its predicted."* (HPP4, 2014).

Other interviewees confirm speaking to the building operators to obtain constant feedback while another advised that they have consistently monitored the electricity consumption and the indoor temperature. In contrast, interviewee 'HPP5' acknowledged that he has not taken any action in this area. Their individual responses included:

> *"....We have spoken with the building operators several time on other items of the project…….Every time we spoke to them about the biomass installation, they usually had nothing to say but always that it worth the price because it worked very well. It gives them the level of control they want....."*(HPP6, 2014); *"...We have monitored temperature and checked electricity consumption since completion."*(HPP7, 2014); *"No"* (HPP5, 2014).

What provision was made to monitor and to more effectively manage the building energy use during the operational phase?

A number of interviewees described the provision they have put in place to monitor and effectively manage the building energy use after completion. Meanwhile, few others had no definite information regarding the building's operational phase. According to 'HPP1', provisions were made using some latest technologies monitor and control energy use in the building such as

".... external sensors that monitor the external temperature etc. and the level of lighting externally..... There are infra-red sensors .....likewise, there are temperature probes in the building itself so they can see what indoor temperature and at the same time they can see what is the output temperature of the boiler itself so like that allow for adjustments to be made where needed…" (HPP1, 2014)

Interviewee 'HPP4' and 'HPP6' vividly described a more sophisticated approach adopted,

> *"We have got the heat meter…….the water meter as well, which metered the water use,……..a standard gas meter,……..taking a meter reading from the heat meter and the heat pump and the gas meter and bring it that back into the office, convert it to KW/h and compare them…..we can work out the electrical energy use as well…..so we can just take away the heat meter readings from the electrical meter*
>
> *reading and that will give us the final outcome of the electrical use the church is using from the heat pump energy."* (HPP4, 2014)
>
> *"The biomass boiler is connected to Building Management Systems (BMS) so the facilities management people can always look at what the boiler is doing…….He can get the number of hours the building runs, he can get fuel consumed whether that in kWh or in tonnes……But any information needed could be obtained from the boiler."* (HPP6, 2014)

Meanwhile, Interviewee 'HPP2' and 'HPP3' acknowledged that they not aware of any provision made in this regard. They expressed: "….Now I don't know now who runs the system and how do you compare it, you can't compare it to pre-use and you can't compare

it with another building because it's an unusual project…." (HPP2, 2014). We haven't considered that yet" (HPP3, 2014).

What provision was made to educate the building operators and/or users on how energy could be managed in the building?

In order to perceive the priority given to the importance of occupant behaviour in managing energy use in their project, interviewees were asked to comment on the provision made to take this factor into consideration. The following responses highlighted the various approaches adopted by the interviewees.

> *"….permanent staff receives teaching lessons so they are taught how the building operate, how the controls operate etc. and also the building has a caretaker who also fully familiar with the setting how to set up the unit from my point of view……if there is evening event/function, then the caretaker know how to reprogram the system locally for that night to extend the heating hours until the event is finished……..."*(HPP1)

> *"Well, that was actually done before the installer went into liquidation. There was a day I know in a morning when they went through the system to show them….. so they did have some training."* (HPP2)

> *"The building operators will have details of operation manual provided by the contractor so that they could know how every system is being installed and how is to be operated. They will also have demonstrations from the company on how to use everything."* (HPP3)

> *"….the vicar has always been involved in the project from the beginning and we provide lots of operation manuals on completion and guides on how to use the heat pumps, the settings and how to set up the heating to come on and off. So they are educated to a point and more appeal would be they can probably be educated a bit more thoroughly because they have additional issues there and because they*
>
> *do not know enough about the system**.....**it would have been probably nice to spend the money on how to show them on how things work….. That was not done; they were just given the manual on how to operate it."* (HPP4)

> *"There is a requirement within our specification for training to be given by the mechanical and electrical contractors to the occupiers, but nothing has been done on that."* (HPP5)

> *"Yes…Training was provided by the main contractor and I know he also attends the site several times to answer questions to help the staff understand how to use the boiler…….The other energy use of the building is the electrical energy use and is just to turn it off when not in use……An operation manual was also provided so that there is full reference book for the client to check up whenever it is necessary."* (HPP6)

> *"We provided simple operation guides for the PCC to use"* (HPP7)

What other circumstances do you consider might be contributing to higher or lower energy use than anticipated in your project?

The interviewee responses to this question revealed a dichotomy of perceptions that underlay the views expressed by the interviewee. On one hand, some interviewees perceived some contributing factor to higher energy use while others argued that it is difficult to ascertain. HPP1 (2014) opined,

> *".....is probably very difficult to accurately predict the energy performance of a building that is not designed to the modern standard.....You can use thermal imaging, you can scan the building from outside, you can establish where the seepage are…….but certainly if it's a grade I listed building like this one, you will not be allowed to put secondary glazing or anything like that and you cannot insulate the walls so is very difficult".*

Other interviewees expressed a number of views perceived to be contributing to higher or lower energy use. These were highlighted by various interviewees as follows:

> *"Well, I suppose, is the intensity of use…….the building is used more often than they might have intended.....The increase in.....energy will just be increase in use at the high heat....if they left it on they would be charge whole lot full of more because with that sort of system, you can only input a certain amount of heat into the floor construction before it's going to take any more heat it's kind of slow heater"* (HPP2, 2014)

HPP2's opinion in concurring with other interviewees' views on the use of the buildings and other issues associated with it as expressed in their responses below:

> *"A lot of it is down to the use of the building"* (HPP6)

> *... "It is the use of the building; the building is used a lot more…for events….with PA system and things like that which use quite a high amount of energy, and also the fact that there has been a few teething problems with the heat pumps and the under floor heating system."*(HPP4)

Other interviewees argued the contributing factor from a different perspective which included; the roof structure, hour of occupation, type of equipment and efficiency of lighting:

> *"I think the roof is probably quite cold and this is very basic and there is no way to insulate it….. Because of the appearance, bigness and the features people want to use."*(HPP3)

> *"Well, it depends on hour of occupation and on the type of equipment they put in so the IT systems for example which may not be anticipated. The efficiency of the lighting is a key issue to the energy performance of any building ....And the trouble you have with historic buildings is that new energy technologies do not necessarily get designed in historic looking lighting products"*(HPP5)

The findings from the analysis of the interviews corroborates with some of the findings in chapter 6 and 7. Observations from Figure 8.3 shows the themes and categories of factors developed from the interveiews while Figure 8.4 presents the new factors which could not be determined by the outcome of the analysis in chapter 6 and 7. Meanwhile, to achieve the objectives of this study, the interview approach is considered to be appropriate to provide a holistic view of the problem investigated.

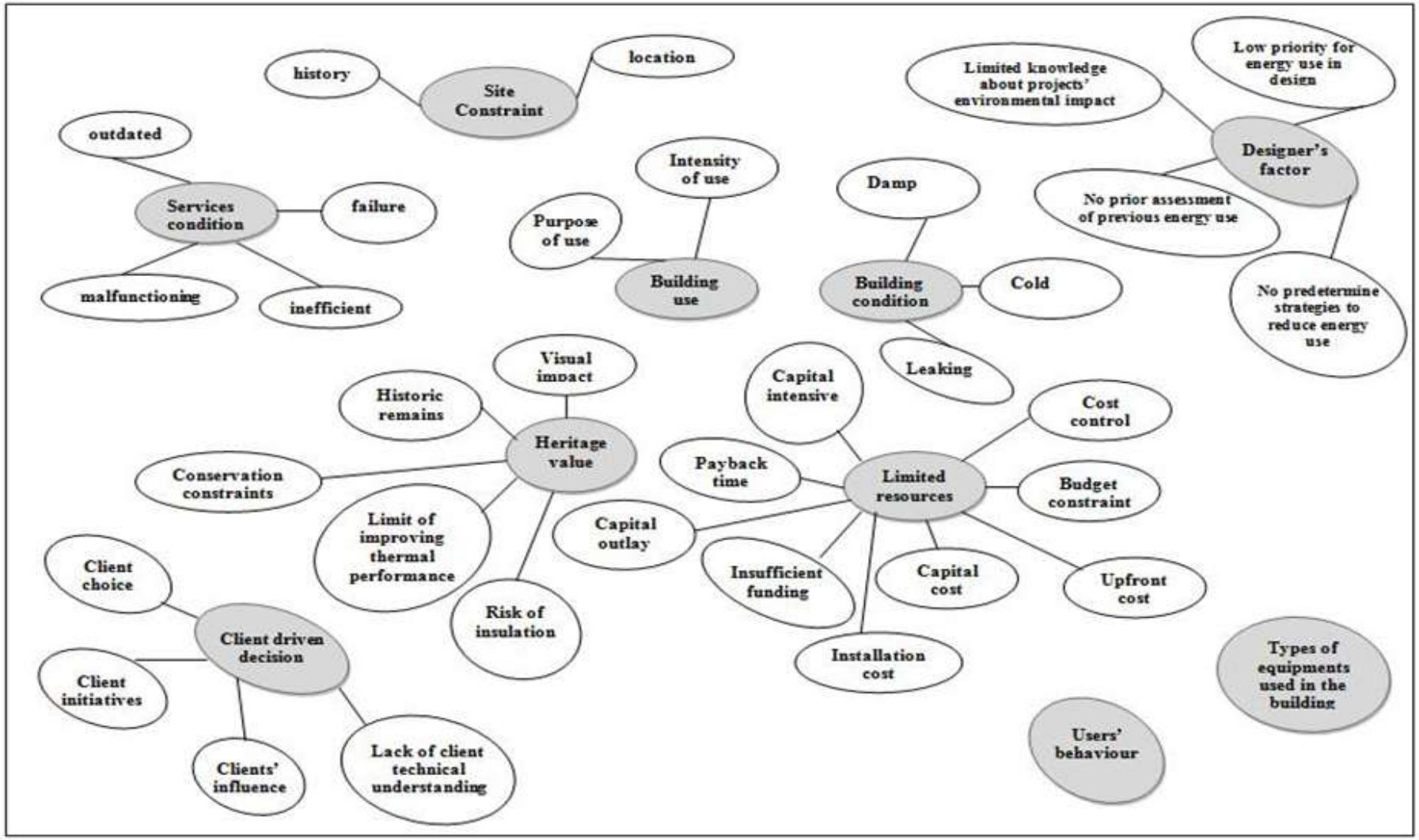


Figure 8.3: Themes and categories of factors developed from the interviews

Figure 8.3 presents the themes and categories of factors from the interview analytical findings based on counting the number of times the interviewees mentioned the terms during the interview as contained in the text. Because of the varied projects carried out by the interviewees, their responses gave insight into other factors that influence energy use in reuse heritage buildings. Initially thirty- five (35) factors were identified before they were later categorised into ten (10) and defined as constraints of site, condition of existing system, condition of building, client driven decision, designer's influence, users' behaviour, equipment used in the building, constraints of heritage value, constraints of resources and use of the building.

A singular project may or may not be directly influenced by all the combination of these factors, however, the interviewee's responses, provides a valid pointer to those factors that constitute the main determinants of a project's energy use. Figure 8.4 shows the influences on energy consumption from various based on the analytical findings derived from Figure 8.3. These factors when combined with the findings from stakeholders' perception and building technical and energy use survey provides adequate information for designers and building operators and/or facilities managers on areas to minimize energy usage when considering future projects or improving the performance of the existing ones.

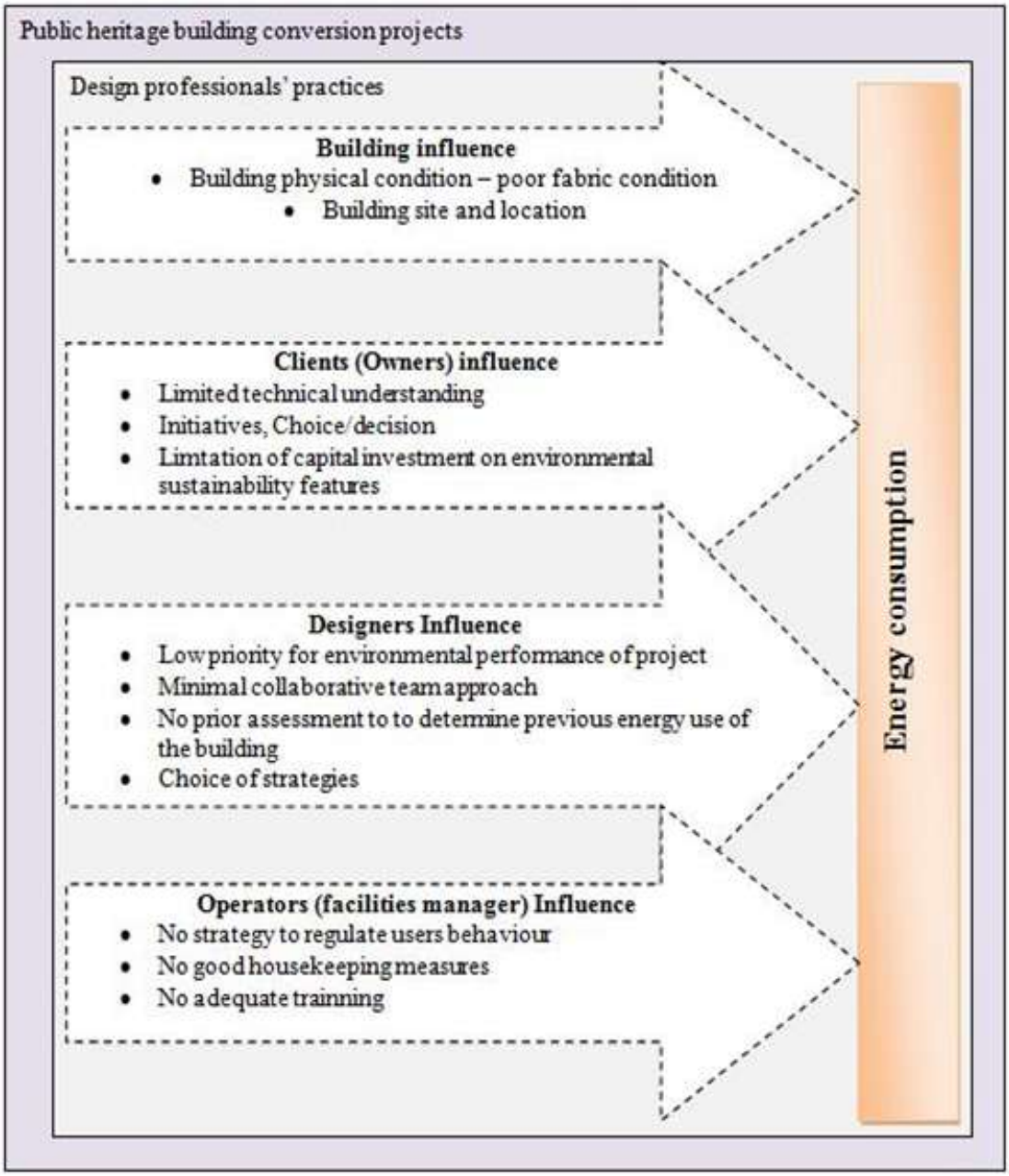


Figure 8.4: Illustrative diagram (C) of design professional's perspective on causes of energy use

What would you suggest to more effectively manage energy use in future similar projects?

In concluding the semi structured interviews, the interviewees were asked to address the issue of energy use in the reuse of listed church projects. The question was meant to

elicit responses that could be brought together to develop effective approaches for appropriate and holistic strategies to more effectively manage energy use in future similar projects. The responses resulted in the following proposed recommendations as captured from the interviewees. HPP1 (2014) suggested some low tech measures that may be implemented such as the possibilities of putting curtains in the building but then caution:

> *....it's still to find the right balance because if you put heavy curtain to reduce draught because this building can be particularly located in winding direction/location, but then you will cut off the light so might save on the heating by reducing draught…. but then you will increase the lighting"*

HPP2 (2014) rather confidently affirmed that there was nothing else that could have been done apart from the measure taken on the project. However, he went further to draw attention to some approaches that have been used in other projects that are not very effective.

> *"....I've done many projects where they don't remove the floors you know they put heating and that's not very effective.... putting ground floor based pipe work in a screed on existing floor that is uninsulated concrete floor would not be an effective strategy"*

The interviewee rather gave some guidelines regarding a more effective approach,

> *"..... if you are going to use under floor heating you need to take the existing floor up only to 300 – 450mm down or very often there are voids below the pew platforms, but you need to take it up and introduce what they call an insulated floor construction, but that doesn't involve any sort of foam, plastic based system of damp roofing is all to do with the aggregate that you use and the lime Crete and the breathability of the floor and the breathability of the finishes and so that would make it to my mind would have made it more effective.*

However, he cautioned,

> "*.....Whether insulation or double glazing helps is questionable because basically the existing church building is damp and it requires a certain amount of air change so I would always go for heating up the fabric, with stable heat where the*

fabric is warm to 12º- 13º and is kept reasonably near that so that summer or winter the fabric let out heat.... I will not install a GSH system or a central heating system of air source into a church unless you could have a new floor construction. So if I'm not doing that then it's just more efficiency in use, more efficient controls,

and depending on whether is main gas or LPG or oil more efficient boilers.... and keep the building to about 10º-12º above condensation and dew point.

HPP3 (2014) was rather of the opinion about

".....its usability and ....what the building is going to be used for. Likewise, if there are complicated systems, it's important to make the complicated system straight forward and simple to be used."

In line with the view of HPP3 (2014) above, while pointing out his suggestions, HPP4 mentioned the use of the building, equipment used in the building, problems arising from malfunctioning of heating installation and more importantly the priority of energy monitoring and management:

".....It is the use of the building.... it is used for events ...with PA system and things like that which use quite a high amount of energy, and also the fact that there has been a few teething problems with the heat pumps and the under floor heating system".....I think monitoring more regularly will help us look in a bit more depth to while things were not working. We make a bit quite a lot of assumptions with our energy management at the moment and the usage.....if we had meter reading in a week rather than once a month we might be able to look a bit more in-depth....why energy was used that way which gives us a lot of indications. So we are able to question that if we are using a lot of energy why are we using it...."

On the other hand, HPP5 (2014) in addition to how energy use can be effectively managed in future similar projects, apart from other interviewees' suggestions relating to the building, HPP5 rather concentrated on what could be of assistance to the client advising:

"....there is a scheme operated by BREEAM called soft landing, which shows how the building is commissioned and operated properly and proper training is given. That will assist the client in understanding the building more and possibly

operating the building effectively…….how much you got into investing in systems could determine how much you can reduce the carbon."

HPP6 highlighted a number of other strategies and actions that needs to be taken to more effectively manage energy use in future projects:

"The best area is electricity usage reduction. Find a way of reducing the electrical loads…….; Change to LED fittings, turn the light off when the building isn't in

use, fit presence detector in areas which are not part of the main body of the church which could be the north and south wings. This keeps the lights off until they sense the people's presence and then they can come on. And in terms of heating, again targeting control programming is much better rather than just turning it on and then leaving it. Running a low background level so that you can boost it up when need be..... Better control is always and never a bad thing.

Some other interviewees recommended focusing on passive improvement by considering fabric improvement where possible. HPP8 cautiously advised considering insulation:

"I think to consider insulation of the roof IF it can be done when the church naturally needs re-roofing and without compromising the building inside or outside."

8.4 Chapter Summary and Conclusion

Nine semi-structured interviews were conducted with heritage building practicing professionals across England. The data from the interviews were analysed using content analysis after Gillham (2000). The outcomes of the interviews with the professionals proved to be both varied and interesting. The interview process produced many diverse factors influencing energy use in the reuse of LCBs categorised in four influencing factors, namely: building influence; clients' influence; designer's influence and the building operators' influence). These findings supported the results found in chapter 6 and 7 of the quantitative analysis and expanded on the critical factors identified in the two

chapters. The factors are linked together and discussed in chapter 9 of this thesis to develop the proposed framework in chapter 10 of this thesis.

PART C: FRAMEWORK GENERATION AND IMPLICATIONS

CHAPTER 9: DISCUSSIONS AND OVERVIEW OF FINDINGS

9.0 CHAPTER OBJECTIVES

- To present the theoretical background underpinning the interpretations of the findings of this research study
- To discuss the findings of this present study in relation to the research objectives.

9.1 Theoretical Background to the Discussion of the Findings

The aim of the research study was to investigate critical factors arising from the influence of stakeholders' perceptions, design strategies and building operational practices as it affects energy consumption in the reuse of LCBs. For better understanding of these factors, heritage building was considered as an open (soft) system, including the multiple variables that interact together with the building to influence its energy consumption. The complexity of listed churches converted to community uses results to multiple factors responsible for its energy use. Thus, it is inadequate to assess the energy consumption with only an analytical approach.

In this present study, heritage buildings were considered as a dynamic, interdisciplinary and complex system which can best be understood by dividing the system into subsystems and reorganising the components within each subsystem ranking them in order of importance. By putting together findings on the relative importance of the components at each subsystem level, a set of overall importance by ranking was achieved. In this context, a systemic approach based on system theory with specific application of soft system methodology was considered appropriate to provide a two-phase sequential mixed method study. This allows for interdisciplinary consideration of different levels of

complexity, of four subsystems identified in Chapter 4 of this present study, namely: human subsystem, building structure subsystem, building operation subsystem, and ecological subsystem.

The first phase of the study focussed on the quantitative approach which included the administration of the two types of questionnaires. The first questionnaire focused on perceptions and covered the human subsystem and was conducted online among heritage building stakeholders. While, the second questionnaire covered the building structure subsystem, building operation subsystem and ecological subsystem and was administered as field survey on the physical building energy use and operational practice. Both questionnaires aimed at achieving the first four objectives of this present study:

Objective 1 To investigate the perceptions, priorities and values of heritage building stakeholders and its influence on energy use reduction in the reuse of LCBs

Objective 2 To determine the relative importance of strategies perceived as most sustainable and implemented in practice by the stakeholders to improve energy efficiency in the reuse of LCBs.

Objective 3 To identify the critical factors responsible for energy use in LCBs arising from stakeholders' perceptions that needs to be addressed to improve energy performance.

Objective 4 To assess the energy performance and operational practices of existing reuse of LCB projects and to determine the factors responsible for their current energy performance.

A qualitative approach was employed for the second phase of the study. An in-depth interview was carried out, with 9 (nine) practising heritage building professionals across England. The interview questions revolved around the concepts developed in the conceptual framework and the themes found in the previous quantitative phase:

Perceptions, Priorities, Practices, Performances, Strategies and *Challenges*. The qualitative phase aimed at achieving the last two objectives of this present study:

Objective 5 To identify the factors preventing energy use reduction for delivery of sustainable reuse of LCB projects in practice.

Objective 6 To propose a strategic energy management framework to serve as an achievable guideline for improving energy performance in the reuse of LCBs.

The discussion of research findings from this present study engages the main theoretical orientation employed for the study - soft systems methodology (SSM). According to Checkland and Scholes (1990), systems ideas are employed as a means of inquiry into the problem situation and are based on the concept of cyclic learning and optimization. Thus, system forms the perceptions of the real world that are modified and improved when faced with other perspectives, experiences that are new and by learning. As system ideas are not ways of describing what exists; rather they are a means of describing an interpretation of what exists or describing some thinking that is relevant to what exists.

The discussion of the findings of this present study provides the platform for developing a framework for the improvements of energy performance in the reuse of LCB projects. The development of the framework is based on the research findings of this study discussed in details in Chapter 10. The framework, thus developed is expected to serve as guidelines for informing heritage building practitioners in the design and management for long- term sustainable reuse of LCB projects.

9.2 Influencing Factors (Human Subsystem) on Energy Consumption in LCBs

The following discussions relate to the influence emanating from the social values aspect of heritage buildings which is labelled as human subsystems in the conceptual framework of the study. In essence, this subsystem utilizes functional values which enable people to fulfil their practical, aesthetic and symbolic needs perceived to have a far more reaching impact on the ecological subsystems (i.e. Energy usage) of heritage buildings. It is human nature to ascribe meanings to how the world is perceived with the meanings founded on the observer's experience-based knowledge.

Checkland and Scholes (1990) posit that whenever feelings arise about how things could be better than they are, the perception of the real world would be that some problems require attention. Thus, in soft system thinking, problems do not occur in a way that makes it possible to isolate them, rather they are often thought of as interactive incidents. It is the perceived problem of energy use identified in the reuse of LCBs with feelings that the situation could be improved better than they are that is explored and discussed through the perception of the stakeholders in this study.

Objective 1: *To investigate the perceptions, priorities and values of heritage building stakeholders and its influence on the reduction in energy consumption in the reuse of LCBs.*

9.2.1 Values and priorities factor

Quantitative results suggest how the perceptions of heritage building stakeholders' influences energy use reduction in the reuse of LCBs. The priorities and values the stakeholders applied in practice was identified showing the respondents have a favourable disposition towards managing energy use in the reuse of LCB projects. The perception of

the majority of the respondents to the questionnaire was that modernisation of heritage buildings should be a priority for conversion project and monitoring energy use after conversion is important. While a comparison between the results obtained from the survey and interviews indicates a very high level of congruence with this perception; in spite of this, they confirmed there are lots of limitations when it comes to upgrading historic churches in order to improve their energy efficiency even though the benefits outweigh the limitations. Notwithstanding, the majority of the survey respondents was in agreement with taking advantage of current technologies and incorporating secondary glazing to windows. On the other hand, they rejected the suggestion of reducing the U-value of the building to cut down energy consumption.

9.2.2 Design decision factor

The perception of survey respondents of considering energy efficiency, particularly in their decision making in the conversion of listed churches was negative. On a general note, result of the findings showed that more importance was given to conservation policies and performance for an intended use while, less priority was given to energy efficiency. This observation may be due (or) line with the directions of the European Energy Performance of Buildings Directive (EPBD), which exempts certain classes of historic buildings from the need to comply with energy efficiency requirements. Although, this exemption is not without a clause on where compliance with the energy efficiency requirements would unacceptably alter their character and appearance. This clause could have informed the perception of the respondents about the possibility of achieving sustainability in terms of energy efficiency.

Congruent with the findings from the interview, conducted in this study, design professionals strongly expressed the restrictions the conservation policies pose with them for every project. Results obtained from the present study also indicated that there were differences in the response of the stakeholders in the decision influencing factors on energy efficiency for sustainable conversion of listed churches. It was recorded from the results that the overall rating for energy efficiency by the practising professionals were considerably higher than that of the policymakers, suggesting that the practising professionals had a better perception of the importance of environmental sustainability of conversion projects whereas, the policymakers tend to concentrate more on the socio-cultural aspect of the buildings.

Similarly, 'performance for the intended use' was found to be the major concern of the practising professionals. These findings are thus noteworthy, as it clearly proves that either the respondents were primarily utilitarian in their perception towards reduction in energy use; on the other hand it might be that their main concern about climate change in relation to heritage buildings is based on an egocentric view. This indicates that their priorities and values on reuse of LCB projects were not explicitly related to energy saving or reduction of the environmental footprint of the buildings.

Research studies conducted by Halder *et al*. (2010) also reinforced this view; the studies showed that there is often a significant discrepancy between environmental knowledge and action. Consequently, this has resulted in gaps perceived to lie in the understanding of operational sustainability measures that could be translated into concrete action plan at

projects specific level. Meanwhile, this lack of operational sustainability measures compatible with heritage buildings could hinder the effective implementation of long term sustainable conversion projects. This observation is consistent with the view Geller and Attali (2005) who also argued that the reasons for many energy efficiency gaps in reuse projects relate to the decision making in one way or another.

Whilst, it is expected that practising professionals involved in adaptive reuse of heritage building projects would need to address the aspects of function and spatial composition; in order to make the buildings perform for their intended use, it should also be considered important that the professionals need to address unique issues such as environmental sustainability of the building they are giving a new use. The argument emanating from the findings of this study is similar to the findings reported by Bullen (2007). The survey results obtained by this author showed that 'environmental sustainability', 'effectiveness in meeting sustainability benchmarks', and 'heritage significance' were the most important factors that should be considered during the decision making process of adaptive reuse projects. It was observed that some of the professionals interviewed acknowledged that they rarely considered environmental features in their projects. This was partly explained by the interviewees that more often than not when the proposal for environmental sustainability features for the projects are made they were often met with restrictions from the conservation officers.

Other professionals were of the opinion that lack of funding for environmental sustainability features for the projects was the major barrier. In spite of these perceived constraints, few professionals who worked on similar projects have found the most creative approach to overcome these limitations, and they have delivered projects to

increase in use of the building, less energy consumption and reduced CO_2 emissions when compared to the former use of the building. Furthermore, the importance of life cycle costing (LCC) during the decision-making process by the respondents was ranked third; possibly it might be that the practising professionals among the respondents tend to neglect this aspect. This negligence was evident from the findings of the interview carried out where most of the interviewees acknowledged that they do not consider life cycle analysis.

The importance of the LCC was reported by authors like by Kirk and Dell'lsola (1995). The authors stated that LCC helps design professionals become more customer-focussed so that problems of rising costs of operation and maintenance are addressed. The majority of the survey respondents and the interviewees referred to the complexity of listed church buildings as a barrier to technical interventions on improving their energy efficiency. This perception validates the respondents' agreement in ranking 'risk of insulation' on heritage buildings as the second top perceived barrier. Consequently, this perception may be justified, because most heritage buildings, particularly listed churches are known to have substantial heritage values and significance attached to them. This heritage value could become lost if energy efficiency improvement measures applicable to modern building construction types are to be adopted to improve their environmental performance.

9.2.3 Energy reduction factor

The respondents indicated that conservation policies were of prime concern than energy use reduction factor. It was observed from the findings that the drivers for refurbishment

of heritage buildings are not explicitly related to energy saving and environmental sustainability of the buildings; as they are noted to be given less consideration by the respondents. This observation agrees with the findings of Gohardani *et al*. (2013) who also reported that energy savings issues are classified as the second most important concerns in renovation of buildings. Nonetheless, it is likely that this might not be the general opinion of all the respondents as the result of the Spearman's Rank Correlation Coefficient test presented in Table 6.14 indicated that there was a significant difference ($\rho < 0.01$) amongst respondents on energy efficiency for sustainable conversion of listed churches.

It was observed that the professionals had a better perception of the need for the low energy operational performance of heritage building projects; this was indicated by their agreement for the low energy operational cost of running the buildings. However, on the contrary the policymakers of LCBs gave more consideration to conservation policies above other factors. The most likely reason for this lack of consensus among stakeholders of LCBs may be that the policymakers possibly have the perception that environmental sustainability are less important as far as reuse of LCB projects is concerned. This is perhaps surprising, as it might be expected that policymakers would have the same or even more interest in environmental sustainability of the projects. Fundamentally, this reveals that the respondents have different views on how the environmental performance of heritage buildings can be improved. Precisely, this conflict lies with the policymakers. It was clearly stated, by most of the interviewees in many instances they mentioned that they were limited in inculcating some energy saving measures in their projects because

they perceived that the features will be met with restrictions by the regulators and the policymakers.

In essence, it appears that the policy makers and the regulators are still lagging behind in adopting the best practice. On one hand, it could be explained that the proposed energy saving measures by the professionals were not appropriate or acceptable for some specific projects. On the other hand, this will not always be the case all the time. Therefore, there is the need for some degree of flexibility by the policymakers to encourage environmental sustainability for reuse of LCB projects. In addition, to the result obtained from the research survey carried out, the findings from the interviews also corroborate with the resulting outcomes of the survey. Clients showed lack of priority for energy consumption reduction over other goals of the project; except for building use functionality and developing local economy, which was evident from the interviews indicating a very high level of congruence from the findings. Thus, one of several other reasons why energy use reductions in most projects are not achieved could be as a result of the fact that they were not demanded by the client. This is particularly a challenging case if energy use reduction strategies are seen to be more expensive or unaffordable to the client.

9.2.4 Perceived technical barriers

The critical factor that ranked the highest among the perceived technical barriers was building complexity (mean=3.85, SD= 0.99) the respondents unanimously agree that this is a major barrier to more energy efficiency improvement to heritage buildings and most especially to listed church projects. The risk of insulation (mean = 3.56, SD = 1.02) was ranked as second top barrier. Meanwhile, the respondents were generally neutral on other

perceived barriers. A test to further investigate the significance of these factors using the Spearman rank order correlation ($\rho < 0.05$) as presented in Table 6.16 shows that there is a significant degree of agreement among the practising professionals and the policy makers as to the complexity of listed churches.

A possible reason for the complexity of listed churches might be due to the dramatic effect any energy efficiency improvement might have on the existing architectural details, texture, appearance and character of these buildings that make them significant in history. These findings are also consistent with other studies that have been conducted on historic buildings (Balaras *et al*., 2007; Naaranoja and Uden, 2007; Cantin *et al*. 2010; Godwin, 2011). The most likely reason why respondents strongly supported risk of insulation on these buildings, might be the fact that most listed churches have solid walls and insulating them can pose a great danger by giving rise to moisture problems. Thus, the nature of listed churches implicitly poses a lot of risks when attempts are made to improve their energy efficiency.

9.2.5 Perceived policy and regulatory barrier

The agreement of the respondents on what they perceived as policy and regulatory barriers to implementing energy efficiency improvement in the reuse of LCBs reveals that not only do the respondents perceived the complexity of heritage buildings as a barrier, but they also considered limited resources and government policies on sustainability of heritage buildings as overriding barriers. This suggests that even when the respondents have alternative measures for improving energy performance of their projects, they are in most cases limited by inadequate funds. The lack of adequate funds is triggered by the

fact that VAT is charged on renovation and repairs to existing properties but not levied on new build properties. Although, few specific grants are allocated for use by heritage buildings, however, these funds are only meant for repairs and restorations of these buildings and not necessarily meant for improvement in sustainability or energy use reduction.

One the interviewees mentioned that the government policies actually constitute a major contributing factor to this barrier, and asserted that the current 20% VAT on the construction cost charged by the government on projects involving existing buildings is disproportional for renovation of existing buildings. While the interviewee acknowledged that the government is taking all the exemptions away from listed buildings and have made provision of a grant scheme for churches where they put money back into churches to pay the VAT. However, it is equally noteworthy that a reversion back to 5% VAT on reuse of buildings would greatly encourage and enhance projects carried on reuse of listed buildings; this opinion is similar to other research authors (Steinberg, 1996; Jakob, 2007; Orbasli, 2009; Zhang, 2011).

Similar research conducted by Empty Homes Agency Report (2008) also pointed out that the manner in which government policies has been applied to construction projects has been an obstacle to refurbishment and reuse of existing buildings in the UK. The authors stated that while a new build project is zero rated for VAT purposes, projects considered as refurbishment or conservation work are taxed at the full VAT rate of 17.5%. This rate even becomes lower in a situation where a property has not been occupied for a period of more than two years. The Empty Homes Agency Report (2008) further extends this

argument by showing from their calculation that this policy often leads to an additional sum of £10,000 for the refurbishment of a house. Orbasli (2009) was of the view that this policy leads to increase in substantial cost to a project and consequently leads to unfavourable decisions against reuse projects. It could be argued that in spite of various national and international campaigns such as those emanating from the Council of Europe with regard to this perceived policy barrier that appears to discourage reuse of existing buildings, yet the government still continues to sustain these regulations, which will continue to make it a prohibitive factor for refurbishment (Orbasli, 2009).

Furthermore, the findings obtained from the survey also indicate that respondents have a strong support for what they perceived as a lack of adequate policy for operational energy management and awareness as a barrier to improving environmental performance in projects involving reuse of LCBs. Meanwhile, grade listing and governments' regulations were equally perceived as a policy barrier. It is therefore obvious that the status of listed building puts constraints on what can be allowed to improve energy performance of heritage buildings, nonetheless, findings from some of the strategies adopted by some of the interviewees shows that there were still areas where compromise could be reached. While it is acknowledged that listing status of heritage buildings is intended to protect historic character and its significance, however, some of the interviewees expressed that care should be taken not to allow this to become a barrier to any improvement that enhance long-term sustainability of heritage buildings. This was one of the main concerns that many of the interviewees raised during the interview.

Conversely, more findings resulting from the analysis of the interviews also highlighted a number of constraints or barriers to achieving environmental sustainability of heritage

projects. Further analysis of the interview responses suggests that perceived technical, policy and regulatory constraints are not the only areas that need to be addressed. Generally, low commitment to understanding how the project performs after delivery, was observed from the responses of all the interviewees except one. Further, it was observed that nearly all the interviewees had no figures to indicate how their projects have contributed to environmental sustainability in terms of reduction in CO_2 emissions.

The most common reason given for this was that it was difficult to establish the CO_2 emissions of the project after its completion. It is important to note that measuring and understanding the energy performance after the completion of a project when compared to either its initial performance or predicted performance cannot be isolated from managing the energy use of the building. This is useful for the designers as well as the building owners as it suggests not only how energy is used by the building but also where it is used unnecessarily. In addition, some of the interviewees indicated that the decision and determination of the project budget are also contributing factors that limits environmental sustainability of heritage projects. Specifically, some of the interviewees alleged that the client decided what the budget is going to be and in most cases, these decisions borders mainly on areas of the client major concern.

More often than not, building owners make decisions based on values. Quite often they pay for features they really want; conversely, if an owner does not want a feature, cost is often used as the reason to eliminate it. Thus, the client financial constraint was also found to be a contributing barrier to implementing environmentally sustainable projects. Further, lack of sustainability considerations was another form of barrier mentioned by a number of interviewees. They expressed how difficult it is to integrate sustainable

considerations into the project's budget. Some reasons given include lack of a supplementary budget, inadequate funds on the part of the clients and the priority of the clients in wanting to make the building fit to their requirements.

Interestingly, it is worth noting the way other interviewees addressed this factor in their project. One interviewee stated how they adopted a design strategy of zoning the internal areas of underfloor heating system so that the building can be heated based on the zone that is used rather than heating the entire area they are not meant to be used. This is quite instructive as it suggests that though the environmental sustainability of the project may not have been given high priority by the client, however, this can still be possible and achievable tactically and operationalally through innovative design approach.

Another important finding was the absence of specific targets for low energy performance, perceived to be a potential barrier as confirmed in the interview. One of the interviewees stated '*it is written in the council policies that we always like to aim and promote sustainability, energy efficiency, to be honest, we didn't have specific target for energy performance, we just sort of work to try to fulfil the client brief'.* Further, some interviewees clearly acknowledged that environmental sustainability was not an option. It is usually expected that every design project is typically driven by a set of goals and target which eventually produces buildings that meet those targets. From the onset of the project, if owners and design teams set measurable performance targets, it could possibly be translated into efficient and improved energy performance. Thus, the design team needs to focus on measurable energy performance targets to achieve better than average and exceptional performance for their projects. But it is necessary that this goal setting

should begin as early in the design process as possible for ease of implementation and best result.

9.2.6 Factors influencing adoption of strategies for energy use reduction

A model summary to predict the adoption of strategies by the respondents to improve energy efficiency presented in Table 6.18 shows the result of the binary logistic regression analysis. This result indicates that respondents' perception of energy use influences their decision to choose certain strategies for energy use reduction in their project above others; and particularly notable is the choice of the strategy to improve building fabric for reduction of U-value. Although the R^2 (0.084) value obtained for the model suggested that a significant relationship actually exists between the respondents' perception and their adoption of improving the U-value; however, the R^2 value indicates a very low relationship. Similarly, because the odds ratio (1.029) obtained for this strategy also surpasses the threshold of 1.00, it implies that the more increase in perception of the respondents, the greater will be the motivation and the odds of adoption of the strategy to improve building fabric for reduction of U-value.

The results also revealed that some heritage professionals were more prone to adopt some of the strategies necessary to improve the building fabric for reduction of the U-value than other professional. This result observation is in line with the reports of several research authors (Janda *et al*., 2002; Khanna *et al*., 2007; Dinica *et al*., 2007; Mori and Welch, 2008). They pointed out that, motivation or adoption of strategies to reduce energy consumption in heritage buildings will vary with the individual inclinations or perception. There are several possible explanations as to why some professionals are more prone than

others in the adoption of some of the strategies. One possible explanation is that those who adopt some of these strategies, perceived the strategies as a better way of improving the energy performance of the buildings, than those who were more likely not to adopt it. Another reason is that the adoption and implementation of certain strategies are more intrinsically risky for the buildings as indicated by the majority of the respondents. In addition, findings from One Way Analysis of Variance (ANOVA) test to determine if there is any difference in perception of the

respondents regarding energy use reduction on the basis of their profession; the F-value (2.740) obtained shows there is a significance difference ($p < 0.010$). Furthermore, the post-hoc multiple comparison test reveals the source of difference is as a result of better perception of the engineers above other stakeholders. Thus, probably, it is most likely that the engineers have a better perception and positive attitude to the environmental sustainability of LCB projects than all of the other stakeholders.

It is surprising that, the perception of engineers was significantly higher than the energy consultants and conservation officers. This is, after all, contrary to the general expectation that professional energy consultants and policymakers would champion the interest in environmental sustainability than the developers. Hence, it is thus realistic to expect the engineers' ratings and decisions on energy use reduction would have had greater weight than other stakeholders during the survey due to their better perception and perspective that is fundamentally different from others. This finding is also consistent with the previous work carried out on the perception of stakeholders, users and investors and sustainable development, by Parnell and Popovics-Larsen (2005) and Heiskanen *et al*., (2012).

The observation drawn from these discussions is that one of many reasons for poor energy performance of heritage building projects could partly be attributed to low perception of the need to improve their energy performance at the decision stage and lack of consensus and commitment to environmental sustainability among heritage stakeholders. From the above discussions, it could be concluded that the findings from this study underscores the need for positive change in perception and attitudes, more enlightenment, training, integrated teamwork and collaboration among heritage professionals to successfully deliver environmentally sustainable reuse of LCB projects.

Objective 2: *To determine the relative importance of strategies implemented in practice and indicators of successful reuse of LCBs.*

9.2.7 Relative importance of adopted strategies in practice

According to the findings reported in Chapter 6 section 6.7.6.2 for the result of the outcome of strategies implemented by the respondents for reduction in energy use of their projects; the result of descriptive analysis shows that the common strategies implemented in practice by the respondents were 'building services upgrade' (55.5%), improvement to building fabric to reduce the U-value (54.0%) and renewable installations (36.0%). However, the relative significance index analysis of the strategies conducted allowed these strategies to be ranked in order of their importance to the respondents.

According to the ranking, building services upgrade (RSI = 0.785) was ranked 1st, user behaviour (RSI= 0.771) was ranked 2nd, and incorporation of building energy management system (RSI=0 .664) ranked 3rd, upgrading and improvement to building

fabric to reduce the U-value ranked 4th while consideration for application of renewable technologies ranked 5th. Thus, this finding shows the order of importance of the strategies adopted by the respondents to address energy use reduction in the reuse of LCB projects by ranking. However, when compared to the findings obtained from the interview in section 8.3.4 (Table 8.6). The findings obtained from the interview shows the ranking of strategies adopted for energy use reduction in practice by the practising professionals as follows: building services (ranked 1st), building maintenance (ranked 2nd), fabric improvement (ranked 3rd) and renewable technologies (ranked 4th).

It could be seen that there are similarity and agreement between the findings obtained from the survey and interview with the heritage professionals as regards most popular strategies commonly adopted by the professionals. However, when this finding was compared to the findings in Table 6.27, it could be observed that there are differences in the order of the most popular strategies implemented in practice. Therefore, it might be argued that although the majority of the respondents may employ certain strategies in their projects, this does not imply that the strategies are the most sustainable. As already discussed above, the adoption of strategies may be influenced by several other unknown factors such as the professionals' perception and priority of energy consumption of the buildings which could influence the strategies they adopted, perceived technical and policy barriers, anticipated restrictions on recommending and implementing certain strategies and even the grade listed status of the building.

Findings from the ranking of the relative importance of perceived indicators of successful conversion projects (Table 6.29) revealed that improved energy performance and reduction in carbon emissions for conversion projects ranked the last (6th). Thus, it

may possibly be that even though there was much emphasis on the role of heritage building industry in reducing the impact of climate change on the environment, this finding reveals that heritage professionals give less consideration to reducing carbon emission reduction in their projects in actual practice. Notably, are the top three concerns of the professionals for sustainable conversion of LCB projects are not found to reflect much commitment to energy use reduction but mainly on design interventions (Table 6.31). A possible reason for this might be that the professionals were majorly concerned with the comfort, preservation of heritage values which are mainly the social cultural aspects of heritage building sustainability.

Arguably, while social-cultural aspects of heritage building sustainability are one of the main motivations behind any conservation projects; however, concentrating on only a certain aspect of sustainability (i.e. Social cultural sustainability) of heritage building projects, and assuming that other aspects (i.e. Environmental sustainability) that are not adequately addressed will be unaffected may be consequential. This finding reinforced the opinions of Cole (1999) and Kua and Lee (2002) stating the necessity and importance of paying attention to all possible repercussions of focussing on the development of one aspect of sustainability might bring at the expense of the other. Nonetheless, while it is acknowledged that design interventions that are sympathetic with the character of the building is relevant and important to conversion projects, yet it should be noted that this consideration alone, will not lead to long-term sustainable reuse of these buildings.

The implication of focusing on this aspect alone, at the expense of environmental sustainability of the project, could have long-term negative consequences on the building. Therefore, if a balance of approach integrating the three pillars of sustainability (i.e.

Social, economic and environmental sustainability) that treat heritage buildings with sympathy and respect are not found for adaptive reuse of these buildings; then the reality is that redundant heritage buildings may suffer from poor sales, poor letting potentials and long-term vacancy of an unoccupied asset. The result of this over a long period of time will be the loss of income for the owner, a decline in the visual amenity of their immediate environment, dereliction and ultimately carbon intensive demolition and redevelopment.

In addition, in a situation where these buildings have already been leased out to either private or public organizations, and as energy prices continue to rise, if these organizations are less able to sustain the operational cost of using these buildings due to rising energy bills; consequently, this might lead to the building becoming vacated thus reverting the building back to becoming empty and redundant. In circumstances where there is very little practical or financial provision for maintenance of historic buildings as opined by Forster and Kayan (2009) the building will be put at risk (English Heritage, 1992). This could be as a result of the high cost of building maintenance, which has already been regarded as a universal issue (Hutton and Lloyd, 1993; Shen 1997; Andreasen, 2000). The resulting consequences as already noted earlier might be to demolish the building, thereby resulting in the loss of the precious heritage which is neither a sustainable option. On the other hand, it may be possible that heritage buildings with low-energy consumption will be easy to operate and affordable to manage with possible lower use costs. This will halt the danger of the building standing vacant and becoming derelict.

A test of the relationship was determined between the respondents' strategies for energy use reduction in their projects and their perception of indicators of successful conversion projects. Although a moderate relationship was found between them, however the relationship was not found to be significant (ρ-value = 0.391 > 0.05). It does appear that the strategies currently adopted in practice for energy use reduction might not be adequate to produce strong evidence for environmental sustainability of the buildings for it to be considered as an indicator of successful projects. Further, the findings presented in Table 6.31 shows the combination of current practice and strategies employed by the respondents for energy use reduction in the reuse of LCB project. The finding shows the ranking of RSI of the combination of current practice and strategies.

It was observed from the findings that the three top ranked strategies in practice, namely: design interventions (Mean = 4.405, SD= 0.798), functional performance (Mean = 4.159, SD= 0.873) and building surrounding context (Mean = 4.019, SD= 0.951) reveals that the central concern of heritage professionals is consistently inclined mainly towards design interventions indicating the respondents' top priorities for reuse of LCB projects. Meanwhile, strategies that concerns energy use reduction such as 'building service upgrade' (Mean = 3.923, SD= 0.977), 'User behaviour change' (Mean = 3.853, SD= 1.039), 'Improved energy performance and carbon emissions reduction (Mean = 3.396, SD= 1.025) and incorporation of building energy management system (Mean = 3.320, SD= 1.098) are ranked 4th, 5th, 7th, and 9th respectively.

Observations from these findings indicate that minimizing project environmental impact appears not to have higher priority in current practice. A more comprehensive view of this result showed that the outcome of the current practice by the stakeholders reflects

little or no success in relation to the outcomes of energy performance of existing reuse listed projects in this study. As findings from the field survey on the energy use of existing reuse projects reveals that 78.9 % of the projects are low performing buildings. In this present study, the strategies employed in current practice are referred to as moderating factors influencing energy consumption in the reuse of LCBs projects. Although, it might be argued that there are other unknown factors that might be responsible for the current low performance of existing reuse projects, however, other contributing factor may probably be the fact that environmental sustainability of heritage building projects was not giving top priority as evident in the findings of this present research study.

9.2.8 Recommended strategies for sustainable reuse of LCBs

In an attempt to determine the most sustainable option for long term sustainable reuse of LCB projects, the respondents made their recommendations based on the projects they carried out and had achieved significant success. Table 6.32 presents the proposed recommendations by stakeholders, which consisted of fourteen (14) strategies ranked and quantified by the relative significance index (RSI) method. Energy management system was found to rank 1st with 62% RSI, as the most sustainable strategies compatible with conversion of LCBs projects. Followed by smart metering which was ranked 2nd with 60% RSI, operational energy management policy and awareness were ranked 3rd with 59% and lastly renewable installations ranked 4th with 58%.

Some notable, but worrisome facts emerging from the findings of the recommendations made by the respondents in this study about achieving the desired long-term sustainable reuse of heritage buildings apart from the lack of positive attitude as earlier observed is

lack of priority for energy management in the refurbishment of LCBs. In addition to these is the limited understanding about employing the most effective and result oriented strategies for reducing energy consumption. The recurrence of these problems within the heritage building industry has posed barriers to attaining and achieving significant results in LCBs. These observations are evident in the responses obtained from the findings of this study that some professional may have been better informed than others as only a very small percentage (29.9%) have achieved significant results.

Objective 3: *To identify the critical factors responsible for energy use in LCBs that needs to be addressed to improve energy performance.*

9.2.9 Critical factors for improvement in energy performance of LCBs projects

In order to achieve the recommended strategies suggested by the respondents, the findings from factorial analysis employed to analyse the responses from the survey and presented in Table 6.34 shows the critical factors that need to be addressed in order to improve energy performance in the reuse of LCBs. The first factor labelled *Energy management* indicates the consensus of the respondents on the importance of giving priority to energy use reduction in conversion projects so as to bring them up to modern building standard; importance of energy monitoring and analysis after conversion to other uses; use of technologies to minimise energy consumption after conversion and listed churches complexity with limiting features on energy efficiency.

The implication of these findings is that if energy use reduction is to be adequately addressed, energy management should top the priority for every project. Findings also suggest that this could be achieved by using technologies available that are

compatible with heritage buildings. The proposition from these findings is in line with those of Lawson-Smith, (1998) and Kua and Lee (2002). Although, realistically it is possible that heritage buildings may not attain a very high sustainability and operational rating standard like their modern building counterparts in a bid to bring them to modern standard; however, based on the result of the findings obtained from the field survey in this present research study, heritage buildings could attain up to C operational rating if all the factors influencing their energy consumption is adequately addressed.

The factor labelled *Design decision* on the findings from the factor analysis table has other factors categorised under it such as 'low consideration given to minimising energy consumption' and 'low priority for energy efficiency in conversion projects'. Although, it could be observed that respondents were neutral in their responses with these factors description, however, the importance of this factor was identified from the findings obtained in the analysis of the interviews. A possible explanation for the response of the survey been neutral could perhaps have a link to do with the ratings of the policymakers as earlier observed and discussed in this chapter. However, based on the findings from the interviews, this factor is considered to be critical to achieving sustainable reuse of heritage buildings.

The factors under the main factor labelled *Government regulations* was strongly supported by the respondents as it can be seen to be associated with government policies, regulations and requirements, influence of grade listing on possible energy efficiency improvements, inadequate operational energy management policy and awareness. This factor has also been supported by other researchers as earlier noted and discussed in this

chapter. Another factor from the findings of factorial analysis that needs to be addressed is a factor labelled *Limited resources and grants.*

It could be observed that this factor is associated with inadequate resources and grants to encourage energy efficiency measures and inadequate energy efficiency framework disseminating effective strategies; however, the general agreement of the respondents is particularly on 'inadequate resources and grants to encourage energy efficiency measures'. This corroborates with studies from several other authors (Rogers, 1995 Stiess *et al*., 2009b; Cadima 2009; Aalbers *et al*., 2009; Huber *et al*., 2011 and Gohardani, 2013) who posited that the availability of grants is not only an important stimulus for energy investments, but can also make impacts that is larger than their actual financial significance as they are a form of economic motivation. Thus, there is a need for more grants and funds from the governments to encourage environmental sustainability of reuse heritage building projects as the availability of more grant schemes can communicate with heritage building owners the priorities of the government to achieve carbon emission reduction targets.

To further substantiate this finding, the majority of the interviewees also emphasised the importance and the need for more grants schemes. HPP6 specifically stated how government grants aided the achievement of a project carried out; ...*"Obviously the more money you have, the more sustainable you can be. Because money had been the object, not only could we have provided the biomass boiler, we could have looked possibly to solar panels as well to generate electricity".* Another interviewee's perspective on the availability of grant is quite instructive. According to (HPP4, 2014), "*It enhanced it (the*

practitioner's decision on environmental sustainability) because we got this extra grant; it really made us to be able to push projects forward."

The combined factors under the main factor five were labelled *Risks of condensation and building complexity*. While there other factors grouped under this main factor, it could be observed that the unanimous agreement of the stakeholders was only about two of the factors, namely: 'risks of insulation and interstitial condensation in the walls or roof' and 'listed churches are complex buildings with limiting features on energy efficiency'. It is acknowledged fact that there are always risks in making changes to existing buildings. While some of the risks could be minimised, others could have grave consequences.

It is worth noting that the most challenging risk has to do with insulating solid wall which cannot be considered in certain cases without adequate assessment and caution. However, for historic churches having several architectural features that make up its heritage values and significance which further adds to the complexity of dealing with them; the risks of insulation are greater for the building. Therefore, the ways this could be addressed is to completely avoid any form of insulation for these buildings. In addition, the risk of insulation could exacerbate the risk of moisture getting into the wall, get trapped and increase the rate of heat loss through the wall and consequently leading to high energy consumption.

The general consensus of the stakeholders on the main factor six labelled *Heritage visual impacts and secondary glazing* is 'agreed'. The concession on this factor encourages the use of technologies to minimise energy consumption after conversion and to accommodate minimum visual impact along with making an allowance of secondary

glazing. One of the key principles and philosophies of conservation in the UK is to minimise the physical and visual impact of any work carried out on historic buildings. This is meant to safeguard the social values attached to historic buildings which help to fulfil people's practical, aesthetic and symbolic needs. However, high running cost is usually the challenge that the owners and users of listed buildings face.

This challenge in turn also poses threats to its ecological values. Thus, from all indication high running costs can jeopardise the building's use and maintenance, which most often leads to the building becoming empty and consequently disrepair. Invariably, this does affect and reduce the building's value as both its functional and market values are brought low. Thus, in the long run, will have much impact on its cultural value. This observation is in line with the view of Kua and Lee (2002); Brostrom and Svahnstrom (2011) who also argued that looking solely for the cultural heritage value can ultimately damage opportunities for a building's long-term sustainable reuse. Therefore it is, paramount that decisions on energy measures for heritage building's visual impact require a conscious and balance of priorities in order to uphold its ecological values.

For instance, the rich tapestries of stained window design in listed churches are an important part of the character of churches which must be retained. However, the single glazed frames are a major source of heat loss. Meanwhile, the Planning Policy Guidance PPG15 recognises that the best way to secure historic buildings is to keep them in active usage which may involve some adaptation to meet current needs. Thus, it might be argued that any energy use reduction measures that could be reversed over time after its application on heritage buildings without being detrimental to the existing fabric should be given considerations with some degree of flexibility. This explanation also applies to

the flexibility in the application of solar panel and even solar tiles which could add significantly to the ecological values of the buildings if installations are done in a careful and reversible way.

It could be observed that the last combined factors presented in Table 6.34 was under the main factor labelled *Conflict over fabric U-value.* The factor is associated with two other factors, namely: 'significant energy use reduction could only be achieved by reducing the U – value' and 'energy saving measures only makes sense if payback is less than 10 years'. It can be seen that the stakeholders rejected these factors. Thus, these factors would not be given considerations while developing the framework. For easier reference, the all the factors identified from all the sections discussed above are summarised and labelled *triggering factors*. These are factors considered to emanate from human subsystems that need to be addressed for long term sustainable reuse of LCB projects.

9.3 Influence of Building Structure, and Building Operational Subsystems on Energy Use

Objective 4: *To assess the energy performance and operational practices of existing reuse of LCB projects and to determine the factors responsible for their current energy performance.*

Part of the objective of this study is to assess the energy performance and operational practices of existing reuse of LCB projects and to determine the factors responsible for their current energy performance. To achieve this objective, the energy consumption rating was calculated using measured annual energy consumption of each building surveyed and dividing the floor area to determine the operational rating. The energy performance of the surveyed buildings was presented in Table 7.2. From the findings, it

found that most of the projects (78.9%) exhibited low energy performance ratings while only 21.1% of them exhibited high energy performance. While there have been controversies among many authors about the energy performance of heritage buildings, this finding provides an insight into the actual performance of many existing LCB projects.

9.3.1 Statistical tests for factors explaining differences in energy performance

In order to draw valid conclusions about the factors that might be responsible for the difference in performance of the buildings surveyed, statistical tests such as the Kruskal Wallis H-test used for non-parametric one-way ANOVA and Wilcoxon-Mann-Whitney rank-sum tests for different means were initially performed. However, the results obtained could not show the difference(s) as to determine the factors responsible for the difference in the energy performance of the buildings. While the reason for this is not clear, however, a possible explanation for the outcome of the results may be due to interplay of a wide range of multiple variables which may have acted to offset or swamp any significant effect on the factors under consideration. However, an alternative evaluative approach employed revealed some of the factors that explained the differences in the energy performance of the buildings.

9.3.2 Building use pattern

Findings obtained from section 7.8.1 and presented in Table 7.9 was to determine the operational energy performance of the surveyed buildings according to building use pattern. The findings reveal a large variation in energy use, according to building use typology, activity and function of individual buildings within each building category.

Observations from results obtained show that the most energy consuming buildings are buildings that use a lot of high-energy intensive equipment. In addition to this, buildings such as 'B5' and 'B7' which had some extended facilities attached to them to accommodate more community use.

Generally, it is well known and documented that traditional buildings are commonly known to have poor thermal performance. Apart from this known fact, other possible explanations for high energy use in buildings 'B5' and 'B7' with extension facilities attached could be that the extended part of the building may likely have a larger floor area compared to the actual size of the heritage building itself. Furthermore, it could be argued that the extension facilities might possibly have more frequent use than the actual heritage building which might result in more energy use of the whole building. Even though this might be considered a significant factor for high energy use for buildings 'B5' and 'B7'; however, it is quite interesting and noteworthy how a similar project undertaken by one of the interviewees of this present study was able to address this factor in his project.

According to the interviewee, a ground source heat pump (GSHP) was adopted in the new extension area, with added insulation to the roof and refurbishment of the glazing systems. With these strategies, a significant reduction of electricity use was achieved by the reduction in CO_2 emission in the project. While, these measures are quite instructive, they should be treated with caution for a number of reasons. First, some strategies may be applicable to certain buildings than others, for instance; the building referred to by the interviewee is a Georgian style building. Thus, the strategies may not be applicable to medieval churches. Secondly, the presence of archaeological remains commonly associated with churchyard may not allow or permit such strategies for conservation reasons. However, the strategies show how reuse of LCBs could be upgraded to the

modern standard and be made environmentally sustainable by reducing its energy consumption.

The high energy usage recorded by buildings ‘B10’, ‘B12’ and ‘B14’ may be due to the fact that were used for large catering services which might possibly have also been responsible for their high energy usage compared to other buildings of similar size. Observations from the results also reveal that building ‘B2’ used for retail services and building ‘B9’ used for religious purposes were among the lowest energy consuming buildings among the surveyed buildings. A factor which partly explains the likely reason for the high energy performance of building ‘B2’ compared to others could be perceived to be as a result of the nature of the retail services provided to the public by the operators of the building.

In a short, informal interview and personal communication with the operator of the building to check up with the figures obtained for energy consumption of this particular building, it was discovered that the type of retail services offered to the public by the building operator was mainly online bookselling services. In addition, this building was also used for storage of books to be sold, and as such, the energy use within the building was minimal. This is because the activities or services carried out within this building was low energy consuming in nature. Another possible explanation for low energy use of this building could also be as a result of the non-conventional energy use reduction strategies adopted by the operator of the building.

According to the operator of building 'B2', 'the *current tenants do not use the church heating system. Apart from being extremely expensive to run, it is also inefficient.' We have a strategy for keeping warm. This involves the erection of gazebo tents (which do not have to be attached to the fabric of the building), covering them with bubble wrap and installing electric heaters or radiators. In other words, we enclose a relatively small space within the church and heat that space'.* (Email communication with building 'B2' operator, 2013). The statement made by building 'B2' operator is quite revealing as well as very instructive.

Although, the strategies employed look crude, however, it is a way of managing energy use. Furthermore, this has also brought to limelight possible factor inhibiting the performance of the building such as; the use old and inefficient heating system which is very expensive to run and managed. Consequently, this is one of the factors responsible for high energy usage in the reuse of LCBs. This factor is in agreement with some of the factors identified by some of the professionals interviewed in the course of this research study. Particularly, of interest is the adoption of the non-conventional energy use reduction strategy by operators of building 'B2'. There is a likelihood that the use of this strategy may be possibly be the basic reason for the differences in energy performance of the surveyed building and might also be majorly responsible for low energy consumption of building 'B2'.

Although, it could be argued that this form of strategy may not have provided the level of comfort needed within the building; as the building operator acknowledged that the

indoor temperature was actually very low at about 5°C below comfort level at the time of the researcher's visit. However, it could be argued that this building may not be as energy efficient and high performing as it appears. This observation agrees with those of other authors such as Beck and Manfred (1980); Erhardt *et al*. (1997); CIBSE (2006) and Makrodimitri *et al*. (2012) who reported that unheated church buildings might appear to be very efficient in terms of energy consumption, however, in cold climates, very low temperatures (2°C - 5°C in winter and 13°C – 15°C in summer) and high relative humidity levels (above 60% - 65%) occur. According to CIBSE (2006), these conditions clearly fall outside the comfort conditions for occupants (40% < RH % <70%) and the recommended relative humidity (RH) values for the conservation of different materials in historic indoor environments (30% - 60%).

It is particularly worth noting that building 'B9' though primarily use for religious purposes combined with some community uses is among the few high-performance buildings. Observation from field survey and analysis show that solar panels were recently installed on building 'B9' in a manner that is not visually intrusive to the buildings. Interestingly, this is a singular and significant factor responsible for the differences in energy performance of the surveyed buildings. Although, the installation of photovoltaic (PV) on heritage buildings to reduce their energy consumption has a lot of requirements to be fulfilled from a conservation point of view; however, a more comprehensive view of result findings of this current study, suggests that renewable energy technologies seem to be a viable option and solution for reducing carbon emissions from church buildings. This view is similar to those expressed by Makroditimir *et al*. (2012) and Akande *et al*. (2014).

Observation from the findings shows that based on the overall ranking of the performance indicator for all the buildings, according to their building typology, buildings use for religious purpose combined with community uses was ranked 1st as the best performing building type. Surprisingly, building used for museum purposes ranked 2nd. However, this is contrary to the general expectation as buildings used for museum purposes are characterised by high energy use pattern. The most likely possible explanation of the ranking position of the building used for museum purposes could be as a result of one of the buildings in this category (which is building 'B8') using air source heat pump as a source of energy generation for its building. Essentially, the ranking of the surveyed buildings could be a valuable information and a tool for owners, facility managers and operators of these buildings to be able to critically evaluate the energy performance of their buildings as well as to be well informed about the necessary actions to be taken to boost or improve the energy performance of their buildings. In addition, the result of this finding could also serve as useful information that can be used as a decision point when leasing, buying or financing any of these buildings.

9.3.4 Energy use by fuel type

The discussions of findings in this section are based on the findings of the ecological subsystems part of heritage buildings which relates to its ecological values. This subsystem is connected to the use of energy and other resources. Thus, understanding the ecological subsystem part of heritage building could provide needed clues to prudent management of this subsystem. This would then help to make the building future value (i.e. Energy usage) as derived from the review of value theory to be more efficient and thus increase its value as a resource for sustainable development.

9.3.4.1 Electricity energy use

The building's exceptional performance in aspect of electrical energy could partly be explained in relation to their single use activity or function and for both main and secondary use of the internal space compared to others with other multiple uses. Another factor which possibly could have partly explained the reason why their energy performance appears better than others could be perceived to be because the buildings only use electrical energy as the only source of energy use. From the comparison between the buildings in this category, it can be seen from Table 7.10 that as the building size decreases, energy consumption increases. This is contrary to expectation because building 'B16' appears to be the smallest in size in this category, however, further observation showed that 'B16' consumed more than half (59%) of energy use within the group. This further explains why 'B16' used more than twice the energy when compared to CISBE benchmarked for energy use.

The high consumption recorded by 'B16' may possibly be due to several reasons such as; intensity of energy use, most especially for lighting as a cultural performance building. Other possible explanations could be as a result of frequent and increased number of people using the building weekly, especially at night, which will require more use of light and energy consuming lighting facilities such as floodlighting, more energy use generating activities that may also require the use of other electricity generating equipment and sound system typically use in theatre and cultural centre. Thus, it is expected that energy consumption for 'B16' will be much more higher when compared to building 'B18' whose main activity is just limited to musical training and building 'B2' whose main activity is only limited to online retail bookshop.

It could be observed that the smaller buildings are, the more put to use and patronise when compared to larger ones. This may be probably due to the perception that smaller buildings are easy to manage and also considering the affordability of paying for the cost of renting the building. This is because often, the bigger the building, the more the cost of renting and managing it. Thus, the preference for smaller buildings could have possibly resulted in more frequent usage which leads to high energy consumption.

9.3.4.2 Gas energy use

Buildings 'B6', 'B8' and 'B13' used gas only for their building operations. As expected, as the floor area of these buildings increases, the energy consumption increases. A noticeable difference observed among this group of buildings (i.e. 'B6', 'B8' and 'B13') when compared to buildings ('B18', 'B2' and 'B16') in Table 7.10 is the dual usage of the buildings except building 'B8' which is used for museum only. In the league of the final ranking on energy consumption rating for all the buildings surveyed, 'B6' ranked 7th; 'B8' ranked 9th and 'B13' ranked 11th. Generally, a building that is use for museum are perceived to be high energy consuming buildings, however, contrary to this perception building 'B8' consumed lower energy than anticipated in comparison with other buildings of similar size.

A possible reason for the ranking position of building 'B8' is perceived to be as a result of using an air source heat pump to meet its energy demand. Data on energy use obtained from these buildings shows the actual energy consumption of these buildings was remarkably higher, more than twice the CISBE benchmarked for energy use. The high energy use of buildings in this group could be perceived to be as a result of multiple

factors arising from energy end uses such as process plant (e.g. Freezers) and other equipment (e.g. catering), user's behaviour and attitude, efficiency of heating equipment etc.

9.3.4.3 Gas and electricity use

Result from data obtained from 'B9' shows significant reasons why this building tops the list as the highest-performing building in this category. Building 'B9' is partly used for religious worship, for 2 -3 services on Sundays and 2-3 services during the week. The building is also partly used for varieties of community-based activities such as music festival. Valuable lessons can be drawn from the approach and strategies employed by the operators of building 'B9' which can be attributed to the high performance of their building in terms of energy use. Firstly, the building operators had a good approach to monitoring energy use of the building on monthly and yearly basis. Secondly, the old boiler dating from the 1950s, which originally runs on coke, but converted to gas in the 1960s was recently replaced with new gas boilers.

Thirdly, the building operators reported *'we try to ensure that full heating is only on when there are actual activities occurring' (Email communication with building 'B9' operator, 2012).* Interestingly, a notable feature which had also enhanced the energy performance of building 'B9' is the installation of photovoltaic (PV) system in 2012 generating 5955kWh electricity and saving 3394 tonnes of CO_2 emissions. It is worthwhile to note that the PV installation does not affect the visual appearance of the building. These factors all contribute to the high performance of the building. It could be observed from the data presented in Table7.14 that building 'B12' and 'B14' uses the building for food and

catering operations, an important factor which may be partially responsible for their high energy consumption.

It is important to also note that catering operations use a variety of high energy, intensive equipment to provide food for customers. The energy consumed by this equipment alone varies considerably according to how it is used and how regularly it is maintained. It is estimated that around 25% of the energy used for catering operations is expended on the preparation, cooking and serving food. By far the largest proportion of this energy is consumed by cooking apparatus from which much of it may be wasted through excessive use, poor utilisation and poor energy management behaviour. Moreover, it is common in catering operations for some of the equipment to be swithed on at the beginning of a shift and left running throughout the day hence, these factors may largely be responsible for high energy use in these buildings apart from heating the building during cold seasons.

Energy consumption in these buildings could also become aggravated if users' energy consumption reduction awareness and behaviour are very poor and when kitchen equipment such as hobs and ovens are used in warming the kitchen area. For comparison between the similar buildings, field data obtained for buildings 'B5' and 'B7' shows that these buildings had extended facility attached to them for other multi-function community uses, such as conference and musical concerts. This could partly explain why their energy consumption is quite high when compared to other buildings using the same fuel type.

9.3.5 Energy performance based on building operational practices

Section 7.12 of the analysis identified several factors arising from building operational practice subsystem. Twenty factors were investigated and the overall energy consumption mean ratings were determined and ranked from 1-20 in order of high energy consumption

ratings calculated for each factor in section 7.13. The identified factors are referred to as aggravating factors for the purpose of this study. To reflect the building operational performance evaluation criteria presented in Table 7.4, the factors that are similar relates to each other were further identified, combined, grouped, and ranked based according to their overall mean energy consumption ratings (Table 7.37). The group energy consumption factor rating and the factors influencing performance was also presented to identify the factors responsible for high energy consumption and consequently requiring urgent attention and interventions; and those responsible for low energy consumption demonstrating best practice and lessons to be learned. The performance factors were grouped into high performance, medium performance and low performance.

9.3.5.1 Low performance factor group

Factors identified to be responsible for high energy consumption in this group are ranked from highest to lowest namely; building use pattern, building services, fabric improvement and lighting were ranked 1st, 2nd, 3rd and 4th respectively. Building use pattern constitutes the highest energy consuming factor in this group. It is likely that energy consumption in the reuse of LCBs will be significantly influenced by the type of equipment/appliances used, and activities carried out within the building. Although a lot of these equipments and appliances vary according to the function of the building,

however, they could contribute significantly to the amount of energy consumed by the building over time.

This finding agrees with those of other researchers (Zhun *et al*., 2011; Bowden, 2013) and the opinions of some of the interviewees in this study. Some of the interviewees' comments on this factor include: *"Well, I suppose is the intensity of use...the building is used more often than they might have intended...*" (HPP2, 2014). *"A lot of it is down to the use of the building"* (HPP6, 2014). *"It is the use of the building; the building is used a lot more for events along with a PA system and things like that use quite a high amount of energy.."*(HPP4, 2014). *"Well, it depends on the hour of occupation and on the type of equipment they put in like the information technology (IT) systems, for example which may not be anticipated…"* (HPP5, 2014).

Some of the appliance and equipment used in some of the buildings surveyed include: tumble dryer, washing machines, beer coolers, up to 10 freezers in a single building, up to 60 halogen theatre lights, several cooling equipment, gas and electric cookers, high energy consuming musical instruments, computers, photocopiers, refrigerators, vending machines etc. While some of the uses could be categorised as either high and low degree of use pattern and/or light and heavy activity use pattern; contrary to expectations, the findings in the current study showed that in some cases energy consumption of this category of use, did not depend on building size. This was especially evident when comparing building using electrical energy use only.

It was observed that as the building size decreases energy use increases (Table 7.10). Furthermore, findings have shown, that smaller building appears to be more energy

consuming than the larger buildings. Possible explanations for this have been extensively discussed in section 9.3.2. The indication from results obtained from this study showed that some form of cooling equipment was used by 4 out of the 16 buildings surveyed. A striking and surprising observation from result findings showed that the mean energy consumption rating of these 4 buildings almost doubled those of the other 12 buildings who did not use any form of cooling equipment in their buildings.

The likely reason for this could be due to user's attitude to saving energy such as leaving the air conditioning on overnight or not switching off fans when not needed. This may be as a result of the common assumption that switching off an extractor fan will not have much of an effect on energy savings. A notable fact is that though a single fan may only signify a small power load, yet could bring about a significant loss of heat from a building if not adequately controlled. The heating system would then have to compensate which could typically increase boiler fuel consumption by around 5%. (Carbon Trust, 2012). These findings may disprove the myths that leaving the air-conditioning on overnight reduces energy costs as the system stays at the required temperature.

This result shows a much higher energy consumption using air conditioning and fans than necessary. In the overall, the mean consumption rating (Mean = 114; SD=39.7) obtained for building cooling strategy and ranked 3rd on the factor identification table (Table 7.36) indicates that this factor has a significant influence on energy consumption. Following building use pattern, building services constitute the second largest factor responsible energy consumption in the surveyed buildings. The factors that constitute this group include; heating equipment, cooling equipment, efficiency of heating system, heating

strategy and age of heating system. Among this group, types of heating equipment constitute the highest energy consuming factor.

The type of heating system observed within the buildings varies from the use of gas boiler with radiator, suspended gas radiant heater, gas boiler with under-floor heating and electric radiant heater used for individual space heating. The possible reasons for the high energy consumption of these systems might be due to the following: type and effectiveness, age and efficiency (e.g. the use of radiant heaters with about 60% efficiency) lack of proper maintenance and possibly lack of heating control. Generally, combustion efficiency of older boilers is commonly between 65 and 75%, while inefficient boilers could even be lower. Whereas, energy efficient gas or oil boilers can have efficiencies that range between 85 and 95%.

Observations of results presented in Table 7.25 show that more than one-third of the buildings surveyed in this current study attained between 60 and 80% heating efficiency, while another one third could not ascertain the efficiencies of their heating systems. This finding was supported by the response from the interviewees as one of them stated that…..*'the system that was already in place was old fashion gas fired Combi boilers and even old fashion sort of warm air gas fired heating system that were not particularly energy efficient...."*(HPP1, 2014). Specifically, this factor which is responsible for high energy consumption in heritage building can be easily curtailed by replacing the old inefficient boilers with new modern effective ones.

Findings from the surveyed buildings reveal that buildings with some form of wall insulation application as a measure to reduce energy consumption did not perform better

in terms of energy reduction when compared with those buildings without wall insulation. Contrary, to expectations that application of insulation to historic buildings could reduce energy demand and increase occupant comfort, it was however, observed from the findings that the mean energy consumption rating was much higher for buildings with some form of wall insulation. While the reason for this is not very clear, several other factors might be responsible. Invariably, this may possibly be the resultant effect of the interplay of other factors, such as: negative user's behaviour and attitude towards energy saving strategies, old and inefficient boiler, high frequency use and patronage of building, bad maintenance and energy management policies, ventilation and heating strategies etc.

Basically, putting all factors mentioned together could act as contributing factors overshadowing the effect of the application of the wall insulation in the buildings, and as well as lead to increase in energy consumption of the buildings if not put into consideration and properly addressed. In essence, this does not however in any manner imply that insulating the wall cannot improve the energy performance of heritage buildings. Furthermore, it is paramount to first assess if a building with solid wall can be upgraded. This is necessary before adopting any strategy or taking any step towards achieving reduction in energy use in LCBs. This will essentially provide full understanding and adequate evaluation of the building in its current condition and use, so as, not to compromise the building's aesthetics.

The findings of this study ultimately support the view that wall insulation is not an absolute solution to enhance energy performance in LCBs. This view is consistent with those of other previous researchers, who stated that historic buildings could perform better without any form of wall insulation to reduce its U-value. (Rose, 2005; Wallgrove

2008; Wood, 2010; Curtis, 2010; Cantin *et al*., 2010; Rye, 2011; Baker, 2011; Godwin, 2011; SPAB, 2014). Therefore, a well-known view expressing 'fabric first' needs to be applied with caution specifically for listed church buildings having a lot of significant architectural features.

In contrast to the fore mentioned views, some of the interviewees in this study strongly maintained that the application of insulation to historic building was the most effective strategy. According to some excerpt from the interviews; *"....The most effective strategy is improving the fabric u-value and reducing infiltration, refurbishing the glazing systems, insulating the roof and floor...."* (HPP5, 2014). *..."We were able to redesign the roof to incorporate insulation, install a small bank of solar panels on the tower roof, and an air source heat pump in the tower"* (HPP7, 2014). While the above strategies by the interviewees were found to be effective, it is important to note that the buildings will have to be treated on a case by case basis. Moreover, where possible, insulation may be applied to other areas of the building elements such as the floor and the roof as indicated by the interviewees.

Another energy consuming factor identified in the lower - performance group is the use of light and type of lighting system in the building. The factors observed to have contributed to high energy consumption are observed to be as a result of type and efficiency of lighting system used. When this result is compared to the findings from Table 7.18, it is possible that those who indicated they had replaced their lighting system with more efficient light source might not have replaced them with the most efficient lighting source due to cost of replacements. This might have explained the reasons for the higher energy consumption rating obtained for the buildings. Another likely reason may

be the type of lighting system used in replacement of the inefficient ones. Generally, the useful life of most lighting systems is about 5 to 15 years. This provides the opportunities to incorporate significant energy efficiency improvements in the short and medium term.

Compact fluorescent lamps (CFLs) consume roughly one-fourth of the energy used by traditional incandescent lamps and provide the same level of light. In addition, compact fluorescent lamps also have much longer lifetimes, with a rated lifespan of 5,000 to 25,000 hours compared to 1,000 hours on average for incandescent lamps. However, if the lighting system had rather been replaced with a light - emitting diode (LED) lighting system, this could have possibly had a greater improvement in lighting service with lower energy consumption. Furthermore, it is also worth noting that the typical effectiveness of halogen lighting is about 17 Lumens per watt when compared to at least 50 Lumens per watt for LED lights. Therefore, if the buildings using halogen lights had replaced them with LED lighting with proper control and management strategies it could be estimated that their total energy consumption could be reduced by almost 60% consequently reducing the building CO_2 emissions (IRTC, 2005).

9.3.5.2 Medium performance factor group

This group constitutes the characteristics of average performing factors observed to comprise of better operational practices compared to the low-performance group. The factors include; energy management, building characteristics, users' behaviour and building maintenance. It is of interest to note that, these findings are to some extent in line with the recommendations of the survey respondents on the best options for sustainable reuse of LCB projects presented in Table 6.32. Observations made from

results obtained, reveals that quality of maintenance seems to be very significant in reducing energy consumption in the reuse of LCB projects. This is quite instructive in that it shows the operational energy use of heritage buildings is associated with regular maintenance, which is consequently linked to improvement in performance of the buildings. This view is also shared by other prominent scholars such as Forster *et al.* (2011) who posits that maintenance is one mechanism by which it may be possible to achieve carbon and energy savings in historic buildings if initiated through necessary proactive and reactive regimes. Thus, this finding reveals that routine maintenance is a key component in energy management.

Generally, it is normal to expect positive users' behaviour to contribute significantly to energy use reduction as observed in this study. It was evident in this study that those who indicated that they always turn off equipment and/or appliances and light when not in use had a better energy performance than those who did not. Users' behaviour appears to be the most neglected aspect of energy management as positive behaviour that influences energy consumption can vary from individual actions to organisation action. Thus, if building users can be persuaded to adopt more energy-conserving habits, costs of operating the building, will be significantly reduced by anything up to 10 percent (Sherratt, 1986). This view invariably shows that users' behaviour in non-residential buildings have a substantial impact on energy use, especially when the lighting, heating, and ventilation are controlled manually (Ueno *et al*., 2006). While on one hand, it may not be easy to control user's behaviour, as people are not easily persuaded to change their habits. However, on the other hand, with adequate and effective control mechanisms or measures put in place such as; outlining guiding rules, placing information labels as a reminder in conspicuous places, providing supervision and monitoring measures,

providing regular feedback on energy, provision of leaflets or flyers on simple energy saving techniques and workshops could be organised from time to time.

All these measures put together could check and reduce negative user's behaviour, and consequently, on the long-run contribute to the reduction in energy consumption in LCBs. Thus, from this finding a proper recognition of the impact of positive human behaviour could generate worthwhile savings as well as help to ensure that savings from other technical and financial measures are achieved. Authors like Sherratt (1986) and Shiel (2009) have also made similar reports.Building structure as a subsystem was investigated to determine if its characteristics such as, its age and heritage value in terms of its listed status, have any influence on energy consumption. Interestingly, result findings show that the highest performing buildings were pre-1919 buildings. This result is supported by the earlier research findings of several other authors, on the thermal performance of pre-1919 buildings, and this has proved contrary to the myth that all older buildings are less energy efficient (Rose, 2005; Wallgrove 2008; Wood, 2010; Curtis, 2010; Cantin *et al*., 2010; Rye, 2011; Baker, 2011; Godwin, 2011; Moran *et al*., 2012; SPAB, 2014).

Similarly, statistical findings presented in Table 7.3 and as indicated earlier in this study corroborate this result by showing that there is no significant difference between building age and energy consumption. Further findings from this study also indicate that not all older buildings are energy efficient as more results show that the age of the building is an important factor that could explain the difference in energy performance of the surveyed buildings. These findings stem from the results presented in Table 7.32 showing far more

than half (60%) of the low performing buildings were specifically buildings built prior to the 19th century.

Similarly, it could also be observed from the findings presented in Table 7.36 that building age (overall mean rating = 101) is a significant factor. Although, other possible explanations for this could be as a result of any other limiting factors which might have arisen from poor maintenance and neglect, old and inefficient heating system, current use pattern, etc. Further findings on the influence of heritage value through its listed status indicate that this factor plays some significant role when considering energy consumption in the reuse of heritage buildings.

It is interesting to discover from the result of this findings that Grade II and Grade II* listed buildings consumed more energy than Grade I listed buildings as indicated in Table 7.34. However, there might be the probability that Grade II and II* listed buildings were likely more patronised during disposal and consequently were used more than Grade I listed buildings, perhaps this might due the fact that they could easily accommodate some internal changes and alterations. Findings on energy management were derived from the questions on energy management awareness, the nature of energy management policy and energy management policy adopted by the building operators. Generally, observation of findings across the entire survey carried out in this study, showed that most building operators did not exhibit the needed commitment in managing energy use.

The result in Table 7.19 shows that most two-thirds (62.5%) of the respondents answer 'Yes' to having an energy management policy in place, as expected the result obtained shows 37 percent that answered 'No' had higher mean of the energy consumption rating.

It's important to note that the evidence from Table 7.17 revealed that integration of energy management policy was observed to be poor as half off (50%) of the respondents stating they had an unwritten energy management policy. However, it was observed to be much poorer at 38 percent of the respondents considering no form of energy management policy in their operations.

Clearly, 'integration' here is a subjective concept and the effectiveness of such is dependent on the strategies adopted to manage energy use by the building operators. However, it was observed that those whose buildings performed better seems to have shown a stronger commitment to energy management policy though they had an unwritten policy. It can be observed from Table 7.21 that only a small number (13%) of the respondents employed monitoring and targeting scheme; while a few (20%) employed strategies of making energy use known to workers to check habits.

It is rather surprising that the majority (46%) of the respondents that adopted energy management strategies belonged to the low performing category, while only a minority (27%) of the total respondents had no form of strategies adopted. However, when compared with findings on the nature of energy management policy adopted, there might have been the likelihood that the 25% of the respondents with high performing buildings may have taken some form of measures or responsibility for energy management of the buildings as the building managers. This is of paramount importance as it has shown to be one of the most successful routes to reducing energy consumption in buildings.

9.3.5.3 High performance factor group

Renewable technology adoption was one of the most effective measures that were observed from the findings in Table 7.31 to have been responsible for the high-performance group. It was observed that buildings ('B8' and 'B9') that adopted solar photovoltaic, ground source heat pump (GSHP) air source heat pumps (ASHP) for energy generation, use of biomass indicated a significant improvement to the energy performance of their buildings. This observation was made from the results obtained from building energy use data, technical survey and interview conducted during the course of this present study. Current research findings from this study shows that the use renewable technologies could facilitate long-term reuse of LCB projects as it allows the building to be heated with less CO_2 emissions and even lower running cost.

This present result findings on effectiveness of renewable technologies for enhancing the performance of heritage buildings is identical with the views of previous researchers (Brostrom and Svahnstrom, 2011; Makroditimir *et al*., 2012; Rostvik, 2013; Akande *et al*., 2014) supporting the importance and contributions that renewable technologies can make in reuse of heritage buildings, and most especially for listed churches. These authors' findings have led to a call to make use of the space around buildings and outside building's own physical footprints in an architectural and sculptural way. Some of the interviewees in this study also confirmed these findings by acknowledging that the application of renewable technologies in their projects has proved to be among the most effective strategies.

One of the interviewees 'HPP4' particularly stated that the combination of certain strategies such as the application of ground source heat pumps (GSHP) provides the

comfort and effectiveness required for the use of the building. According to the interviewee, *"…. the most effective strategy is probably the GSHP… Because it enhances the building, made it more comfortable to inhabit…..and just really encourage the use of the building. I think if we had not done it, people would be less inclined to book it for events.…'* (HPP4, 2014). Although it might be argued that the installations of some of the renewable technologies could have impact on the appearance and heritage value of the buildings; conversely, non-installation where it could be allowed would only protect the building's heritage value for a short period of time. Consequently, decision on non-installation would result to the buildings becoming less attractive for long term reuse and thereby limit opportunities for their preservation (Brostrom and Svahnstrom, 2011).

Objective 5: *To identify the factors preventing energy use reduction for the delivery of sustainable reuse of LCB projects in practice.*

The discussion under this objective covers the experience of heritage building professionals in practice on their projects on reuse of listed churches. Putting into consideration the strategies employed, challenges encountered and their perception of the exogenous factors preventing energy use reduction for the delivery of sustainable reuse of LCB projects. The purpose of the interview conducted within the framework of this present research study, was aimed at discovering other exogenous factors posing as barriers to the reduction in energy consumption in LCBs and to triangulate the findings of the study with the subjective view of heritage professionals.

The limiting factors influencing energy consumption in reuse LCB projects that are paramount were highlighted by some of the interviewees. This was based on their

experience and direct involvement in several LCB projects. For instance, the interviewees indicated that in some cases, factors such as building conditions and building site location hindered energy efficient measures requirement. In order to confirm the limiting effects of these factors, one of the interviewees made mention of how all the feasibility studies, they conducted to explore alternatives for energy use reduction of their projects were limited because the building was located on a site with mining history and surrounded by a graveyard.

Another observation from the findings of the interview conducted in this current study indicated that most decisions on LCB projects were largely influenced by the clients (building owners). Having little or no understanding or knowledge of the important technical aspect of the projects as it affects the environmental sustainability and energy efficiency of the buildings. Basically, some of the factors identified that influence clients decisions and budget as it affects projects carried out on LCBs are namely; the high initial cost of the project, the long payback time and the effect of VAT as it tends to reduce the funds available to them. Holt *et al*., 1994 and Chinyio *et al*., 1998c also reported similar influence on clients' decision on projects which also concur with the views of the interviewees of this current study.

On one hand, it is likely possible in several instances that the clients (building owners) already have a planned budget to guide their spending limit, even before the consultant are appointed to carry out any project on LCBs. Actually, this is a very difficult and challenging situation for professionals and consultants working on LCB projects. On the other hand, indications of the results, show that in situations where the design team, (i.e. The consultants and heritage professionals) are actively involved and make significant

contributions to major decisions affecting projects carried out in LCBs, sustainability goals are given top priority. Consequently, other aspects such as; comfort and building performance for intended use also become achievable. Thus, energy use reduction for the delivery of sustainable reuse of LCB projects may be influenced by the clients' decision and objectives.

The findings confirmed those of other authors such as Melet (1999); Ofori *et al.* (2000) and Chan *et al.* (2009), who found that few clients are committed to sustainable environmental sustainability despite the evidence that it makes business sense. It was also found that the designer's influence is also a significant factor as it was observed that low priority for environmental sustainability in the design; minimal collaborative teamwork; little or no prior assessment to determine previous energy use; little or no target for energy use reduction on the part of the designer were evident from the findings. It could be argued that the role of the designer is essential to weave various parameters necessary to achieve sustainable delivery of the project. This becomes a strategy in itself when sustainable features become inseparable from other project objectives. In addition, references were made by the interviewees to poor fabric condition and site location constraint. The poor fabric conditions might perhaps be due to neglect of maintenance, which remains one the reasons for high energy consumption in the building.

To bring to the fore, the sections discussed from the analysis of the data collected for this study have helped to identify the interplay of multivariable and/or critical factors having an interwoven effect on the energy performance of LCBs. Each of the factors having been identified and adequately discussed in this chapter could be concluded to be contributing little or more effect to the energy performance of LCBs. Thus, accounting for non-specific

effect of a particular factor, these critical factors constitute the drivers for sustainable conversion of LCBs and consequently the rationale for proposing an operational energy management framework. Figure 9.1 diagrammatically illustrates the interrelationships of these critical factors as derived from stakeholders' practice, design influence and operational practices of existing reuse LCB projects and consequently their outcomes on users' comfort, energy consumption and CO_2 emissions and operational cost of the building.

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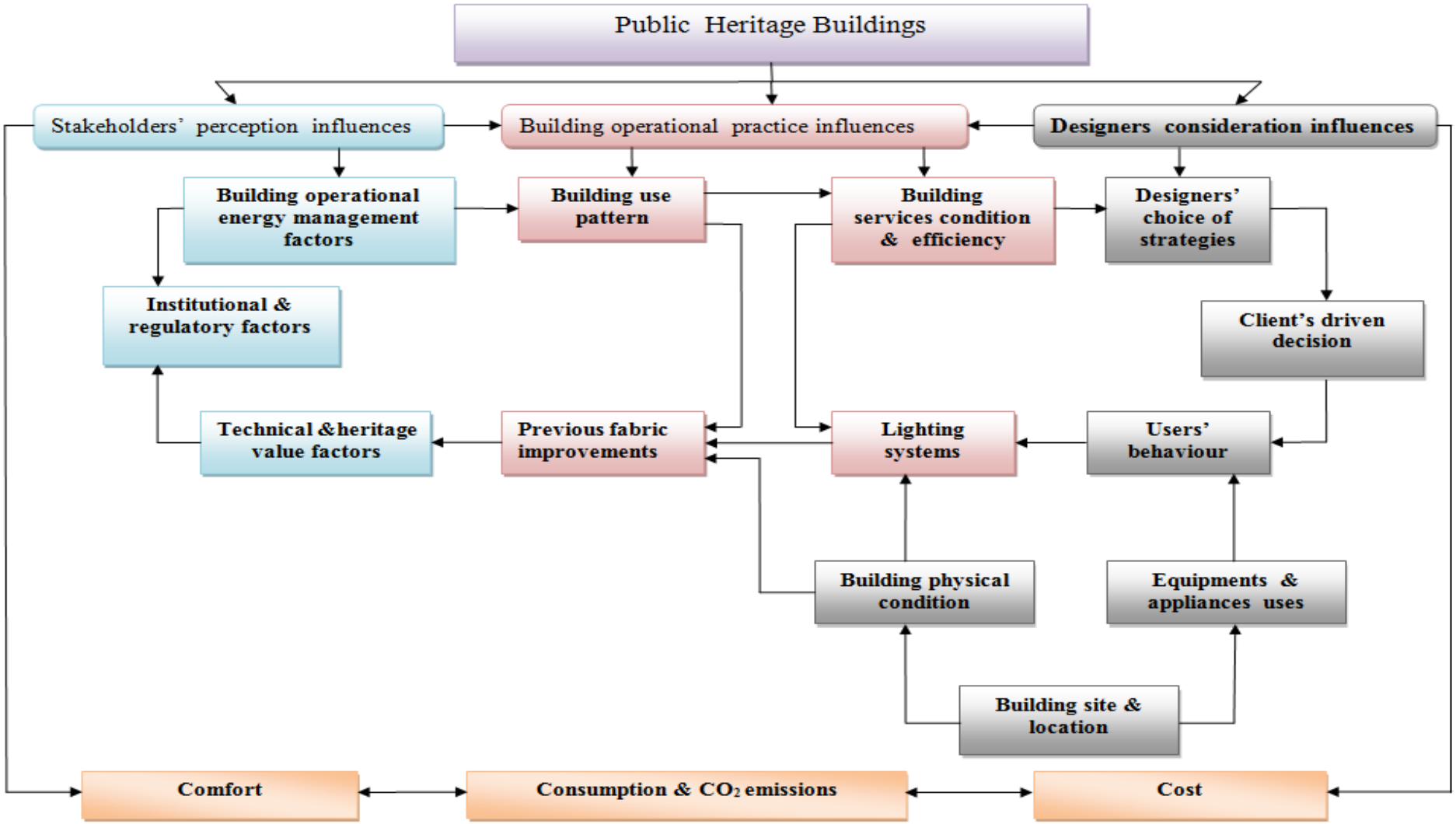

Figure 9.1: Diagram (D) Interrelationship between comfort, consumption, CO_2 emissions, cost, stakeholders and design influence
Study Author (2014)

Objective 6: *To propose a strategic energy management framework for reuse of LCBs*

In order to develop the proposed framework, findings from the analyses of both sets of data in this current study were integrated and triangulated to form the basis for the development of the proposed operational energy management framework for reuse LCBs. The development of the proposed framework is fully discussed and the framework presented in Chapter 10.

9.4 Chapter Summary and Conclusion

The discussion in this Chapter integrates the findings obtained from three phase sequential method of data collection adopted for this current study. The quantitative findings highlighted the critical factors to be considered as perceived by the stakeholders for operational energy management and improved energy performance of LCBs. Findings from the analysis of the data obtained from field survey provided substantial evidence to provide explanations for both low and high energy performance in existing reuse of LCB projects. Meanwhile, the degree of subjectivity of the qualitative findings provided more information needed and gave further insight into the strategies adopted by the practitioners. Themes were identified during the analysis of the qualitative data and supported by the evidences obtained from the quantitative data. Thus, the initial assumptions of the study were therefore supported by both the quantitative and the qualitative findings.

CHAPTER 10: ENERGY MANAGEMENT FRAMEWORK FOR REUSE OF LISTED CHURCHES

10.0 CHAPTER OBJECTIVES

- To provide background for the development of the strategic energy management framework
- To present the framework and describe the components and steps within the framework.
- To make recommendations for the users of the framework.

10.1 Background of the Framework

Evidence from the review of literature coupled with the findings from the data collected and analysed in this study has shown the need for an integrated strategic energy management framework for reuse of LCB projects. According Dickoff *et al.* (1968) developing a framework rooted in phenomenological theory is a process, with the final aim of providing a guide for action or practice. The authors' seminal work on 'situation-producing theory' emphasized the characteristics of developing theory in a practice-based discipline. The authors expressed that theory is not only applicable to practice; practice is equally applicable to theory and both are applicable to research. In addition, they argued further that theory and practice are jointly interconnected and symbiotic while action is directed towards a specific goal (Dickoff *et al.*, 1968:425).

Dickoff *et al.*, (1968) placed emphasis on important components required for developing a situation-producing theory, namely: (1) *"goal-content: conceptualization of the content as a desirable goal (2) conceptualization of prescriptions: the actions that should be undertaken to realize the goal content, and (3) a list specifying activities which an agent*

or practitioner must undertake in order to bring about situations the desirable outcome in the conception of the goal". Thus, the components described and suggested by Dickoff *et al*., (1968) for developing situation-producing theory provided the platform and the direction for the development of the strategic energy management framework in this research. Figure 10.1 presents the illustrative diagram of how findings from theory and practice in this study are linked together to develop strategic energy management framework for reuse of LCBs. Figure 10.1 illustrates how the procedure overlapped starting with the theoretical orientation and ending with the final outcome. The purpose of the framework is to provide guidance from planning (pre-conversion) stage to operation and management (post-conversion) stage for designers and facility managers with the goal of achieving improved energy performance in the reuse of LCBs.

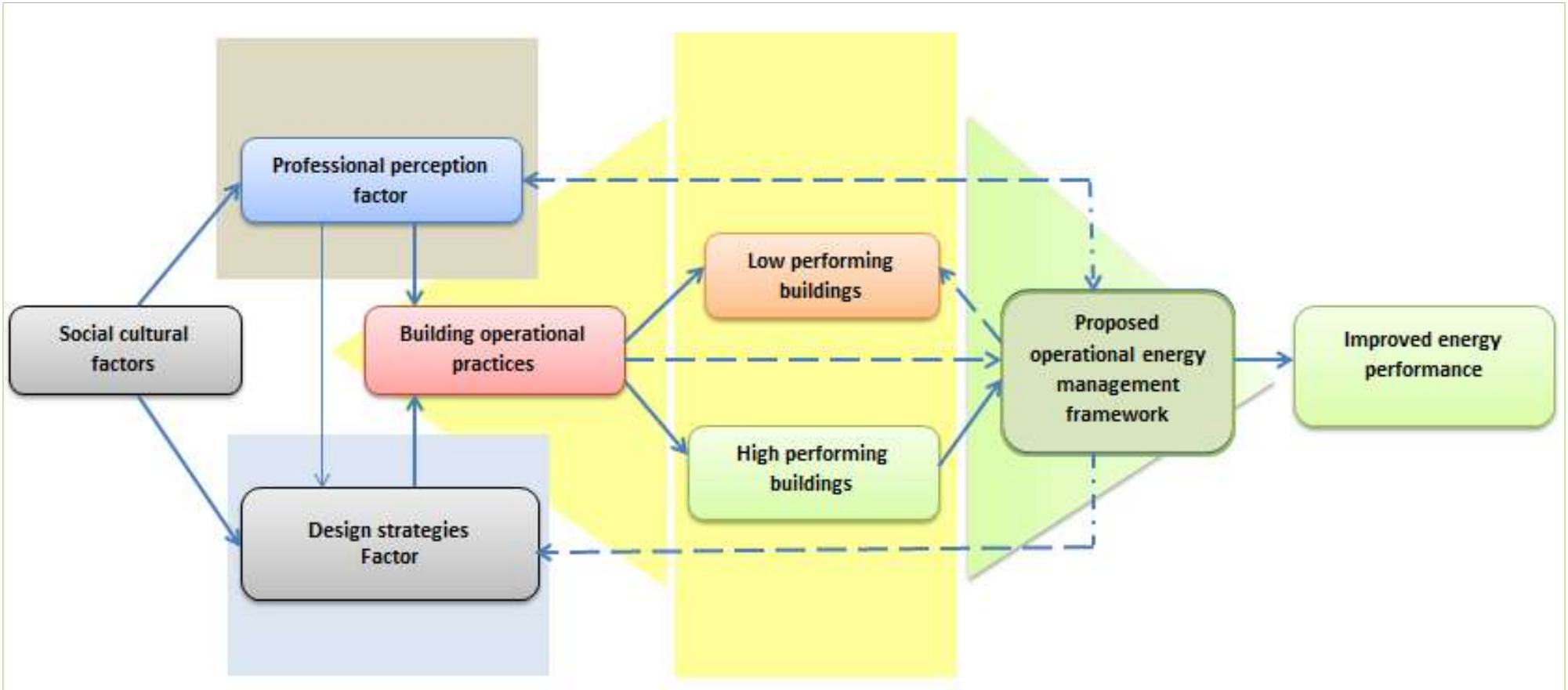

Figure 10.1: The connection between theory and practice in the development of the strategic energy management framework
Source: Study Author (2014)

10.2 Objectives of the Proposed Framework

The primary objective of the proposed framework is to aid the users in identifying, selecting, and adopting appropriate strategies to address the problem of operational energy consumption in the reuse of LCBs. In addition, the framework enables the users to identify individual and combine approaches to sustainable delivery of LCB projects based on effective evidence-based strategies. Furthermore, the framework is meant to operationally deliver a balanced approach to implementation of effective strategies and practices used by other stakeholders in the industry.

Further objectives of the proposed framework include to assist other heritage building stakeholder in the following ways: (1) to build upon the findings arising from the identification of the long-term energy consumption problems in LCB projects that heritage industry needs to focus on; (2) to boost the stakeholders' understanding of underlying critical factors contributing to these problems; (3) identify the most sustainable strategies and practices appropriate to addressing the problems. Finally, the proposed framework is intended to encourage effective approaches by other practitioners in improving energy performance and reducing heritage building's environmental impact through more coordinated and systematic actions. Thus, the framework is hoped to answer the key research questions of this present study on 'what framework can be proposed to improve operational energy performance for sustainable reuse of LCBs?'

10.3 Approach to Developing the Framework

For the purpose of exploring all possible avenues and precision, a logical model approach aided in developing the structure of the proposed framework. WK Kellogg Foundation

(2001) describes logic models as "a systematic and visual way of representing and presenting activities to be carried out, changes to be made or results hoped to be achieved". It visually links program inputs and activities to program outputs and outcomes showing the basics (logic) for the expected outcome. It is an iterative tool providing guidance for program planning, implementation and evaluation along with the theory or rationale underlying it (Taylor-Powell et al., 2002); making implicit the program theory explicit (Dwyer and Makin, 1997).

A broad range of knowledge and perspectives from the stakeholders' perception of energy use reduction, and field data collected was explored and integrated to develop the proposed framework along with suggestions and recommendations of action to be taken on current and future projects. Five components and three phases are proposed with each phase corresponding to at least a component (Figure 10.6) namely: (1) investigation of the long-term problems; (2) identification of underlying critical factors causing or contributing to the long-term problems; (3) exploration and implementation of evidence-based effective strategies and practices to address the causal or contributing factors; (4) evaluation of impacts anticipated from the implementation of the strategies; and (5) assessment of the achievement of the long-term objectives and goals. To ensure the development of a standard and acceptable framework, characteristics and attributes of other frameworks and tools as suggested by Burstein *et al.*, (2008) and Davis (2009) was incorporated; consisting features of being comprehensive, flexible, easy to use, compatible and affordable (Figure 10.2).

Comprehensive	Flexible	Easy-to-use	Compatible	Affordable
• Clear structure • Descriptive • Accurate output	• Adaptable to new or in exceptional situation • Can be followed for the duration of the life-cycle	• Customisable according to the needs of the users • User friendliness & reliability	• Compatible with other framework and process • Produces consistent results	• Consideration to project cost • Helps to reduce or save cost

Figure 10.2: Feature of a good framework adapted from Davis (2009); Burstein *et al.*, (2008)
Source: Sheth (2011)

10.4 Framework Development Process

This research through the application of the framework could help to sharpen the focus, coordination and dissemination of appropriate strategies for addressing energy consumption in LCBs projects.

10.4.1 Methodology used in the framework development process

Using extensive literature review, the method of developing the framework consist of (1) recognizing the drivers and barriers to energy use problems; (2) developed a conceptual framework to identify non-generic underlying factors to the problem; and (3) assessed strategies adopted in practice to moderate the factors. Related technical and managerial literature from other fields was examined and appropriately applied to enlighten the researchers' perception of the components of the framework. This approach enables the development of the components and sub-components of the framework to be built on existing knowledge. Figure 10.3 shows the graphical illustration of the methodology for the proposed framework.

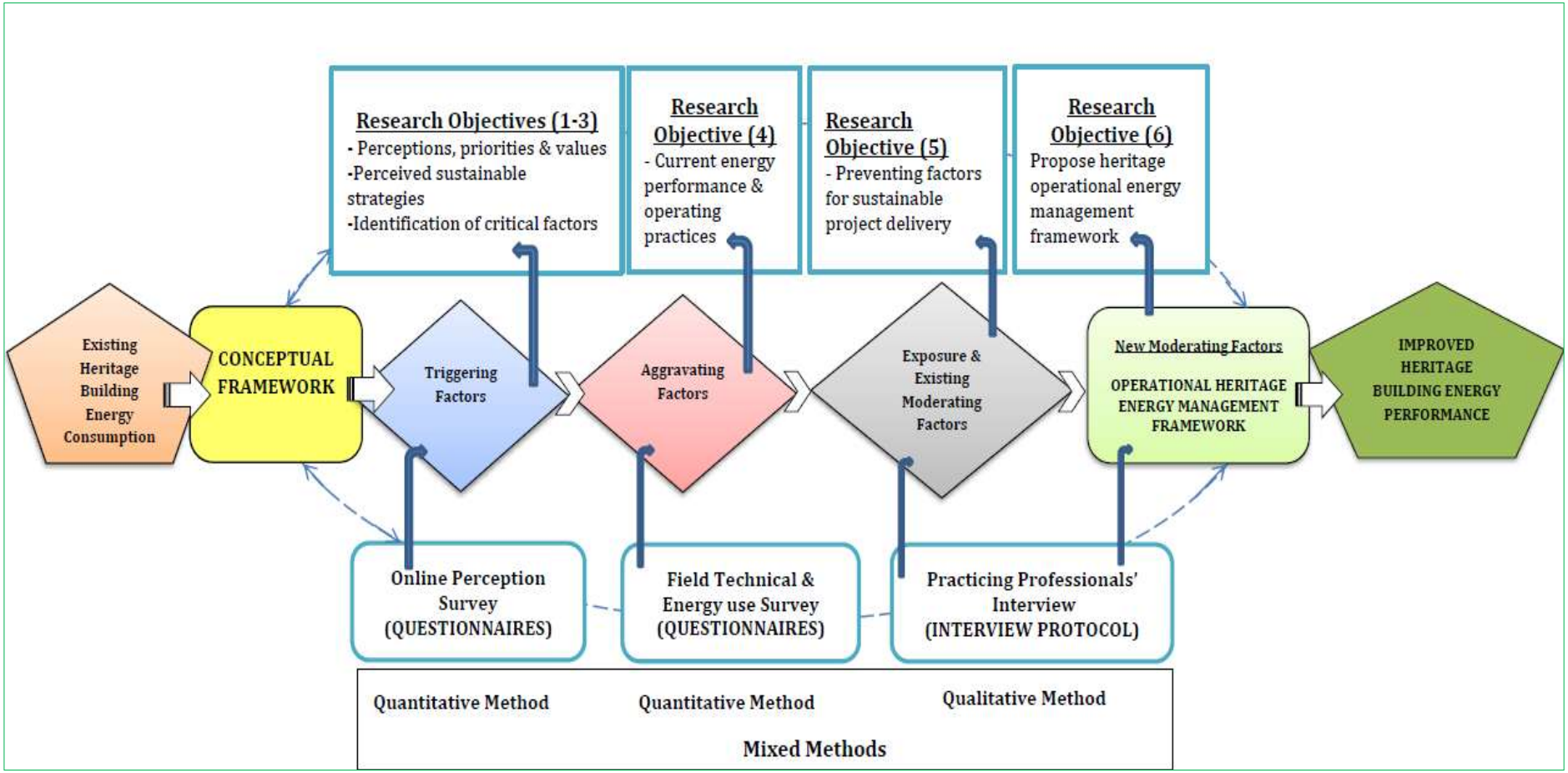

Figure 10.3: Methodology for the development of heritage strategic energy management framework.

Source: Study Author (2014)

10.4.2 The process of abstraction used in developing the framework

Cresswell (2002, p.273) suggested that when building a situation producing theory, information should be extracted and grouped in four levels from the most basic, uncomplicated data gathering level to the most sophisticated level. Cresswell's approach was used to establish the interrelationship of the subsystems showing the process of abstraction in developing the framework. The emerging themes from the findings of this study provided the representation of the critical factors impacting on energy. Figure 10.4 illustrates the procedure of the interrelating set of indicators responsible for energy consumption in the buildings. Several themes that emerged while analysing the data and triangulating the findings led to the gradual development of the framework; evolving from combining the illustrated diagrams developed from the analysis (i.e. Diagram A, B, C, D and F). Minor themes were subsumed within the major ones while layering and interconnection of the major and minor themes within the data take place. Thus, the analysis became robust as the researcher moved towards increasing levels.

According to Creswell (2002, p.273) layering is the representation of data using interconnected levels of themes forming the process of abstraction using diagrams. Thus, by linking the themes emerging from the analysis; the process progressively broadened the levels of abstraction leading to the process diagram relating input to outcomes in the proposed framework. The illustrative diagram presented in Figure 10.4 employs the concept of nesting systems to model the outcome of this process and to explain the interaction of the subsystems (Banathy, 1992).The nesting systems concept helps to view a heritage building system as a subsystem of a wider society primarily designed and influenced by the policies and values of the social context which it serves.

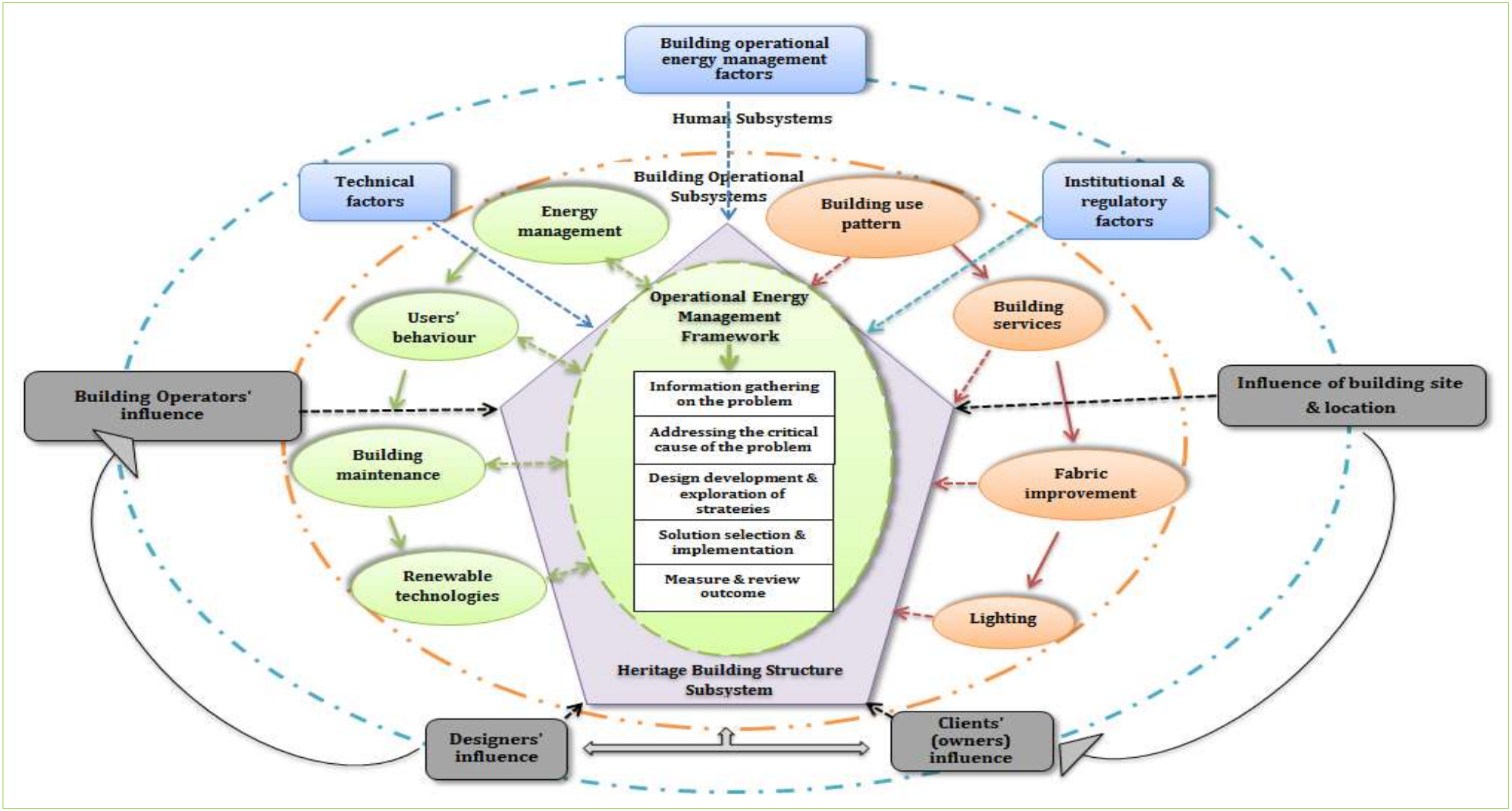

Figure 10.4: Diagram (E) Abstraction process of interconnected factors in the strategic energy management framework development
Source: Study Author (2014)

At the lower system level, heritage building structure subsystem is depicted as one influenced and operated by a larger building operational practices subsystem. This in turn is influenced by the larger social-economic and cultural systems referred to as human subsystem. The human subsystem is represented as a subsystem of the built environment completely dependent upon the functioning of the built environment.

Several authors (Meadows *et al.*, 1992; Clayton and Radcliffe, 1996; Brown 2001) opined that the socioeconomic system is a subsystem of the encompassing built environment. They argued that the fact that the current source of environmental sustainability crisis is as a result of the economic system often viewed independently of the built environment system. This is a critical factor and the beginning of understanding how individual, organizational and corporate concerns are perceived as fundamental to addressing energy consumption problems of heritage buildings.

In the dynamics of the three levels, the top-down (i.e. Human subsystem) influence on energy consumption is much stronger than the bottom-up influences (building structure subsystems). This indicates that any approach to reducing energy consumption in LCBs would require looking at area to address within the context of the operational practices of the building; implying paying attention to the next system level and the higher circumstantial level. Thus, it could be concluded from Figure 10.4 that the current approach adopted for energy use reduction of heritage buildings for decades is misdirected or overly subsumed in one direction. Meanwhile, the operational practice and management subsystem have been much underestimated by the concern for the thermal performance of the building structure subsystem. Thus, the process and adoption of this strategic energy management framework could bridge this gap.

10.4.3 Description of the framework

Figure 10.5 shows the proposed framework comprising of three (3) major phases. Phase I constitutes the planning and the project initiation which is the pre–conversion stage. Phase II constitutes the design development and implementation which is the conversion stage and phase III constitutes the use, operations and management which is the post-conversion stage. Phase II is where the proposed framework is situated comprises of components with different sections having logical steps to be taken in each phase. The expected steps and actions to be taken also comprise of a series of guidelines suggested within the components of the framework. The expected outcome and output of the framework comprise the long term goals expected from the application of the framework.

10.5 The Framework Components

The components of the framework are divided into five (5) parts, namely: (1) the focus; (2) the phases; (3) the components; (4) the expected steps and actions to be taken; and (5) the expected outcome or output of the framework. The focus of the framework is the design of existing LCBs to be converted to other uses and improvements of operational energy performance of existing reuse projects.

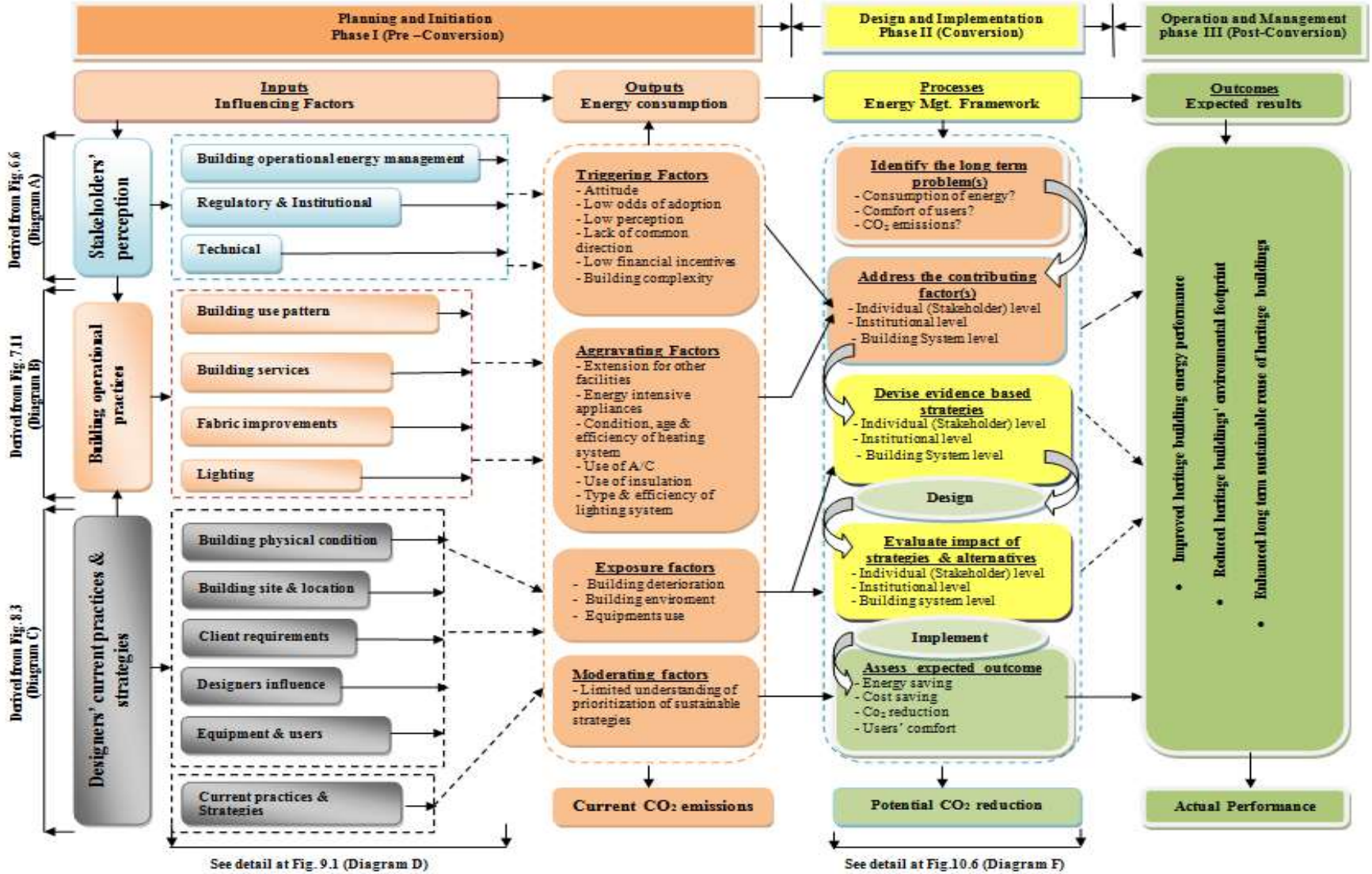

Figure10.5: The framework diagram relating inputs to outcome

The components are divided into five, structured and presented sequentially (Figure 10.6). Each component contains corresponding steps to be taken by the users.The approach of the framework follows after the systems approach which require integrated design procedures different from the traditional design/build procedure as it is necessary to examine disparate strategies, integrate and interrelate them from various subsystems that make up the whole systems to optimize energy performance and environmental impact reduction of the building through an iterative process. Systems approach, systematic development and appraisal of actions across all components is needed to achieve the final goal of the framework (i.e. Improving energy performance). Each subsystem needs to be given adequate attention so that the stakeholder involved would be able to work together as parts of the interconnected subsystems in the efforts to achieving the goal of the framework. The major components of the framework are fully discussed in the following sections and sub-sections.

10.6 Phase I: Pre-Conversion Stage

10.6.1 Step I: Identification of long-term problems

The long-term problems to be determined and addressed should primarily be: (1) energy use and CO_2 emissions reduction; (2) users' comfort; and (3) high building operational costs when considering sustainable reuse of LCB projects. Addressing these problems should be a priority at the beginning of every conversion project with none to be achieved singly at the expense of others. In addition, the decision of the problems would be addressed to more effectively manage energy use in the projects should also constitute

part of the deliberations between the client, designer (individual stakeholder) and the local planning (institutional level) authority.

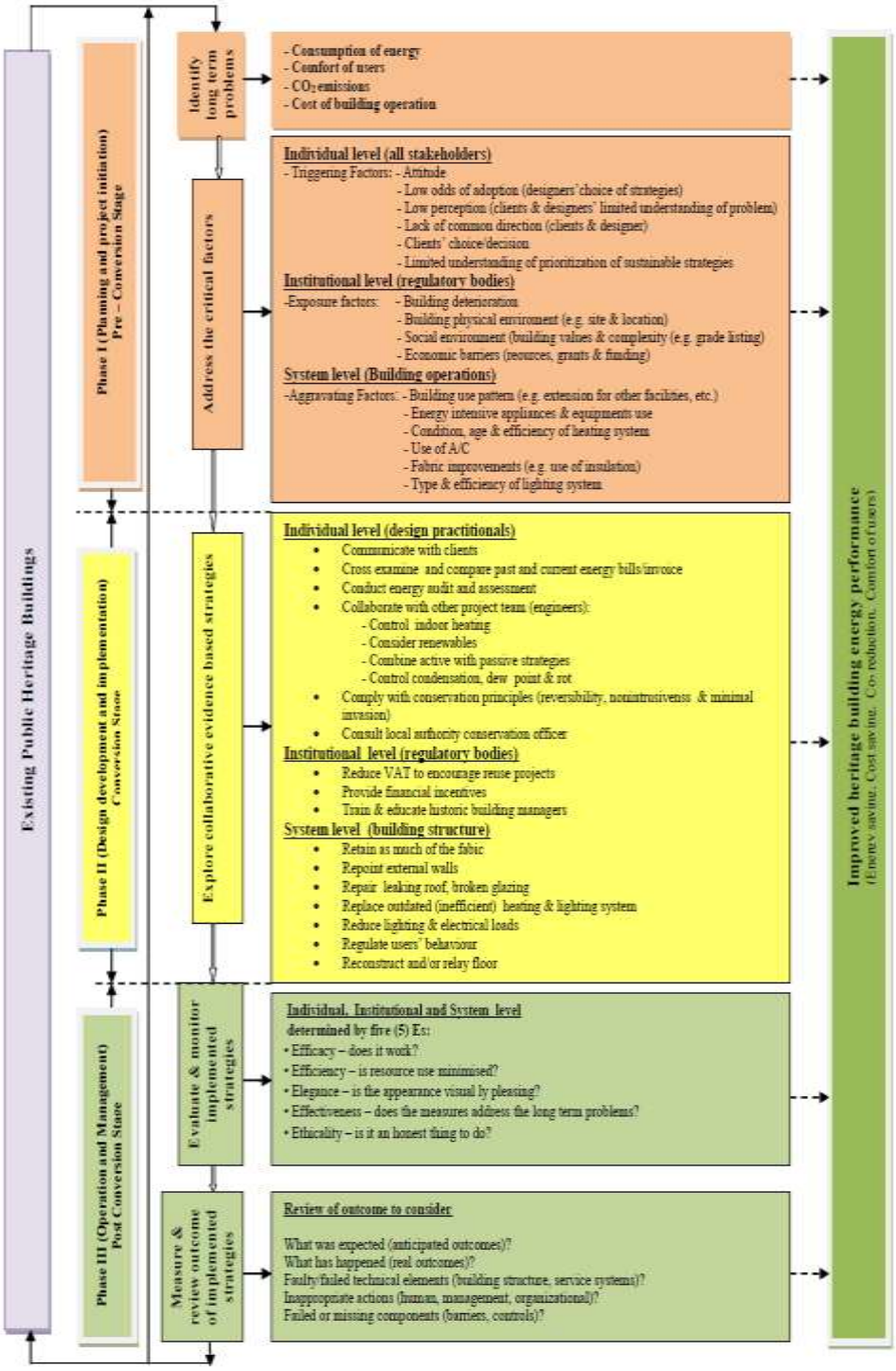

Figure 10.6: Digram (F) components of the strategic energy management framework

10.6.2 Step II: Identifying and addressing the critical (contributing) factors

Since the factors contributing to poor performance of many heritage buildings are numerous and multifaceted, they have been classified into four categories in this study, namely: triggering factors, aggravating factors, exposure factors and moderating factors (Figure 10.7). The influence of any of these factors on energy consumption in heritage buildings could be at individual, institutional and system level as indicated in Figure 10.6. Each factor is discussed within the framework as it relates to the relevant section of the components.

10.6.2.1 Triggering factors

Findings from this study show that energy use problems in LCBs originate from human subsystems which are perceived to trigger energy consumption in other subsystems. Observations show that efforts to reduce energy use in LCB projects are often targeted in the wrong direction because of inadequate understanding of critical human factors to be addressed. The human subsystems are critical human factors constituting the biggest challenge to achieving long-term sustainable reuse of LCB projects; therefore labelled as 'triggering factors'. Based on the findings presented in Figure 6.6 (diagram 'A') from the online perception survey; two factors, namely: building operational energy management; institutional and regulatory factors emerged constituting the highest loaded factors. Unless these factors are adequately addressed, the efficacy of other energy use reduction strategies may be neutralised by the effect of the triggering factors. The triggering factors encapsulate the extent of knowledge, perception and attitudes of the stakeholders to the long term problems.

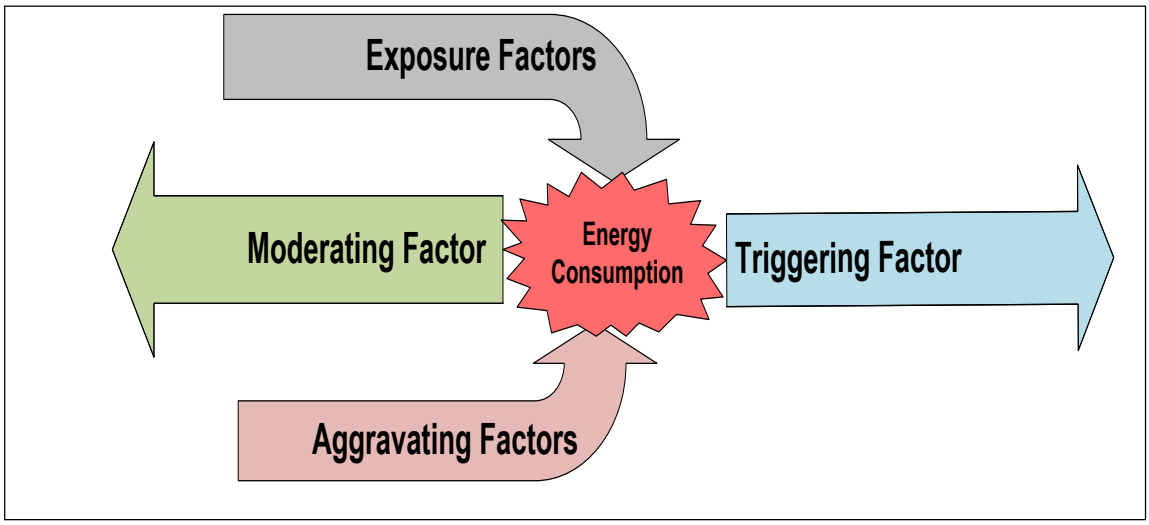

Figure 10.7: Interaction of identified and named critical factors
Source: Study Author (2014)

As obtained from the findings in this study, energy consumption in LCBs could be triggered at the individual or collective level. This could originate from users' energy use behaviour (bad housekeeping); lack of common direction (clients and designers; professionals and regulators); clients choice and decision (client's limited understanding and readiness to address the problem); low perception of the problem (designer's and regulators); low odds of adoption and wrong approach to energy use reduction strategies (designers' choice of moderating strategies); limited understanding of prioritization of the most sustainable options (strategies) to other inherent human factors that could impact the building's vulnerability to increasing environmental impact.

10.6.2.2 Exposure factors (Building structure subsystem)

The exposure factors are factors that predispose the buildings to harsh climatic conditions unnecessarily, due to lack of adequate protection from rain and especially driving wind. This is probably because of lack of clear, systematic and preventative maintenance strategy. The exposure factors are primarily linked to the institutional level (i.e. Building

owners/corporate organisations) and could largely be responsible for energy consumption of the building structure subsystems. Energy consumption of the building structure subsystems could also result from the building's physical environment (immediate site/surroundings and location within built environment) and social-cultural characteristics (building complexity and heritage values e.g. grade listing) of the buildings.

The exposure factors put the buildings at risks if neglected for a long time, which more often than not, results in the building's deteriorating and consequent higher energy consumption and inability to provide the level of needed comfort for the users. The high energy consumption could either result from dampness in the building or some cases from excessive air infiltrations beyond the permissible level of heritage buildings to breathe. Other exposure factors could also result from inappropriate use of energy consuming equipment and appliances for the building activity pattern.

10.6.2.3 Aggravating factors

The factors that tend to worsen or further contribute to higher energy consumption in the reuse of LCBs are named in this study as aggravating factors. These factors, primarily emanate from the building operational practice subsystem; an area of the whole subsystem that has suffered neglect from heritage building professionals, policy makers and scientific community. It is the subsystems that have received less focus, little attention and perhaps the subsystems aggravating higher energy consumption in the reuse of LCB

projects. Aggravating factors are due to operational policies that a building operator might have (or not have) or approaches used (or not used) in the course of operating or managing the building.

There are two levels of interventions that interact to form the context for addressing energy consumption resulting from aggravating factors. Based on the findings presented in Table 7.36, the two levels of interventions include firstly, the factors that are specific to building technical aspects. These factors require the design professionals' attention to the following energy performing indicators: the heating equipment, cooling equipment, efficiency of heating systems, age of heating systems, lighting systems, fabric improvements and renewable installation systems. Secondly, are those factors specific to building operational aspects which require the attention of building operators or facility managers in the following energy performing indicators: building use pattern, energy management strategy, operation hours, energy use awareness, the nature of energy management policy and building users' behaviour.

10.6.2.4 Moderating factors

Part of the critical factors identified and presented Table 6.31 of Chapter 6 of this thesis is named by the researcher as moderating factors. The moderating factors constitute the current approach of heritage professionals to reduce energy consumption in their projects. Based on the ranking of these approaches presented in Table 6.31 observations from the rank order in which these approaches are implemented indicate that the approaches adopted in current practice also form part of the critical factors to be addressed. To address this factor, a range of recommended strategies perceived by the stakeholders to

have successfully achieved energy efficiency improvement to a significant extent in their past projects as presented in Table 6.32 was suggested. These recommended strategies constitute the new moderating factors recommended in the proposed framework.

10.7 Phase II: Design Strategies Development and Implementation

This phase involves the design approach required at individual-level (human subsystem) with key steps for designers to explore collaborative and evidence-based effective strategies in order to moderate energy consumption in reuse of LCBs.

10.7.1 Step III: Exploring collaborative and evidence-based effective design strategies

Strategies recommended and discussed in this step represent the combination of findings from literature and appropriate strategies perceived by the stakeholders to moderate energy consumption in reuse of LCB projects. Some strategies may address several factors at the same time or separately depending on the project. A number of strategies could be combined to effectively address the problems; other cases might require new strategies to be developed, tested and guided in practice.

10.7.2 Strategies to Address at Individual Levels (New Moderating Factors)

Effective and sustainable energy solutions in the reuse of LCBs can be achieved through integrated and collaborative efforts among two key groups of stakeholders: (1) building owners, developers and managers (building operators) and (2) heritage building authorities. The strategies for the solutions involved requires not just a technical ability, but a combination of monitoring system, operational plans and top management efforts

to address a combination of individual-level (designers), institutional-level (owners, corporation, company, government and regulatory bodies) and system level (building structure) that interacts with either inhibit or enhance the desired outcomes (Figure 10.8). The procedure for individual-level (designers and facilities managers) is illustrated in an outline form in Figure 10.9 by a sequential description of the framework.

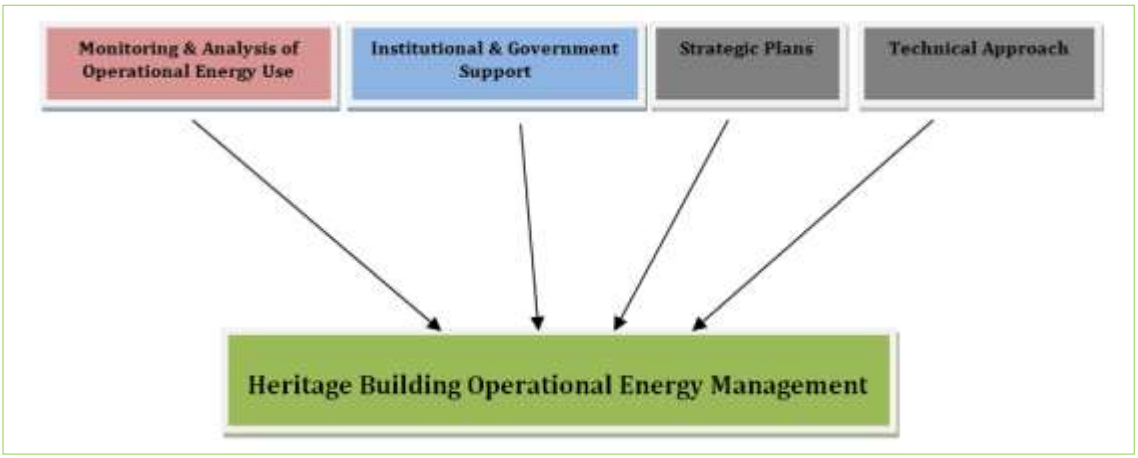

Figure 10.8: Requirements for heritage building strategic energy management

10.7.2.1 Building assessment based on activity or use pattern.

Buildings use energy at the rate dictated by the activity pattern within the space and comfort levels expected. This first approach to manage operational energy usage in conversion projects is necessary in order to review the significance, construction, condition, and develop a picture of the user or type of activity in the building.

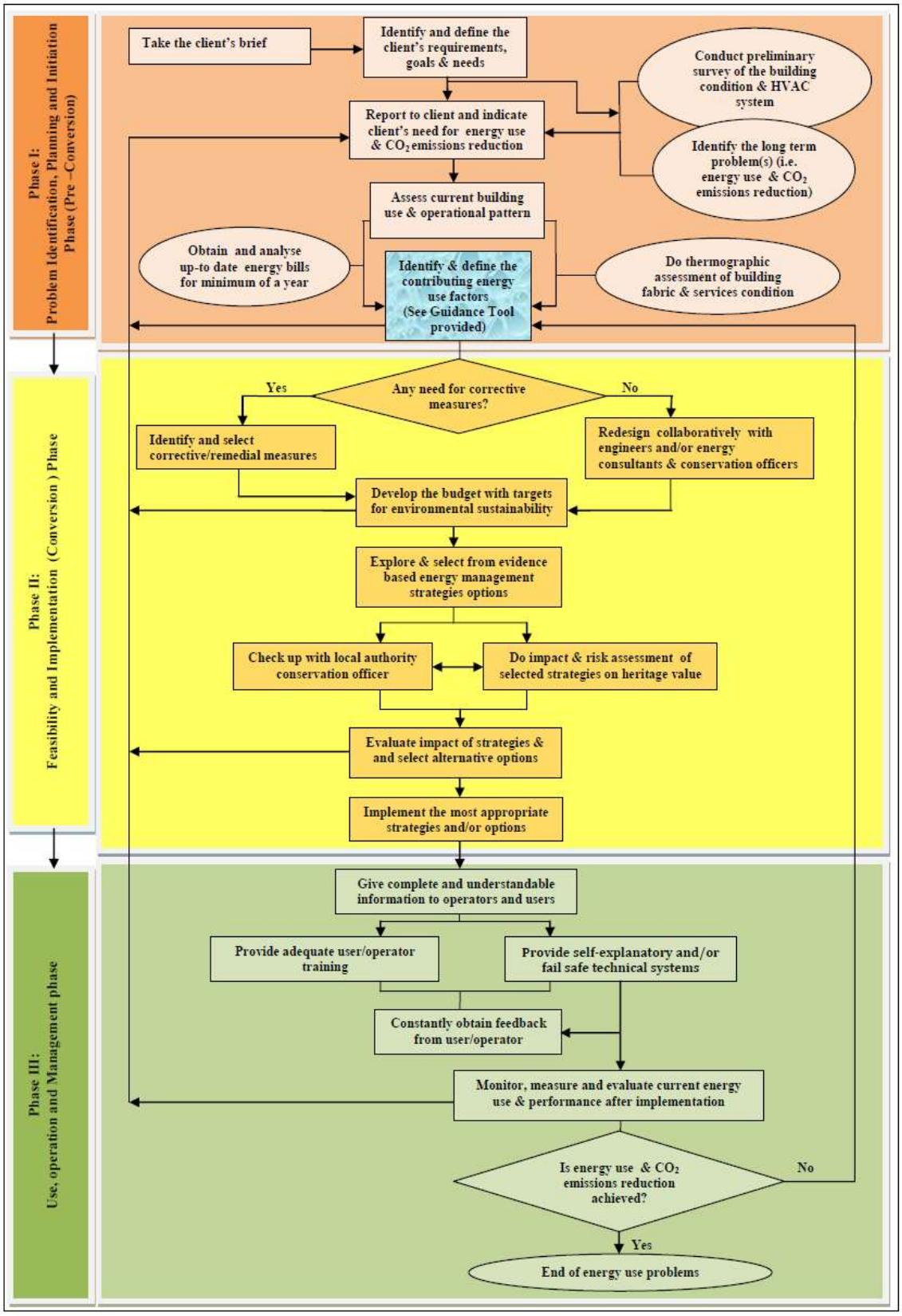

Figure 10.9: Flow chart of the strategic energy management framework

Key Actions (A)		Description (B)	Further Recommended Action (C)	Recommendations for Improved Energy Performance (D)
Identify the long term problems	(i) Conduct preliminary building condition and HVAC system survey	(a) energy use and CO_2 emissions reduction; (b) users' comfort; and (c) high building operational costs	(i) Communicate with clients on building and HVAC system condition (ii) indicate client's need for energy use and CO_2 emissions reduction	These problems should be identified at the outset of the project with none to be achieved at expense of others. The long-term problems should constitute part of an ongoing discussion between the client, designer and the local planning authority before the commencement of the project for effective management of energy use.
Identify and define the contributing energy use factor(s)	(ii) Understand the building and assess the use pattern (iii) Undertake an energy audit (iv) Communicate and share goals for low energy use with the clients (v) Set energy performance targets and benchmarks before design	**1. Building use pattern** (a) Buildings with extension for other facilities (d) Buildings used for commercial food preparation. (e) Buildings used for arts & entertainment (g) Buildings used for retail (f) Buildings used for multipurpose function	(iii) Obtain and analyse up-to date energy bills for minimum of a year (iv) Diagnose infiltration and service conditions with technologies such as infrared thermo graphic inspections to detect where improvements can be made (v) Redesign collaboratively with engineers and/or energy consultants & conservation officers	Diagnose existing infiltration conditions with technologies such as infrared thermo graphic inspections to detect where improvements can be Do thermographic assessment of building fabric and services condition **1. Options for redesigning:** Option I: Optimize space use Option II: Alter the layout Option III: Create heating zones Option IV: Add new spaces Option V: Create buffer zones Option VI: Integrate renewable technologies
Explore collaborative evidence based strategies	(vi) Incorporate energy management strategies during the design (vii) Engage collaborative teams to explore collaborative evidence based strategies (viii) Prioritise strategies and make selection based on suitability, achievability and energy savings (ix) Carbon impact and risk assessment on selected strategies (x) Consult and verify with local authority conservation officer, planners and building control officers (xi) Design the interior space of the building integrating the selected strategies (xii) Obtain necessary permissions and implement strategies	**2. Services:** (g) Heating equipment (h) Efficiency of heating system (i) Heating strategy (j) Heating system age	(vi) **Improve and/or replace existing heating systems:** Several options to address energy consumption through the operating heating systems depending on available funds.	**2. Options for service upgrade and improvement** Option I: Upgrade by increasing the capacity of existing heating system. Option II: Installing a new and higher capacity system to replace the old inefficient system. Option III: Replacing electric heating systems to gas fired heating systems. Option IV: Install underfloor heating where the interior space has minimum partitioning for maximum performance of new function.
		(k) Cooling equipment	(vii) **Consider intelligent use of cooling systems:** Activities requiring cooling systems such as museum, theatres and dance halls	**3. Options for the use of cooling systems:** Option I: Substitute ceiling fans to reduce the use of air conditioning system Option II: Reduce operating hours of the air conditioning system to reduce energy consumption Option III: Increase temperature
		3. Fabric improvement (l) Maintenance (m) Upgrade (n) Insulation	(viii) **Retain as much of the historic fabric as possible** The safest rule is to retain as much of the heritage fabric as possible by giving minimal disturbance to the existing fabric and at conservation areas where insulation can be applied because limited.	**4. Other options of improvements to building fabric** **Floor** Option I: Most heritage floors are either solid or suspended timber floors. Some may need to be repaired and/or replaced depending on their conditions during refurbishment and/or reuse projects. Option II: A new reconstructed floor system to improve thermal performance introducing underfloor heating system with added floor insulation offers the most effective means to reduce heat loss through the floor **Roof** Option I: Roof repairs and maintenance should be the conducted as it offers the most practical area and opportunity to reduce heat loss Option II: Consider applying suitable insulation when undertaking roof works to listed church buildings to improve insulation standard of the building. **Window** Option I: Repair and renovate for effective performance. Option II: Consider secondary (additional) glazing system in the inner side of the opening where the window is renovated
			(ix) **Repoint external wall:** Available technologies using infrared thermo graphic inspections will detect areas where unnecessary draughts (but with a degree of ventilation vital for the church fabric put into consideration) can be minimized.	
		4. Lighting (o) Type of lighting system (p) Efficiency of lighting system	(x) **Reduce lighting loads** Some changes and improvement to more efficient lighting systems can be achieved to reduce lighting loads by considering various retrofit options for the following lighting systems:	**5. Options for Reducing Lighting loads:** Option I: Incandescent lamps: Old lighting technology use of incandescent lamps is should be substituted with Compact Fluorescent Lamps (CFLs) for maximum efficiency and reduction in the amount of artificial lighting energy consumed. Option II: T-12 fluorescent lamps: The use of T-12 fluorescent lamps should be replaced with energy efficient T-8 and T-10 to reduce fluorescent lighting energy consumption by as much as 10%. Option III: High Intensity Discharge (HID): The major advantage of this type of light is their long life and energy efficiency compared to incandescent lamps. Option IV: Light Emitting Diodes (LEDs): They have the advantage of producing very low power consumption and the light emitted from them is directional with virtually no heating effect compared to incandescent, halogen, or fluorescent lights with some directional lights whose lights must be redirected using secondary reflectors.
			(xi) **Control the use of light** Three combinations of lighting controls should be considered in reuse of listed churches for significant reduction in electricity consumption.	**6. Options: for Lighting Controls** Option I: Manual controls should be used in spaces within the building that have access to daylight and accommodate different tasks. User behavior control is required to turn off the lights whenever they not needed. Option II: Automatic controls should be used in less used (unoccupied) spaces such as storage areas, offices, etc. Option III: Automatic dimming controls should be used where daylighting is inadequate to complement light levels. Option IV: Scheduling controls should be used to activate, extinguish, and/or adjust lighting on predetermined schedule.
Evaluate & monitor implemented strategies	(xiii) Give complete and understandable information to operators and users (xiv) Constantly obtain feedback from operator	**5. Energy management** (q) Energy management awareness (r) Nature of energy management policy (s) Energy management policy	(xii) **Monitor and manage existing energy usage** (xiii) **Set realistic target and compare your energy performance with similar building use pattern**	**7. Options: for energy management** Option I: The simplest method is to benchmark consumption against energy saving benchmarking available for similar type of building by regularly studying meter readings and bills to compare performance annually against benchmarks. Option II: Installing smart meters equipment and other building energy management systems (BEMS) to keep track of how, where and when energy is mostly used and to identify any waste. Option III: Realistic target should set on monthly bases by motivating the staff through incentives, daily announcement, written it, making it a desktop background screen saver and giving the feedback to the staff. Option IV: Meter reading on electricity, gas and water should be a routine with constant tuning of the systems to optimal performance continually after meter readings to adjust air temperature and water temperatures.
Measure & review outcome of implemented strategies	(xv) Monitor, measure and current energy use and performance after implementation	**6. User's behavior** (t) Frequency of turning off equipment/appliance	(xiv) **Establish behavioural change campaign to regulate users' behaviour** (xvi) **Provide staff training and supervision on appropriate use of equipment and appliances**	**8. Options: for behavioural change to regulate users' behaviour:** Option I: Providing information on energy use reduction on notice boards, stickers on equipment and/or appliances. Option II: Use of visual and written materials. Option III: Use of posters and plasma screens placed in strategic places. Option IV: Spending time talking to the staffs on one-on-one and/or group basis according to their area of operations. Option V: Public display of utility invoices. Energy bills posted monthly on a notice boards and/or bulletin will stimulate interest in reducing energy usage, operation costs and CO_2 emission in a drastic way. Option VI: Adequate staff training, orientation and supervision on keeping equipment and appliances off after use, how new control systems, equipment and/or appliance function, maintained and save energy.

Table 10.1: Guidance tool for the users of the framework

This step should be done in an adequate and effective manner so as to develop an operational energy profile of the building based on the hours of use per day/week/month and the type of appliances and equipment that are used or will be used within the building. Generally, by liaising with LCB owners and users, it may be possible for them to provide adequate information on energy demand the building might require for its operations for peak and off-peak usage levels. For listed churches converted to different uses, the energy usage levels will vary because energy demand is mainly based on the building activity or use pattern. Buildings use or activities are namely; for community uses, commercial food preparation, arts and entertainment, retail services, music and training, museum multipurpose uses and dual purposes (i.e. Worship and community activities).

10.7.2.2 Establish an energy baseline assessment

The purpose of establishing an energy baseline, is to be able to outline the current energy performance of the building and to provide the basis from which to measure change. It serves as a reference point to devise integrated energy management strategies. Baseline data could be obtained from energy invoices, and utility providers' reports which should include at least twelve months to account for seasonal variations. The assessment would facilitate the identification of the largest energy users and best opportunities for reduction.

10.7.2.3 Undertake an energy audit

Operational plans for managing energy use in conversion projects, should draw on existing energy use data from the building by undertaking energy audit, in order to incorporate the information obtained in the planning. Different levels of energy audits could be carried out. For the necessary details needed to develop a business case for

energy improvements, collaborating with consultant engineer would be required at this stage, in order to ensure critical areas of energy use are not overlooked. Areas to audit for listed churches should include the type of heating and cooling systems and frequency of use, efficiency and age of heating systems, strategies of heating required or currently in use. For churches converted to community functions, the best approach is to look for areas where continuous heating strategy is adopted. To minimize those areas, spaces required for user comfort could be provided and insulated spaces with controlled ventilation.

10.7.2.4 Communicate and share goals for low energy use with the clients

Designers and clients should come to a consensus on specific shared goals for energy use reduction after the appropriate energy audit has been conducted and the report written to show areas of managing the energy use during building operations through the design. Specifically, the goals should be tailored to achieving low operational non-renewable energy use, reduction in environmental impact and achieving occupant comfort or users' satisfaction. The importance of communicating with the owners or clients at this stage, is very crucial, in order to provide adequate advice on possible energy efficiency intentions, as well as seek the clients' input or support.

10.7.2.5 Set energy performance targets and benchmarks before design

In most conversion projects, targets for energy use reduction are not often considered important. In terms of energy management, target could be made for a forecast of over a twelve month period of the expected utility consumption (e.g. The electricity and gas for heating, cooling and lighting loads). Target could also be set for the CO_2 emission reduction to be achieved yearly. Developing and setting performance targets from the

outcome of the energy baseline assessment and audits will reveal areas that can further be explored to achieve energy savings. There are several targets set for existing building projects imposed by the government and other authorities.

The general performance target for existing buildings energy consumption is to achieve a 55-65 GJ/m^2. Although heritage buildings might not be able to meet the targets set for modern buildings, however, the existence of targets allows room for performance evaluation after project delivery; and also in comparison to be made of actual performance against target. Similarly, having energy saving benchmarking incorporated into the decision will facilitate comparison of performance with like-for-like with other similar building use and size. Without benchmarking, it will be impossible to ascertain if energy use is high or low, frugal or wasteful.

10.7.2.6 Incorporate energy management strategies during the design

It is crucial that a more integrated approach be adopted early in the design phase. This, in essence, is to ensure that energy management goals are linked to and support the overall operational business plan. This should allow energy, users' comfort and sustainability to be more fully integrated to the benefit of the owner, users and other stakeholders. It will also facilitate a broader life cycle assessment of construction and equipment selections, partially addressing the tendency to base all decisions on first cost. The use of control system can be integrated into the design depending on the size of the project as this can significantly reduce energy wastage. The use of intelligent systems like sensors to detect and control artificial light and variable speed controls on pumps and fans can be specified in the design to save significant amount of energy. Where funds are available, a BMS

(Building Management System) can be specified for optimum operation and minimal energy use. However, if costs are prohibitive, then most economic measures could be specified.

10.7.2.7 Engage a team of heritage building experts in collaborative exploration of effective strategies

One of the most effective strategies in design for low energy use in conversion projects is to assemble and integrate a team of knowledgeable and experienced heritage building professionals who can contribute to the various technical aspects of the work so as to provide a comprehensive approach to the project. With the establishment of energy targets within the design goals a range of strategies necessary to achieve the goals should be explored and considered. Selection by collaboration and partnerships with other professionals should also be carried out to explore strategies from pooling and leveraging of expertise advice. This would foster synergies and benefits from identifying energy improvement creativities and also facilitate lessons learned from other similar projects.

Consideration should not only be given to one strategy alone or competing strategies. Rather should also be given to combinations of strategies with detailed investigation of the real benefits; and opportunities of improving energy performance based on the return they offer against targets; and also the feasibility or practicality of their implementation. An important area of effective collaboration at the design level is to engage the conservation officers and local planning authorities; to brainstorm the options or possible alternatives for energy management; and to be able to explain the rationale

for the strategies and the level of information that may be required for permission. This could reduce the level restrictions and sometimes opposition to effective strategies often encounter by the designers with the conservation officers at the approval level.

10.7.2.8 Prioritise strategies and make selections based on suitability, achievability and energy savings

The strategies should be ranked in order in which it will have less impact on the heritage buildings. This should be done to prevent jeopardising the historic significance of the building for energy refurbishment actions.

10.7.2.9 Conduct impact and risk assessment of selected strategies

Having identified and selected the strategies to be adopted, an impact and risk assessment should be made in order to determine the short and long-term impact of the proposed strategies of heritage values using the principles of reversibility, non-intrusiveness and least intervention on historic fabric. Another assessment could also be carried out on the basis of non adoption of strategies to weigh the benefits of not managing energy use against any harm that might be of significance to the historic asset. A proposed risk- benefit- matrix that could be adopted to identify possible risks against the benefits any strategies might pose is presented in Figure 10.10. Strategies involving low energy savings benefit or and a high risk to heritage value, marked in red require caution and some level of restriction should be applied. Whilst low-risk strategies and high benefit of energy savings marked green should be considered as a win-win situation. Meanwhile,

strategies involving medium risk and medium to high benefit marked in yellow would need some attention and further consideration.

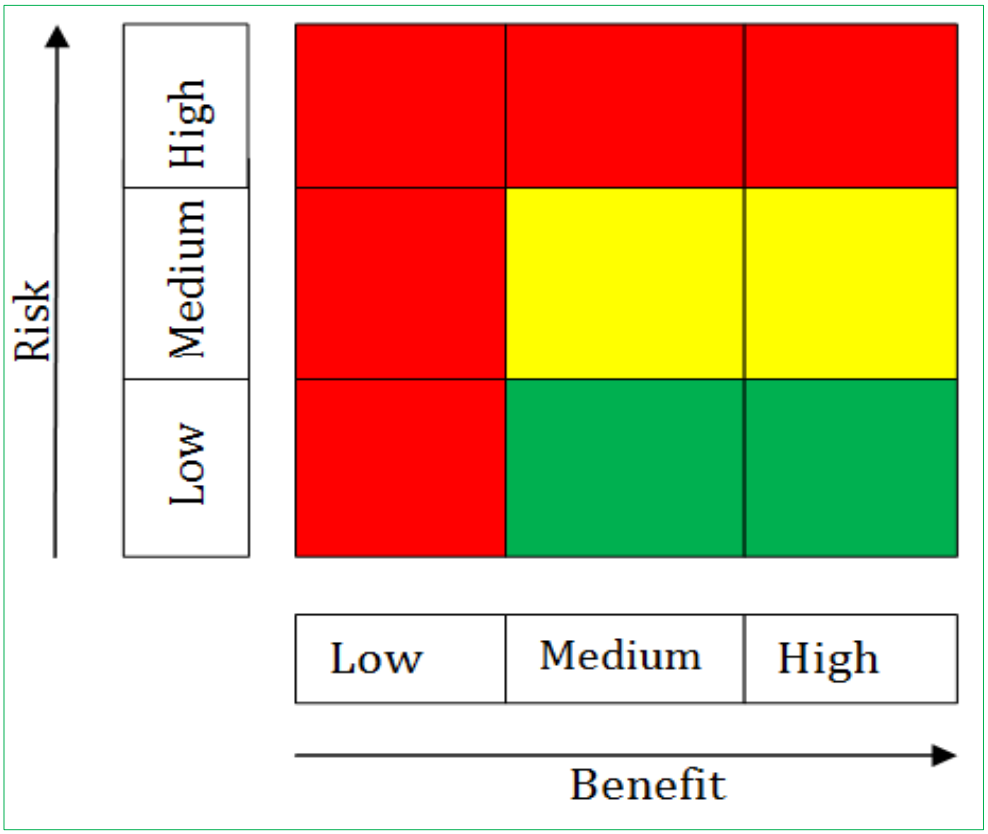

Figure 10.10: Matrix for risk – benefit assessment
Source: Brostrom and Svahnstrom (2011)

10.7.2.10 Consult and verify with the local authority conservation officer

Consultation with the local authority conservation officers is essential as this would help to identify and classify what level of constraints are expected, restrictions that may apply and opportunities available.

10.7.2.11 Design the interior space, integrating the selected strategies

Churches are characterised by high volume space and large floor area. Depending on the type of activity pattern of the conversion project, the internal areas should be designed to

reduce the volume and space areas to be heated. This could be in form of partitioning or subdivision of the space to create smaller spaces that could be used to create heating zones. This will enable a reduction in energy consumption and gross energy use in some cases as the client can heat the zones they needed to use and not the entire areas they are not using. This approach would allow for better control of the heating the spaces. This can best be achieved by recommending underfloor heating in replacement of the perimeter wall heating.

Another approach to design could be to insert additional floors for other users. That means a larger volume of space could now be used by two separate organisations one on the ground floor and the other on the additional floor. This would reduce the volume of space to be heated at a time and thus reduce the loss of heat into roof spaces. However, caution needs to be applied as uninformed alterations can produce big potential implications for humidity as it might take a long time for the problems to show (e.g. The long-term effects of condensation on roof timbers).

10.7.2.12 Obtain necessary permissions and implement strategies

After consultation and the design of the interior space, the next step before implementing the strategies already verified and agreed with the local authority conservation officer is to obtain necessary permission or consent from the local planning authority. This should include the development proposals, the change of use and the strategic energy management plan which should be based on the constraints on use and alterations clarified with the local planning authority.

10.7.3 Strategies to address at institutional level

Basically, strategies to be employed at this level will address three groups, namely; (1) owners or clients of LCBs; (2) regulatory bodies; and (3) government

10.7.3.1 Owner/clients of LCBs

- Develop and execute a written energy management policy plan and effective strategies or methods for disseminating and translating it into actions for building users. This is to be submitted as part of requirement for planning approval.
- Appoint energy manager as the building operator to be responsible for monitoring and controlling energy consumption and make this role should be specified requirement in the job description. The individual could the assistant manager in-charge of every energy invoices. It would be necessary for the individual to utilise the operation manual for energy consumption and to keep records of changes in energy use and give feedback to the rest of the staff. Whilst this strategy cost almost nothing, it could be responsible for most reductions in energy use and cost. This strategy should be included as one of the organisation's energy management policies and goals as an effort to lower energy use, costs of operation and commitment to a reduction in CO2 emissions.
- Search and switch to the least expensive energy provider. It is important to consider choosing the type of energy that is less expensive in operating the building and to continually seek to switch to the least expensive ones. Terms and prices changes depending on energy providers in a deregulated market. Different provider offers different types of rates. For instance,

money could be saved with time-of-use electric rates or purchasing contracts of fixed-price fuel. Whatever the choice made in the type of energy purchased there is a need to continually search and switch to energy providers with better deals.

- Adopt an energy efficiency, purchasing policy. There will always be need to replace energy using systems in the building use for community purposes. Needs may arise to replace motors, air conditioners, refrigerators, freezers, coolants, dishwasher, heating systems, lamps, ballasts, appliances, office equipment, etc. The premium cost of more energy efficient equipment is usually justified when purchasing replacement equipment. Caution should be applied in shopping for cutting-edge technology appliances and equipment without a track record of measured performance. A way of managing energy use is to adopt a policy of purchasing energy efficient products.
- Include energy costs in leasing space. Some of the building tenants are not often metered separately or charged directly for their energy use. This implies that the benefits of savings, perhaps does not go to the building owner making the investment and that billing practices can mean tenants do not pay specifically for the energy used. This is a potential barrier to energy use reduction as the operating conditions and energy consuming decisions are not often directly influenced by direct costs to the owner. Thus, including energy costs in leasing the building would provide a sense of responsibility to the tenants in reducing their energy use.

10.7.3.2 Regulatory bodies

- Encourage an effective and evidence-based interventions that demonstrate energy management strategies suitable to heritage buildings with the potentials of carbon emission reduction. To achieve this, some circumstances will dictate the need for flexibility by the local planning authority.
- Provide more financial incentives and funding to encourage energy management in the reuse of LCBs.
- Train and educate historic building operators or managers in energy efficient operations and management practices.

10.7.3.3 Government

- Government will need to encourage and accelerate the implementation of best practices by adopting supportive policies in the aspect of reducing and removal of VAT on reuse of LCBs.

10.7.4 Strategies to address systems-level

10.7.5 Building strategic practices

Essentially, various approaches are required at systems-level (building operational practices and building structure) to provide the users of the framework with meaningful information on how to effectively manage energy use and improve performance as a means of moderating energy consumption in reuse of LCBs identified from the findings of the research. The potential impact and benefits for minimal financial investment and impact on heritage building this step has made it very important. Buildings consume energy at the rate dictated by how they are operated in the course of usage. Thus, there is the need to reduce the demand through organizational and operational process. Positive

changes by individual operating the building will reduce its energy consumption and carbon emissions.

10.7.6 Facility manager

10.7.6.1 Monitor and manage existing energy usage

The panacea for high energy consumption in operation of reuse of LCBs is to monitor and manage existing energy consumption during use of the building. Thus, an important assignment for the building operator. It is necessary that churches used for community purposes to establish existing energy use patterns by having a measure of how the systems and the buildings are operated and identify where there is high energy usage. Limited knowledge in this area would make it difficult to effectively manage energy use for the building operation. Monitoring existing energy use is the key action for building operators to short–term energy management with potential to yield the basic information for long term-term management and there should be a continuous process of measuring energy use and making the regular comparison.

Listed Churches are 'hard to treat' buildings therefore, the simplest method of energy monitoring for listed churches is to benchmark consumption against energy saving benchmarking available for church. It is paramount to regularly read, study and keep a record of meter readings and energy bills to compare performance annually against benchmarks. Another least invasive method of energy monitoring for these types of buildings could take a form of smart metering by installing smart meter equipment and other building energy management systems (BEMS) to keep track of how, where and when energy is mostly used monthly and to identify any waste.

The benefits of this technology are that a monthly or even daily metering is possible and the outputs can be visible to users who can see the effects of their actions in real time. It can also generate automatic reports on energy use; reduces the time for manual meter readings; and complement benchmarking as an essential energy management tool. However, where cost is prohibitive, a continual manual monitoring would mean observing and keeping records on energy use and the cost and demand charges on energy bills. This would aid in spotting billing errors, provide feedback on change of existing practices, implementation of new equipment and techniques, identifying where progress is made and help to determine if actions to reduce energy use are achieving results.

10.7.6.2 Encourage and establish positive users' behavioural for energy reduction

The building operator should not only rely on technology and systems for energy use reduction, but could involve the users (i.e. The staff) in the practice of realizing and making energy saving as part of their duty and responsibility. This can be done by approaching them in an educational and systematic way on what to do. Basically, this can be achieved by involving and enlightening staff interacting with the building, the equipment and appliances used in the operation of the building, the building operators would likely discover fall in energy consumption in areas that they might not otherwise have found out before. Approaches that could be used to regulate users' behaviour should include a broad range of informational/educational methods and materials, dissemination channels, and avenues to communicate practical energy savings tips such as:

- Providing information on energy use reduction on notice boards, stickers on equipment and appliances;
- Use of visual and written materials;

- The use of posters and plasma screens placed in strategic places;
- Spending time talking to the staffs on one-on-one and group basis according to their area of operations within the building; and
- Public displays of utility invoices. More often than not, it is assumed by operators of churches used for community purposes, that these buildings also use almost equal energy as their homes. If energy bills are posted monthly on a notice board and bulletins, it may stimulate notable interest in reduction in energy usage, operating costs and CO2 emission in a drastic way.

10.7.6.3 Set realistic target and compare energy performance with similar building use pattern

As much as designers need to set targets for energy use reduction, similarly, it is also important that building operators set achievable targets; and include it in the day to day building operations. The target could be for energy use reduction on monthly bases and could be achieved by motivating the staff through daily announcement, writing it, making it a desktop background screen saver and giving the feedback to the staff. Additionally, the ability to benchmark energy performance against other similar building use pattern and size could provide building operators with useful information regarding energy savings opportunities that has not been realized. The extent of energy reductions made in other buildings can be used as a realistic measure of the benefits that should be included in payout calculations.

10.7.6.4 Adequate staff training and supervision on appropriate use of equipment and appliances

The roles that staff plays are very important part of any energy management strategy; their involvement in energy use reduction is a key to success. Listed churches converted

to community uses are buildings that use more energy as they make more use of equipment and appliances than before the building was converted. The use of office equipment and plug loads have increased significantly in the reuse of LCBs converted to community uses as a result of building use pattern. This involves the use of office equipment and plug loads such as computers, printers, photocopiers, up to ten (10) refrigerators use in a single building, beer coolers, ice machine, tumble dryer, washing machine, freezers which could account for a significant proportion of energy consumption required to operate this equipment and associated loads on heating and air conditioning and/or cooling systems. Therefore, it is essential to ensure that plug load energy use is put into consideration and closely monitored.

In order to reduce equipment and plug loads, adequate knowledge and thorough understanding of staff in the operation of systems, equipment and appliances is very critical in managing the energy use of equipment and plug loads. Hence, the need for proper and staff training, orientation and supervision on energy saving practices such as; keeping equipment and appliances off when not in use, how new control systems function and save energy and how new system, equipment and appliance is maintained maintenance is required to ensure efficient operation. In a situation where an appliance is inefficient, greater savings can be made by replacing it with a more energy efficient type.

10.7.6.5 Make meter reading the first and the last assignment daily

It is good practice to make routine meter reading of electricity, gas and water the first and last assignment daily. Hence, energy consumed for electricity, water and fuel used overnight can be easily be determined and monitored. High water use could be as a result

of leakage. On the other hand, high electricity consumption could be due to outside lighting, refrigeration, appliances left mistakenly on overnight, lights in vending machines and other controllable loads. While on the other hand, excessive gas use could result from unnecessarily too warm interior temperatures and because the clock thermostat may not be saving as much as expected on energy and cost as it should. Thus, building operators need to understand how to control systems for optimal performance continually. This is essential after meter readings in order to adjust the water and air temperatures.

10.7.7 Design professionals

It is worth noting that during the design development, a range of strategies aimed at building structure and its services should be generally acceptable, not conflicting with conservation philosophies while taking into account the unique historical and cultural values of the building. A review of literature on heritage building systems and synthesis of research findings from this study revealed that approaching the building fabric first would need to be applied with caution because of the architecturally significant features of listed churches. Importantly, the designers would need to put this into consideration when employing systems-level strategies recommended for building structure subsystems.

10.7.8 Systems improvement

10.7.8.1 Improve or replace existing heating systems

Generally, listed churches often have outdated and inefficient environmental control systems before they are converted to other uses. This makes space heating become more

responsible for high energy use and carbon emissions. Changing the building use pattern to community uses means energy usage would increase thereby making room for opportunities for the existing systems to be considered for upgrade to address high energy consumption. Several options to address energy consumption through the operation of heating systems depending on available funds as follows:

- **Option I:** The upgrade can take the form of increasing the capacity of the existing heating system. However, the challenge of increasing the capacity of existing heating system is that as changes is now made to the building use pattern and the building is now used more frequently because of its new function, more energy will now be used and operating cost will also become higher.
- **Option II:** Considering installing a new higher capacity system to replace the old inefficient system. However, to manage energy use more effectively for a new use of the building and for improved energy performance, the appropriate option, perhaps might be to replace the existing with system with a new and higher capacity for efficiency.
- **Option III:** Effectively managing energy use could also be achieved by replacing electric heating systems to gas fired heating systems.
- **Option IV:** Another available option that would increase heat output within the large voluminous space in listed churches is to provide underfloor heating, especially where the interior space has minimum partitioning for maximum performance of the new function. Underfloor heating would introduce a very large warm radiant surface heating into the space close to the building users with significant improvement for thermal comfort; and as well reduce the effect of buoyancy due to the stratification of warm air characterize within the church heating. However, underfloor heating installation would require taking up the

existing floor and replacing with a new floor with the additional benefit of introducing rigid insulation board and another new floor. Possible constraints to underfloor heating would be if there are graves underneath the existing floor of the building or if the floor construction is made of stone which could be damaged making replacement difficult or seemly impossible task.

10.7.8.2 Consider the intelligent use of cooling system

Some community uses of historic churches require cooling systems for their operation. Such uses include museums, theatres and dance halls, etc., and perhaps would probably consume more energy than other similar size buildings with different use pattern. An efficient use of cooling system will be to reduce the operating hours of the cooling system. Where air conditioning is used, turning it down by 1 degree could result to an estimate of 5% energy savings as a result of 1 degree change.

10.7.8.3 Reduce lighting loads

Studies have revealed that about 30% of energy consumption in churches relates to lighting systems, making lighting to be the second principal electrical load in these buildings. Reducing artificial lighting provides an achievable option in conversion of listed churches for community uses considering the limit of other strategies owing to the architectural significance of the building. Hence, making some changes and improvement to more efficient lighting systems can be achieved considering various retrofit options namely;

- **Compact Fluorescent Lamps (CFLs)**: Substituting the oldest lighting technology, use of incandescent lamps which is the least energy-efficient and least

efficacious with Compact Fluorescent Lamps (CFLs) for maximum efficiency and reduction in the amount of artificial lighting energy consumed.

- **T-8 and T-10 Lamps:** The use of T-12 fluorescent lamps should be replaced with energy efficient T-8 and T-10. Although T-8 lamps could be more expensive, however, they can provide 98% as much light as with less use of energy, of about 40% when installed with an energy-saving electronic ballast. The benefits of installing it with energy-saving electromagnetic ballasts is that it can reduce fluorescent lighting energy consumption by as much as 10%, which would be a significant reduction of energy consumed from lighting systems.
- **High Intensity Discharge (HID):** As the use pattern of reuse of listed churches varies considerably compared to worship use, the use of High Intensity Discharge (HID) lighting provided by mercury vapour, metal halide, and high-pressure sodium lamps may become necessary for certain activity within the building. The major advantage of this type of light is their long-life energy efficiency compared to incandescent lamps.
- **Light Emitting Diodes (LEDs)**: The use of Light Emitting Diodes (LEDs) could also reduce significant amount of energy consumed in the reuse of LCBs as they are fast evolving light technologies and option that are more efficient than incandescent and most halogen light sources. They have the advantage of producing very low power consumption and the light emitted from them is directional with virtually no heating effect compared to incandescent, halogen, or fluorescent lights with omni directional lights whose lights must be redirected using secondary reflectors. However, the directional nature of LEDs can reduce loss of lighting intensity required and as a result has more fixture efficiencies of 80-90% requiring less total Lumens to provide the same level of luminance.

- **Lighting controls**: Energy use reduction cannot be fully realized with maximum lighting efficiency without effective controls. The benefits of lighting controls range from less demand for electrical energy and energy savings. Three combinations of lighting controls should be considered in the reuse of listed churches for significant reduction in electricity consumption.
- **Manual controls**: this should be considered with spaces within the building that have access to daylight and accommodate different tasks. However, user behaviour control will be required to turn off the lights whenever they are not needed.
- **Automatic controls**: this will be required in less used (unoccupied) spaces such as storage areas, offices, etc., within the building. The use of occupancy sensors to turn off lights when it is not used can have a result of significant influence on the overall energy consumption for lighting.
- **Automatic dimming controls**: to complement lighting levels to where daylighting is not adequate.
- **Scheduling controls**: to be used to either activate, extinguish, and adjust lighting according to a predetermined schedule.

10.7.9 Improvements to Building Fabric

Most listed church buildings vary in the extent to which they can accommodate change on their envelope due to aesthetic and architectural reasons. This consideration influences the extent of change that is appropriate to improve energy efficiency. However, from the findings of this study, quality and constant maintenance and improvements to the heritage fabric such as openings, roofs, and floors can result in a notable energy reduction. Whilst

improvements to the building fabric varies, it is important to consider and carefully analyse factors such as the effects of changing the temperature, moisture and ventilation conditions of the fabric before embarking on any improvements. The following improvements are therefore recommended to improve the building fabric:

- Retain as much of the historic fabric as possible: Improvements measures to the building fabric to reduce heat loss can only be provided if they do not alter the unique character of the building or increase the risk of long term deterioration to the church fittings; the safe rule is to retain as much of the heritage fabric as possible by giving minimal disturbance to the existing fabric and as a consequence, areas where insulation can be applied becomes limited.
- Repoint external walls: Sufficient diagnoses of the external wall should be carried out to reveal areas where excessive infiltration occurs in the building. Available technologies using infrared thermographic inspections will detect areas where unnecessary draughts (but with a degree of ventilation vital for the church fabric put into consideration) can be minimized. Reducing the infiltrations should commence with repointing of the external fabric of the building with like-for- like mortar that will not be destructive to the stone work along with repairing the stonework. Further improvement to the building envelope could be achieved through window repair, draught-proofing of doors and openings, floor insulation, and insulation of non-heritage areas of the building extension. Listed churches are mainly constructed of solid walls and contain sensitive historic interiors that rule out the possibility of considering measures to insulate the walls, though it is a vital step to energy use reduction that should not be overlooked. However, because these buildings have several features and characteristics that provide natural regulation of internal environmental conditions that balance their high mass, lofty

ceilings, low heat gains, moisture absorption, evaporation and ample natural ventilation through the walls; these characteristics thus present a serious challenge and risks to insulating the walls.

- Repair or reconstruct and insulate existing floor: Most heritage floors are either solid or suspended timber floors. Some may need to be repaired or replaced depending on their conditions during refurbishment and reuse projects. Whereas, others may need to be reconstructed to improve their thermal performance by developing a new floor system and using the opportunity to introduce underfloor heating with added floor insulation to reduce heat loss through the floor. Although insulation in heritage buildings is a significant issue, however; they could either be introduced above or below the existing floor and this will depend on the floor. Assessment of visual impact and archaeological implication will be required on the chosen option.
- Repair roof leakages and insulate where appropriate: It is important to consider applying suitable insulation when undertaking roof works to listed church buildings. The roof repairs offer the most practical area and the opportunity to reduce roof leakages and to improve the insulation level of the building. However, this depends on the roof construction such as the availability of the spacious roof void, the choice of material, suitable access to roofs with open ceiling vaults, and under-drawn ceilings may require waiting until opportunity arise to re-roof the building before insulation can be considered.
- Repair and improve existing historic windows: Glazing in listed churches and most historic buildings represents a large percentage of heat loss. In spite of this, they remain a contentious issue as the replacement of their frames and stained glass is contrary to conservation legislation. Notwithstanding, improvement can

be made to them by repairing and renovating them. Another available option is to consider secondary (additional) glazing system in the inner side of the opening where the window is recessed thereby retaining the original window. This measure can significantly improve the thermal performance of the system. In essence, the potential for improvement of heritage windows is a feasible and promising area of energy reduction in reuse of public heritage buildings.

10.7.10 Consider the potentials of renewable energy sources

Renewable energy sources and micro generation play a major role as supplementary to energy saving measures; addressed mostly by photovoltaic panels, biomass and solar thermal systems. Photovoltaic panels could be installed on the buildings if it would be out of view and can be removed with a little long term impact to the building.

10.8 Phase III: Building Use, Operation and Management

This phase describes the design approach required at individual-level (human subsystem) providing the designers with key steps to explore collaborative and evidence based effective strategies to moderating energy use in reuse of public heritage buildings.

10.8.1 Step IV: Evaluate and monitor implemented strategies

Feedback is required for individual, institutional and system level to aid in decision-making for further development activity determined by five (5) Es from the systems thinking and methodologies which are:

• Efficacy – does it work?

• Efficiency – is resource (i.e. Energy use) use minimized?

• Elegance – is the appearance visually pleasing?

• Effectiveness – does the measures address the long term problems?

• Ethicality – is it an honest thing to do?

The first three criteria apply more to process oriented evaluation while effectiveness suggests sustainable change. The last element, ethicality, is an aspect that deal with conservation issues

10.8.2 Step V: Measure intermediate outcomes and long-term impacts

In recent times, efforts are been directed towards addressing energy use problems, however, it has become apparent that the necessary strategies and practices have not been noticeably connected to intended outcomes and impacts. Moreover, there is the need for adequate and appropriate evaluations to be carried out to determine if really, the strategies and practices yield significant outcomes. The purpose of this step is to determine the effectiveness of the implemented strategies by measuring both outcomes and impacts in relation to how the contributing factors have been addressed. The outcome could be how much energy reduction has been achieved while the impacts could be what level of improved energy performance has been achieved. The following questions should guide the review of the outcome after the project:

What was expected (anticipated outcomes);

What has happened (real outcomes);

What could have happened (potential outcomes);

Any faulty/failed technical elements (installation of service systems);

Any inappropriate actions (human, management, organizational);

Any failed or missing components (barriers, controls)

10.9 Chapter Summary and Conclusions

The framework developed in this chapter clearly identifies five steps that must be taken to ensure the strategies and practices aimed at improving energy performance of heritage buildings are effective. It also highlights the relationships between and among the five steps, and made recommendations in which the framework can be used at individual, institutional and system levels. It could be concluded that there are diverse and appropriate energy management strategies suitable for sustainable reuse of LCBs without the buildings loosing their historical significance. However, while the proposed framework has recommended corresponding energy management strategies, particularly suitable to reuse of listed churches, it is important to note that these strategies could be applicable to other heritage projects provided the principles highlighted are adopted on a case by case basis. However, caution needs to be exercised by the users to avoid the lopsided type of approach to using the proposed framework. Observations from the data collected from building technical and energy use survey conducted for this study reveals five main types of energy management strategies adopted in operational practice in existing projects which corresponds with findings from the literature on prevailing energy management strategies summarized by Russell (2005) in Table 10.2.

Table 10.2: Types of energy management strategy

Do nothing	Ignore energy improvement. Just pay the bill on time.Operations are business-as-usual or "that's the way we've always done it" attitude. The result is essentially "crisis management," in that energy solutions are induced by fire-drill emergencies and undertaken without proper consideration of the true costs and long term impacts.
Price shopping	Switch fuels, shop for lowest fuel prices. But make no effort to upgrade or improve equipment and appliances. Make no effort to add users' energy-smart behaviour to daily operations and maintenance procedures.
Occasional operations and maintenance projects	Make a one-time effort to tune up current equipment, fix leaks etc. Unable to/unwilling to make capital investments. Revert to business-as-usual Operations and maintenance behaviour after one-time projects are completed.
Capital projects	Acquire big ticket assets that bring strategic cost savings. But beyond that, day-day operations and maintaenance procedures and behaviour are business-as-usual.
Sustained energy management	Merge energy management strategies with day-day operations and maintenance discipline. Diagnose improvement opportunities, and pursue these in stages. Procedures and performance metrics drive improvement cycles over time.

Source: Centre for Sustainable Energy (CSE) (2012) adapted from Russell (2005)

Whilst it could be concluded that every energy management strategies have their implications for the projects, according to CSE (2012)," only sustained energy management would entail a mix of behavioural and project based strategy thought to be the optimal approach".

CHAPTER 11: SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

11.0 CHAPTER OBJECTIVES

- To present the summary of the research
- To present the main findings of the study
- To highlight the contribution to knowledge
- To outline the limitations of the research
- To make recommendations from the study
- To present the final conclusion of the study
- To provide personal reflections and final remarks

11.1 Summary of the Research

The heritage building sector has been identified, particularly as a promising industry in contributing to meeting the UK target of carbon emission reduction. However, current energy performance of heritage buildings is still low with little research into the causes of the low performance. Meanwhile, the available research on the causes of high energy consumption in these buildings has often been attributed to their thermal performance, which are often researched in isolation with little or no relationship with other critical factors. Consequently, available research mostly focuses on improving the thermal performance with greater emphasis on reducing the U-value. Particularly, much emphasis is laid on residential buildings with less attention to the impact that other building types in the heritage sector can make.

Further, most design and management of reuse of public heritage building projects more often than not, also overlook environmental sustainability of these buildings in their

priorities for these projects. This research has identified varied factors influencing energy consumption in the reuse of LCBs; brought together these factors in order to bridge the research gap between influences of stakeholders' perception, designer's influence and building operational practices that impact on energy consumption on reuse of LCBs. Thus, the purpose of this research was to evaluate how these can be addressed to more effectively manage energy use; thereby improving the energy performance of these buildings with specific focus for long term sustainable reuse of listed church projects. To investigate these issues, this research focused on two main research questions: 1) what are the critical factors influencing energy use in the reuse of listed church buildings? How can they be identified and addressed to more effectively manage energy use and improve performance for long term sustainability? 2) How can these be influence built asset management framework for refurbishment decision making?

To achieve this, seven objectives which were formulated and employed to address the research problem include: i) to review existing literature and research relating to reuse of LCBs' contribution to energy use and carbon emission reduction; ii) to investigate the perceptions, priorities and values of heritage building stakeholders' influence on energy use reduction in reuse of LCBs; iii) to determine the relative importance of strategies perceived as most sustainable and implemented in practice by the stakeholders to improve energy efficiency in reuse of LCBs; iv) to identify the critical actors responsible for energy use in LCBs arising from stakeholders' perceptions that needs to be addressed to improve energy performance; v) to assess the energy performance and operational practices of existing reuse of LCB projects and to determine the crtical factors responsible for their current energy performance; vi) to identify the factors preventing energy use

reduction for delivery of sustainable reuse of LCB projects in practice; and vii) to propose a strategic energy management framework to serve as an achievable guideline for design professionals and operators of LCBs. In order to more effectively manage energy use and improve energy performance of LCBs for long term sustainability, it was first necessary to identify critical factors (i.e. Triggering, aggravating, exposure and moderating factors) influencing energy consumption in these buildings. This was done through a comprehensive review of existing literature on heritage buildings generally and their energy behaviour and adaptive reuse of listed churches (Chapters 1, 2, and 3).

The literature reviewed confirmed research has been done on energy performance of heritage buildings, however, many of the findings have been controversial and conflicting. Further the review of literature suggests that much of the controversy may possibly be sorted out by establishing a distinct theoretical framework that provides the basis for formulating questions, defining further evidence in the body of literature and research design as fully discussed in Chapter 4. It was decided that many of the seemingly conflicting reports may be understood by adopting different approaches in investigating the performance gap. Thus, in this study, the investigation was conducted through a research design consisting of quantitative and qualitative method of data collection (detailed in Chapter 5). The quantitative method comprised of the design, pre-test and administration of a structured questionnaire through an online survey. Following the same procedure, semi-structured questionnaire was administered to obtain field data from facility managers or building operators on building technical and energy use survey; and a qualitative method of data production through interviews with a number of heritage building professionals was carried out to generate important constructs or theme.

The analysis and discussion of the data collected for this research provided the necessary information in identifying the critical factors to be addressed (Chapters 6, 7, 8 and 9). It is noteworthy that the final objective of the research was successfully achieved; by developing a strategic energy management framework for heritage building designers and facility managers to serve as a guidance tool for the design and operational management in the reuse of LCB projects (as presented in Chapter 10). It is noteworthy that all the objectives set for the research were rigorously explored, the research problems satisfactorily resolved and the research questions were adequately answered.

11.2 Main Findings of the Research Study

In general, the findings of this research stem from taking stakeholders' perspective, designer's influence and building operational practices with respect to energy use reduction in the reuse of LCB projects; systematically exploring them and comparing the findings with those of extant literature. The findings have been found to be in agreement with the findings from other authors as discussed previously in Chapter 9 of this thesis; thus, increasing the validity and reliability of the results. The main findings are summarised under the following sub-headings.

11.2.1 Factors influencing energy consumption in the reuse of listed churches

The findings from this study has shown that heritage building stakeholders agreed that priority should be given to modernisation every project involving reuse of heritage buildings. Furthermore, findings also suggest that this could be achieved by integrating energy use monitoring in post conversion projects; taking advantage of current technologies and incorporating secondary glazing to windows. However, there was no

agreement among the stakeholders with regard to the application of wall insulation to reduce the fabric U-value as a viable measure to reduce energy consumption. This perhaps could be due to the negative impact the measure could possibly have on the historic significance of the buildings.

Further findings from this study showed that while 'conservation policies' was rated higher for conversion projects, the concerns for energy use reduction remains secondary. Similarly, 'performance for intended use' appears to have higher priority in the respondents' decision at the design stage when compared to energy use problems. This shows that the design decisions for adaptive reuse often concentrate on the change of building use pattern with less consideration for the consequent energy consumption of the new use. Thus, based on the above mentioned findings, the respondents priorities and values on reuse of LCB projects are not explicitly related to energy saving or reduction of the environmental footprint of reuse projects.

One of the most significant findings emerging from this study is that barriers to energy efficiency in heritage buildings are not specific to the thermal performance of the building. Rather, there were other previously unidentified underlying factors that were discovered in this study that triggered their high energy consumption. The unidentified underlying factors are:

- Low perception of the need for low energy operational performance of LCB projects by the stakeholders;

- The attitude of the clients indicating lack of priority for energy use reduction over other goals of the project;
- Lack of financial and limited resources from the government coupled with government policies as it affects environmental sustainability of heritage buildings;
- Perceived lack of adequate policy for operational energy management and awareness;
- Absence of specific targets for low energy performance in the design;
- Low commitment on the part of the designer to understanding the project energy performance after delivery; the decision and determination of project budgets strongly influenced by the clients;
- Lack of integration of sustainability considerations into the project budgets;
- Lack of supplementary budget for sustainability measures;
- Inadequate funds on the part of the clients; and
- The priority of the clients in wanting to make the building fit into their requirements.

11.2.2 Current and recommended strategies for sustainable reuse of LCBs

The evidence from this study suggests that the three top current strategies adopted in practice further confirms that the central concern and top priorities of heritage building professionals is mainly inclined towards design interventions for reuse of LCB projects. These findings, therefore, highlight the current practice which reflects little or no success in relation to the outcomes on energy performance of existing reuse of the listed projects. This finding was strongly supported by the results obtained from the field survey on the energy use of existing reuse projects revealing that 78.9 per cent of the projects were low

performing buildings. Among the most emergent conclusion emanating from the findings of this study revolves around the recommendations proposed by the stakeholders on strategies to achieve long term sustainable reuse of LCBs.

Findings from ranking quantified by the relative significance index (RSI) showed that 'energy management system' was ranked 1st and the most sustainable strategies compatible for conversion of LCBs projects. Followed by smart metering ranked 2nd; and operational energy management policy and awareness ranked 3rd. Basically, the findings in this study suggest that insufficient knowledge and understanding of what is achievable and appropriate for long term sustainable reuse of heritage buildings is one of the recurring problems within the heritage building industry. In order to achieve the recommended strategies suggested by the respondents, the findings from factorial analysis employed suggests the critical factors that need to be addressed to improve energy performance in the reuse of LCBs are namely: energy management, institutional, regulatory and technical factors.

11.2.3 Building structure and building operational practices influence on energy use

The results from this research also support the view that many LCB projects are characterized by high energy consumption. The most pronounced among the existing conversion projects for high energy usage, are those buildings used for community purposes and functions. The results of the findings from operational practices of these buildings suggests that energy use in these buildings is heavily influenced by the pattern

of building use and inefficient operating practices especially in buildings used for restaurants, commercial purposes and theatre performance.

Other factors found to influence energy use include: inefficient and outdated heating services system; use of air conditioning; lighting system; and more importantly plug loads which also constitute energy users in the buildings. These findings suggest that inefficient operating practices of these functions, allow for energy waste, which arises from poor users' behaviour; and little or no strategy for operational energy management, etc. Although, the installation PV on heritage buildings for reduction of energy consumption has a lot of requirements to be fulfilled from a conservation point of view. However, it could be argued from the findings of this study that renewable energy technologies seem to be a viable solution for reducing carbon emissions from churches.

11.2.4 Development of heritage building strategic energy management framework

Findings from this study formed the basis for the development of the proposed heritage building strategic energy management framework characterised by:

- Identification of five steps that must be taken to ensure that strategies and practices aimed at improving energy performance of heritage buildings are effective.
- Consideration of range of multiple and complex factors that contribute to energy consumption in the reuse of LCB projects and poor energy performance for many of the existing heritage building projects.
- A simple format which allows flexibility in its application by the users for different purposes.

- Targeted methods for identifying and developing best or evidence-based practices compatible with heritage buildings which can be used to strengthen the justification for requesting and directing grant and resources towards efforts for delivery of sustainable reuse projects.

11.3 Contribution to Knowledge

This study has made contributions to the existing body of knowledge in several ways; outlined as: (1) General contributions (2) Practical contributions (3) Methodological contributions (4) Theoretical contributions

11.3.1 General contributions

Notably, this study is the first research to investigate critical factors that influence energy consumption in the reuse of LCBs. As such, it provides needed intervention in a long-overlooked area essential for sustainable reuse of heritage buildings. Additionally, findings from this study would provide a platform and reference for future researchers to build on. This study has contributed to the body of knowledge by means of using the research findings to address complexities linked to the challenges of attaining sustainable reuse of LCB projects in the UK. Furthermore, the contribution of this study would be of significance to building conservation projects and asset management practices in achieving holistic sustainability. This is earnestly needed in the built heritage management literature with practical significance for building conservation projects.

In addition, this research study as further added to the body of knowledge by providing valuable information to the existing scant research on sustainable reuse of LCBs,

particularly for listed church projects. The findings from this study will help the heritage professionals in practice to be able to identify and effectively address the multiplicity of the issues embodied in the achievement of long term sustainability of heritage buildings.

Finally, this study is a time-critical research moving LCBs into the mainstream among other buildings to effectively address the challenge of global warming and climate change; while simultaneously leading to delivering a broad range of potential balanced benefits and outcomes to the building owners as well as increase the asset value of the buildings. The potential benefits are environmental; leading to LCBs using less energy than in current practice; social; leading to high performing buildings with indoor comfort conditions for the users; and economical; leading to more efficient and cost effective operational practices.

11.3.2 Practical contributions

Practically, the contribution made by this present research is the development of proposed framework that would contribute to long-term benefits in emerging reuse projects of LCBs. By outlining an approach that could be adaptable to other conversion projects; it would provide the needed guidance to design professionals and facility managers in both design and operational energy management as well as provide a better regulatory framework for project development that reflects good practice. In essence, other important contributions relating to the outcome of the proposed framework would be to:

- Assist in using a purposeful system-oriented and planned approach based on existing knowledge to address energy use problems related to reuse of LCB projects.

- Enhance the understanding of policymakers, researchers, practitioners, and others about the key operational components that must be considered in developing strategies to address energy consumption that affect reuse of LCB projects.
- Assist in deepening the understanding of multiple and complex factors interacting and relating together to influence energy consumption in the reuse of LCB; making it easier to articulate these relationships, as they play out in concrete situations within the industry and the building.
- Make it easier to identify areas and issues that need more attention either by improved research, provision of services, or training of practitioners where progress is to be made in improving energy performance of LCBs.
- Help users to identify the exact problems and factors to address, types of components of strategies and practices that may best contribute to effectiveness; the measures of outcomes and impacts that are appropriate and feasible.
- Provide better social, economic, and environmental outcome in the reuse of LCBs than those currently obtained from the existing industry practice.

11.3.3 Methodological contributions

The incorporation of quantitative and qualitative methods in this thesis assisted in revealing the contextual, operational and the technical perspectives of heritage building practices; with an explanation for the shift that needs to take place in approaches to heritage building management practices. Although, this study is predominantly qualitative in approach; the architecture discipline has not used much of phenomenology within a broader mixed methodology framework to establish the generalizability of specific and identified phenomena to a significant degree. Particularly, for this study, the

use of phenomenology comes into play as the phenomenon (i.e. Heritage buildings) dealt with has emotional roots (i.e. Social-cultural factors) attached to it which cannot be easily explained through higher-order cognitive processes.

The sequential mixed-methodology employed in this research from the perspective of architecture discipline, shows that it is possible to use phenomenology to inform a quantitative survey methodology and still produce compatible and congruent results. Therefore, other built environment disciplines would find the design of this study useful or applicable to other research areas. Fundamentally, the methodological contribution of this thesis is that it establishes a methodological non-intrusive approach for an aspect of heritage conservation and asset management that could be applicable to other heritage building related research. In particular, the approach could be very helpful to other countries in Europe and other nations with similar heritage buildings conservation and management approach.

11.3.4 Theoretical application/contribution and implications of the study

In terms of theoretical application, this study has provided a base for future researchers carrying out studies related to reuse of LCB projects to adopt or build upon in their study. Firstly, the combination and integration of management and technical oriented theories using a soft system methodology framework helped to provide an empirical example of using these theories to identify critical factors that need to be addressed for long term sustainable reuse of LCB projects. Thus, indicating the potential development of this theory's application in other heritage building conservation and management research; an approach which has not been previously explored or used. Secondly, this study

demonstrates the prospect of using multiple theories to identify appropriate strategies that could be adopted to bring about positive changes and improvement to the current low energy performance of heritage buildings. Therefore, it is possible for future studies related to reuse of LCB projects to use the approach employed in this study as a base for further research.

In addition, the research has contributed to theory by concentrating on the phenomenological motivated approach to perceiving the influence of stakeholders' practices. Thus, by involving the designers and the facility managers, the researcher hoped to trigger heritage design professionals and facility managers' interest and attention to academic research relating to heritage building conservation and asset management. By integration of tacit knowledge and experience of the stakeholders (Polanyi, 1967; Collins, 2010) in this study, the study hoped to have added designers and facility managers in contributing to the development of the discipline body of theory.

An implication of this study is that a tool, such as the proposed strategic energy management framework could aid designers and facility managers to take informed decisions early in the design and operational practices; supporting them and other stakeholders in achieving environmental sustainability in the reuse of LCB projects. Furthermore, the author in this study has challenged the theoretical conceptualization of the stakeholders' with the perspectives of those actively involved in the practice. From the perspective of Fetterman (1997, p.93) stating the importance of triangulation in ethnographic related research; the study author pictured evidence coming from different sources (i.e. The literature, field data, online survey and face to face interviews) to obtain a robust and deeper understanding of the phenomena studied. Figure 4.8 in the thesis

demonstrates how each concept from the stakeholders intertwined to features of the theoretical conceptualization of the problem studied. The analysis of the interview data also pointed to the existence of various approaches and viewpoint among the practitioners with regard to the feature of the theoretical concepts.

11.4 Limitations of the Research

Whilst the main aim and objectives of this research were achieved and the research questions adequately answered, however, the research is limited in a number of ways.

- Firstly, the number of surveyed buildings used for the collection of field data was confined to the East of England. Meanwhile, extending the field technical and energy use survey to other regions in the country would have increased the sample size and produced statistically significant results. Notwithstanding, efforts were made to extrapolate the data and research findings.
- Secondly, all public heritage buildings could not be covered within the limited time available to complete this study and most importantly, such broad coverage could lead to misleading results because of multiple variables that may arise. Therefore, the scope and findings from this research is most applicable and limited to reuse of listed churches.
- Thirdly, the energy used and CO_2 emission reduction figures achieved in the projects discussed by interviewees could not be taken into account as sufficient data was not available. Thus, for the strategies and the outcome of the projects, it was necessary to rely on expert opinion regarding what might be adequate and effective.

- Fourthly, another limitation of this research is the inability to test and validate the effectiveness of the proposed framework on specific case study projects. This is due to the time it may take to complete as such time falls outside the time allocated for the duration of this study.

Thus, the results of this study invite a number of additional studies that should be conducted to build upon the findings of this study. Such future studies could incorporate the same methodological framework, but applied to different building types for comparisons.

11.5 Recommendations

Based on the research findings of this current study the following recommendations are made as an effective means of improving energy performance for reuse of LCB projects.

11.5.1 Recommendations relating to the outcome of this study

- Generally, it is expected that every design project is typically driven by a set of goals and target which eventually produces buildings that meet those targets. It is therefore imperative that from the onset of the project, LCB owners and design teams set measurable performance targets, which could possibly be translated into efficient and improved energy performance. Thus, the design team needs to focus on measurable energy performance targets to achieve better than average and exceptional performance for their projects. However, it is recommended that this goal setting should begin as early as possible in the design process for ease of implementation and best result.

- Basically, the impact of negative user behaviour as it affects energy consumption can be addressed with adequate and effective control mechanisms or measures put in place such as; outlining guiding rules, placing information labels as a reminder in conspicuous places, providing supervision and monitoring measures, providing regular feedback on energy, provision of leaflets or flyers on simple energy saving techniques and workshops could be organised on a regular basis. All these measures put together my check and reduce negative user's behaviour, and consequently, on the long-run contribute to reduction in energy consumption in LCBs. Thus, from this finding a proper recognition of the impact of positive human behaviour could generate worthwhile savings as well as help to ensure that savings from other technical and financial measures are achieved.

- The recommendation for the need of combination of strategies for effective and sustainable operational energy management in the reuse of LCBs cannot be overemphasized in the light of the findings of this research study. This can be attained through the collaboration and integration of two principal groups of stakeholders, i.e. (1) Designers and building operators (2) Authorities of heritage buildings. These strategies, thus require the combination of the monitoring system, strategy plan and top management (institutional level) efforts that address a combination of individual-level (designers), institutional-level (owners, corporation, company, government and regulatory bodies) and system level (building structure).
- Current findings from this study shows that the adoption of renewable technology can be recommended in reuse of heritage buildings, and most especially for listed churches.

11.5.2 Further emerging recommendations as a result of this study

Previously, in chapter 10 of this thesis various recommendations has been given in regards to the three levels (individual, institutional and building system levels) identified to influence energy consumption in LCB projects. However, the following recommendations stem from discussion of various issues surrounding this study which could also improve the level of energy management in LCB projects if implemented:

- **Need for collaborative team working synergistically**

  Sustainable reuse of existing LCBs originates with a knowledgeable team of architects, engineers, and other professionals who can guide the clients through a successful reuse project. Therefore, there is a need for more collaboration to be established between heritage stakeholders' groups; policy makers, designers, engineers, planners, surveyors; and government bodies such as English Heritage for transparent information sharing and most effective measures to be implemented. This is critical to create more efficient, cost effective and successful sustainable historic refurbishment projects.

- **Develop operational energy management plan for LCB projects**

  Developing an operational energy management plan tailored specifically to LCB projects, heritage will be an effective tool in reducing energy consumption. The scope of documents to be submitted as part of the proposed work to heritage buildings should be broadened and not just limited to the conservation plan on any proposed work and its impact on the historic building fabric, systems and significance; but should also involve the submission of an energy management plan and policies of the organization that includes target reductions possible

through operating efficiencies. These targets should emphasis on what is possible in specific operating areas.

- **Consider a sustainability scheme for heritage and existing buildings**

  Historic buildings present complex energy challenges that need careful evaluation. Thus, if the goal for aggressive energy savings in existing heritage buildings is to be achieved; there is need to consider an alternative route to current sustainability rating scheme for heritage buildings to evaluate a better outcome of their sustainability. This is because the current sustainability rating scheme prescribe standards that most fit into modern buildings with high expectations that do not fit into the framework of historic buildings. Developing sustainability rating systems similar to BREEAM for heritage buildings would be a great asset as they can assist in the process of design, create a recognizable level of performance, and increase heritage asset values. Meanwhile, the knowledge and the assessment that goes into developing it should be from respected authority in conservation in the UK; taking into account listed building's status.

- **Increase education, training and involvement of other professionals in policymaking**

  Heritage building projects require interdisciplinary teams of professionals that are knowledgeable not just in historic conservation, but also understanding energy management as part of historic asset management. Thus, there is a need for building operators with appropriate training, education and expertise with understanding energy management to fulfil their role. More training on understanding energy management as part of historic asset management needs to be increased for, such as conservation officers and professional planners. Moreover, there is need to encourage the involvement and regular training of good

professional planners, engineers, energy consultants in policymaking with regards to energy management involving heritage building projects.

11.5.3 Recommendations for future studies

- It is suggested and recommended that for the purpose of continuity of this research that future studies may be carried out on specific case study projects to further refine or validate the proposed framework within England.
- As it was not possible within the scope of this present study, further research studies could likewise be conducted on LCB projects involving reuse of listed churches in the Northern, Southern and Western parts of England.

11.6 Research Conclusions

This study investigated critical factors perceived to be responsible for energy use problem in the reuse of LCB projects from the perspectives of stakeholders' energy use reduction, design and operational practices of existing projects. This study identified the critical factors responsible for energy consumption in the reuse of LCBs. The factors has been classified into four, namely: triggering, aggravating, exposure and moderating factors and a framework have been developed. The key contribution of this study has been the presentation of the critical, clearly defined and classified factors perceived to potentially significantly influence energy consumption in the reuse of LCBs.

Among the critical factors integrated into the framework, human related subsystem factors were discovered as both key trigger and most critical influence. The triggering

factors which permeate the individual, the institutional and the system level constitutes the biggest challenge to achieving sustainable reuse of LCBs. Hence, the outcomes from this study demonstrates a need of a more refined approach, a redirection in current practice and a tool to bridge the gap of operational energy management islands created between the designers and facility managers in the refurbishment of built heritage asset management. It is worthy of note, that through this research study, the development of a strategic energy management framework of relevant application to addressing sustainable reuse of UK LCBs became a possibility.

Whilst there are numerous listed churches and other PHBs across the UK of heritage value that is being reused for community purposes, many would still probably undergo conversion to new uses. Research findings from this present study has shown that LCBs could use less energy and perform better if there is a tool with appropriate measures that are compatible with the nature of their construction for redirection in current practice to improving their environmental sustainability. Thus, a new approach to sustainable refurbishment of LCB projects to address the problem was proposed in the form of a framework. The new approach adopts performance based principles used for asset management in other industries embodying conservation philosophy for a more effective built heritage asset management process in the heritage industry.

The novelty of the performance based framework is that it integrates the identified critical factors as well as reflects a new moderating factor for improved operational management of LCB projects into an objective framework to inform the stakeholders' decisions

making. Additionally, key performance indicators and benchmark targets were used in this study to identify the need and priorities of operational management actions. It is hoped that the performance based framework could offer not just operational cost savings but also improved operational performance. However, for the performance based framework to be efficacious a change in mindset and a redirection in current practice is advocated.

The conclusion from this study is that heritage buildings do not necessarily need to conform to stereotypes conventional energy efficiency strategies for modern buildings to be environmentally sustainable. However, they can be effectively adapted to achieve further reductions in energy use if a sensitive and an appropriate approach is deployed. The internationally accepted conservation rules state that appropriate intervention in heritage buildings should ensure that:

- The building is firstly studied in depth to understand its history.
- Any changes carried out can be easily reversed without damaging the existing fabric.
- New works are clearly legible as opposed to original material.
- Interventions would not alter the elements that make up the special historic character of the building.

In order to fulfil these requirements, this research has found that operational energy management, institutional and regulatory support, strategic energy management plans and a well-informed technical approach integrated in the proposed performance based

framework would enhance and improve environmental sustainability of LCBs. Whilst the new performance based strategic energy management framework is currently theoretical, a limitation of the proposed framework is that it is yet to be tested and validated in a real world situation for further development before it can be introduced in the practice. In particular, this limitation arises from the limitation of soft system methodology used as the main theoretical orientation that guided this study. It could be concluded that if the critical factors influencing LCBs' energy consumption are identified and addressed appropriately a long term sustainability of their reuse could be achieved.

Finally, there is a need to re-examine how energy use and emission reductions are conceptualized in the heritage building industry. Meanwhile, pro-environmental, behavioural change among the building operators and users of heritage building is pivotal to the desired energy use reduction trajectories.

11.7 Personal Reflection and Final Remarks

It is difficult to think comprehensively about how energy use can be more effectively managed in projects involving reuse of LCBs to improve their performance; firstly, because of multiple interplay and interaction of unidentified underlying factors that influence energy consumption in these buildings. Secondly, the literature on the subject is very scanty and the few studies that are available have focused mainly on domestic heritage. Thirdly, there are two schools of thought with conflicting claims on energy efficiency of heritage buildings. One school of thought believes that heritage buildings are energy efficient; while the other believes that they are energy consuming buildings when compared to their modern counterparts. Thus, these perceptions made the task of

understanding energy use problems and operational performance of these buildings particularly daunting; given the amount of diverse literatures on them.

Further, most literatures and projects on heritage buildings tend to focus either on thermal performance and investigating U-values; thus, neglecting how the operational performance could be improved for sustainable project delivery. This further leads to more gaps that exist on the question of how energy could be managed in these buildings. The identification of these gaps is what informed the choice of reuse of listed churches - a population of heritage building types that has not been explored needing the attention of the scientific community for research.

Confronting this research task from architecture discipline, I positioned my philosophical thinking within the context in which it would be possible for me to address the gaps in knowledge without bias to any of the schools of thoughts. My first approach was to take advanced courses on energy efficiency with the Chartered Institute of Building Service Engineers (CIBSE) and architectural conservation with Royal Institute of British Architects (RIBA). These courses provided the platform I needed to combine my interest in environmental sustainability and heritage building conservation with a rigorous search for insights into where the compatibility lies in both areas without being overly subsumed in one while underestimating the importance of the other.

The above mentioned approach helped me to identify part of the underlying issue I discovered in the course of my research. I found that one of the major causes of the conflicting claims within the literature on the subject of energy use in heritage buildings lies in the limited understanding of the appropriate intervention from both perspectives

without becoming overly subsumed in one and underestimating the importance of the other. The outcome of which has led to the proliferation of many articles, journals and publications which presents research and projects successful from a single perspective without much evidence of really leading to improvements in environmental sustainability. This background is what led to the task of reviewing numerous articles, including publications, journals and reports to establish the goal of this research.

The extensive review of literature informed this decision to adopt a multi- theoretical perspective; using the SSM approach to assist in approaching and managing the research by reducing the complexity of the subject to a set of simple questions. The outcome of this research has further enhanced my understanding that heritage buildings are laden with cultural and historic values that possesses soft value because of the emotional attachment that people have for them thus making them very significant and more fragile. Moreover, because of the challenge of climate change, their environmental sustainability as part of their ecological value requires attention with a balance of approach.

11.7.1 The challenging process of the research

Conducting this research has taken me through a gradual journey; though full of new discoveries, in which I gained deeper understanding of the research area of my present study, but not without challenges. The challenges encountered were related to: knowing initially the level of authority to approach for relevant information on the buildings needed for field data. Longer waiting period to get a response and consent from the building owners and managers to participate in the research. The concern over sensitive

issues such as information on energy consumption of the buildings. Sometimes, an outright refusal to participate in the research. The lack of proper record keeping by some building owners or operators required for data collation for the present research. Other unforeseen circumstances encountered during the course of the research; and the challenge of changing the initial focus of the research due to lack of required equipment.

11.7.2 The rewarding process of the research

Fundamentally, this present research has been of keen interest to me. In this study, the research experience and knowledge gained is vast, and this has helped me to develop expertise in my chosen field of study. I had the opportunity to discuss with experienced heritage practitioners, securing and sustaining their interest in participating in the research, obtaining their attention to complete the survey in the world of busy working environment, and about how they perceive the problems and get a better understanding of the importance of the research has been informative.

Along this research journey, I have found the research process quite rewarding and fulfilling in the following aspects: learning new concepts; new methodological approach to studying and solving complex research problems; developing more critical thinking and research skills; learning to understand and apply new and appropriate technology and software to undertake my research; ability to cope with with various unforeseen circumstances while undertaking my research work. Finally, I have the privilege and the advantage of being supervised by collaboratively by a multidisciplinary team of experts from architecture, heritage building surveying and engineering. Interestingly, this consequently gives a broad-based application of the final product of the research study

and also widens its horizon across the multidisciplinary professional setting in LCB sector which I found quite rewarding.

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APPENDICES

Appendice A: Copy of online questionnaire

Energy Management in Public Heritage Buildings

Section A: Your Role and Experience with Heritage Building Projects

This section would help in understanding your current role, your region of operation and your years of experience working on heritage buildings

***1. How would you describe your profession and/or role in heritage industry? (please tick the most applicable)**

- ○ Architect
- ○ Churches Conservation Trust Officer
- ○ Conservation Officer
- ○ Energy Consultants
- ○ Engineers (e.g.Mechanical, Electrical etc. Please specify in the box below)
- ● Planning/Development Control Officer
- ○ Regulatory Bodies Officer (e.g. English Heritage etc.Please specify in the box below)
- ○ Surveyors (e.g. Building Surveyor, Quantity Surveyor etc.Please specify in the box below)
- ○ Others

Others (Please specify here)

***2. Which of the following applies to where you are currently based?**

- ○ East Midlands
- ○ East England
- ○ Greater London
- ○ North East
- ○ North West
- ○ South East
- ○ South West
- ○ West Midlands
- ○ York & Humber
- ○ Scotland
- ○ Northern Ireland
- ○ Wales

***3. How many years of experience working on heritage property do you have?**

- ○ None
- ○ 1 - 5
- ○ 6 – 10
- ○ 11 - 15
- ○ 16 - 20
- ○ More than 20

***4. How many heritage refurbishment projects have you been directly involved as a professional?**

- ○ None
- ○ 1 - 5
- ○ 6 – 10
- ○ 11 - 15
- ○ 16 - 20
- ○ More than 20

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SECTION B: Professional Values and Priorities Applied to Conversion Projec...

The objective of this section is to know your views and priorities on projects involving public heritage buildings before redeveloping them for change in and/or modern use and what you think could encourage greater efforts to improve their energy efficiency

***5. Please indicate your response to the following statements regarding conversion of public heritage buildings**

	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
It is just as important to reduce energy consumption in conversion projects of public heritage buildings as modern buildings.	○	○	○	○	○
Adaptation of public heritage buildings should be done with focus to upgrade their energy efficiency	○	○	○	○	○
Energy monitoring and analysis of energy consumption of public heritage buildings is important after conversion to other uses	○	○	○	○	○
With application of current technologies, energy consumption of public heritage buildings can be significantly minimised when they are converted to other uses	○	○	○	○	○
Where possible with minimum visual impact on the character of public heritage buildings, secondary glazing should be incorporated to the windows during conversion to reduce their energy consumption	○	○	○	○	○
Significant reduction in energy use could only be achieved by reducing the U - value of the building at conversion	○	○	○	○	○
Energy saving measures in conversion of public heritage buildings only make sense if payback is less than 10 years	○	○	○	○	○

***6. Which of the following do you think could encourage greater efforts to improve energy efficiency in heritage building conversion projects (please tick those applicable)**

- ☐ Flexibility to building regulation requirements
- ☐ Award schemes to promote and encourage best practice
- ☐ A framework disseminating effective strategies for conversion projects
- ☐ Local authority supplementary guidance
- ☐ A sustainability scheme for heritage buildings
- ☐ other innovative suggestions (please specify below)

Other (please specify)

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Energy Management in Public Heritage Buildings

Section C: Energy Efficiency for Sustainable Conversion of Listed Churches

This section is about the principles that guide your decisions and actions on projects involving listed church buildings when redeveloping them for change in and/or modern use

***7. How many conversion of listed churches projects have you been involved in?**

- ☐ None
- ☐ 1 - 5
- ☐ 6 – 10
- ☐ 11 - 15
- ☐ 16 - 20
- ☐ More than 20

If your answer to question 7 is 'None', please move to question 12.

8. Please rate (on a scale of 1 – 5) how the following affects your decision making when listed churches are to be converted to other uses

	1(Lowest)	2	3	4	5(Highest)
Sustainability in terms of energy efficiency	○	○	○	○	○
Conservation policies	○	○	○	○	○
Performance for intended reuse	○	○	○	○	○
Lifecycle cost (capital cost,maintenance cost,repair cost)	○	○	○	○	○

9. Please rate the consideration that you will give to the following when listed churches are considered for conversion to other uses

	1 (Least Considered)	2	3	4	5(Most Considered)
Low energy installation costs	○	○	○	○	○
Low energy operational cost	○	○	○	○	○
Users comfort/productivity	○	○	○	○	○
Strict compliance to conservation Policies	○	○	○	○	○

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Section D: Perceived Barriers to Energy Efficiency Improvements to Conversi...

Below are a number of factors which are perceived to constitute barriers to energy efficiency improvements to listed churches.

10. In your opinion, do you feel there are limiting factor(s) preventing energy efficiency of listed church conversion project?

- ◯ Yes
- ◯ No

If your answer to question 10 is Yes, please indicate the extent of your agreement or disagreement to question 11 and 12. However, if your answer to question 10 is No, please move to question 13.

11. Please indicate your response to these perceived technical barriers

	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
Energy efficiency is not often considered a priority for conversion projects	◯	◯	◯	◯	◯
Listed churches are often converted to other uses mainly for efficient use of their internal spaces	◯	◯	◯	◯	◯
Little or no consideration is given to how their energy consumption can be minimised	◯	◯	◯	◯	◯
Most sustainable options in practice are limited in application to heritage buildings	◯	◯	◯	◯	◯
Compatible and sustainable options for improving energy efficiency are capital intensive and unaffordable to owners	◯	◯	◯	◯	◯
Risks involved in the use of insulation that may lead to interstitial condensation in the walls or roof	◯	◯	◯	◯	◯
Listed churches are complex buildings with features limiting interventions on energy efficiency improvement	◯	◯	◯	◯	◯

Other (please specify)

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12. Please indicate your response to these perceived policy and regulatory barriers?

	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
Influence of grade listing (i.e. grade I,II*,II) on possible energy efficiency improvements	○	○	○	○	○
Government policies, regulations and requirements (e.g.FiTs, VAT, etc)	○	○	○	○	○
Inadequate and/or absence of operational energy management policy and awareness	○	○	○	○	○
Too much restrictions on renewable energy installations on listed churches	○	○	○	○	○
Inadequate energy efficiency framework disseminating effective strategies for conversion of listed churches	○	○	○	○	○
Inadequate resources and grants to encourage energy efficiency measures in conversion projects of listed churches	○	○	○	○	○

Other (please specify)

If you have not been involved in conversion of listed churches, please move to question 15

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Section E: Current best practice in conversion listed church projects

The key focus of this section is center on best practices in incorporating energy efficiency strategies to conversion of listed church. The goal is to highlight the most effective methods used in practice to reduce their energy consumption and lower their related greenhouse gas emissions.

13. Please rate the following on a scale of 1-5 what your recommendation(s) would be for most sustainable option(s) for energy efficiency in conversion of listed churches

	1(Lowest)	2	3	4	5(Highest)
Upgrading and improvement to building fabric to reduce its U-value	○	○	○	○	○
Building services upgrade	○	○	○	○	○
Consideration and application of renewable technologies (e.g. Photovoltaic)	○	○	○	○	○
Incorporation of Building energy management system	○	○	○	○	○
Users behaviour change	○	○	○	○	○

Other (please specify)

14. Please rate the following on a scale of 1-5 your view as indicators of successful conversion projects involving listed churches

	1(Lowest)	2	3	4	5(Highest)
Perform the functions well for which they are redesigned and/or converted	○	○	○	○	○
Respond well to their surroundings and enhance their context	○	○	○	○	○
Improved energy performance and carbon emmisions reduction after conversion	○	○	○	○	○
Conversion is reversible and the building can be reinstated to its former use.	○	○	○	○	○
Design interventions are sympathetic with the character of the building.	○	○	○	○	○
Improve users comfort	○	○	○	○	○

Other (please specify)

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Section F: Strategies Adopted for Successful Energy Efficiency Improvements...

The survey results will be combined with a set of case studies in the thesis which will be produced from this research. Your response to the following questions will be helpful to identify best practices that will be useful to facilitate future sustainable conversion projects.

***15. To what extent do you consider any of your past conversion projects to have successfully achieved energy efficiency improvement?**

- ◯ Yes to a significant extent
- ◯ Yes to a very limited extent
- ◯ Yes to a moderate extent
- ◯ Not achieved

16. If your answer to question 15 is Yes, which of your own conversion project(s) or other conversion project(s) do you consider successfully achieved energy efficiency improvement?

Please identify the project(s) and the location below.

17. Which of the projects mentioned in question 16 have recieved award(s)? Please specify the project(s),type and date of the award below.

***18. Please indicate below the strategies you adopted, or know others have adopted in conversion project(s) to improve energy efficiency.**

- ☐ Improvements to building fabric to reduce U-value
- ☐ Building services upgrade
- ☐ Energy management system
- ☐ Smart lighting control
- ☐ Smart metering
- ☐ Renewables installations (e.g. solar, geothermal,biomass)
- ☐ Operational energy management policy & awareness
- ☐ Other

Please specify others here

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***19. Are you willing to have your project(s) selected for case study and be interviewed (in person) to discuss the above indicated strategies?**

- ◯ Yes
- ◯ No
- ◯ Not involved, but can refer you to relevant contact(s)

If Yes/referal, please provide your email and/or relevant contact details below

Thank You for your response and time!

If you are able to forward this email/link to relevant colleagues who will be able to complete the survey, I would be very grateful.

If you would like a copy of the results to this survey, please email oluwafemi.akande@student.anglia.ac.uk

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Appendice B: Copy of building technical and energy use survey

Energy Management in Public Heritage Buildings

Dear Centre Manager,

Building Energy Use & Technical Survey

I would be extremely grateful if you could spare some of your valuable time to give your response to the questions below about..... The questions are just tick in boxes and should take no more than 15 minutes to answer.

Thank you.

A, Total internal floor area (m^2) of the building?

1, what is the total annual electricity use in the building in kWh?
(Note: if the above information is not known, most recent energy invoice for 12months could be made available to the researcher to do the calculation)

2, what is the annual cost of electricity usage in the building?
(Note: if the above information is not known, most recent energy invoice for 12months could be made available to the researcher to do the calculation)

3, what is total annual gas use in the building in kWh?
(Note: if the above information is not known, most recent energy invoice for 12months could be made available to the researcher to do the calculation)

4, what is the annual cost of gas usage in the building?
(Note: if the above information is not known, most recent energy invoice for 12months could be made available to the researcher to do the calculation)

B, General use of the building

5 How can you describe the category of the use of the building?
( ) Arts & Entertainment use (Art studio and/ or gallery, photography, theatre, cultural performance and dance etc.)
( ) Retail use (Bookshop, Rental center (such as for videos, DVDs, books etc.) & Internet use
( ) Food Service use (Community Cafe/Drop in center e.g. Restaurant or cafeteria, fast food)
( ) Multi-purpose use (Conference, music concerts, exhibition, information center and visitors' attraction etc.)
( ) Museum use
( ) Religious use (Church Service) & Community meetings
( ) Bookshop & Food service use (Community Cafe/Drop in center e.g. Restaurant or cafeteria, fast food)

1

( ) Religious (Church Service) & Food service use (Community Cafe/Drop in center e.g. Restaurant or cafeteria, Fast food)
( ) Recreation & Training use (Gymnasium, health club, bowling alley, ice rink, indoor racquet sports etc.)
( ) Others (please specify)

6 What is the main (75%) use of the building?
( ) Art studio and/ or gallery,
( ) Photography,
( ) Theatre,
( ) Cultural performance and dance
( ) Bookshop
( ) Rental center (such as for videos, DVDs, books)
( ) Internet use
( ) Food Service use (Community cafeteria & Fast food)
( ) Conference
( ) Music concerts
( ) Exhibition
( ) Heritage and/or Information center
( ) Visitors' attraction
( ) Museum
( ) Church Service (Religious use)
( ) Other Community meetings
( ) Recreation
( ) Training use

7 What is secondary (25%) use of the building?
( ) Art studio and/ or gallery,
( ) Photography,
( ) Theatre,
( ) Cultural performance and dance
( ) Bookshop
( ) Rental center (such as for videos, DVDs, books)
( ) Internet use
( ) Food Service use (Community cafeteria & Fast food)
( ) Conference
( ) Music concerts
( ) Exhibition
( ) Heritage and/or Information center
( ) Visitors' attraction
( ) Museum
( ) Church Service (Religious use)
( ) Other Community meetings
( ) Recreation
( ) Training use

8 What is the most energy- intensive activity in the building?
( ) Art studio and/ or gallery,
( ) Photography,
( ) Theatre,
( ) Cultural performance and dance
( ) Bookshop
( ) Rental center (such as for videos, DVDs, books)
( ) Internet use
( ) Food Service use (Community cafeteria & Fast food)
( ) Conference
( ) Music concerts
( ) Exhibition
( ) Heritage and/or Information center
( ) Visitors' attraction
( ) Museum
( ) Church Service (Religious use)
( ) Other Community meetings
( ) Recreation
( ) Training use

9 How many hours is the building use in a week
( ) 1 - 16
( ) 17 - 31
( ) 32 - 46

2

( ) 47 - 61
( ) 62 - 76
( ) 77 - 91
( ) 92 - 106
( ) 107 - 121
( ) 122 - 137
( ) 138 - 153

10 What is total number of employees working in the building including volunteers?
( ) 1 to 4
( ) 5 to 9
( ) 10 to 19
( ) 20 to 49
( ) 50 to 99

11 What is Year of Construction of the building?
( ) 10th - 11th Century
( ) 12th - 13th Century
( ) 14th -15th Century
( ) 16th - 17th Century
( ) 18th - 19th Century

12 What year was the building Converted to another use (Please specify exact date)
( ) 1969 - 1979
( ) 1980 - 1990
( ) 1991 - 2001
( ) 2002 - 2012

13 What is the Grade Listing of the building?
( ) Grade I (A)
( ) Grade II* (B)
( ) GRADE II (C)

14 Is Electricity Use in the building?
( ) Yes
( ) No

15 Is Electricity use for heating the building?
( ) Yes
( ) No

16 Is Electricity use for cooling the building?
( ) Yes
( ) No

17 Is Electricity use for water heating in the building?
( ) Yes
( ) No

18 Is Electricity use for cooking in the building
( ) Yes
( ) No

19 Is Electricity use for lighting in the building?
( ) Yes
( ) No

20 Is Natural gas use in the building?
( )Yes
( ) No

21 Is Natural gas use for heating the building?
( )Yes
( ) No

22 Is Natural gas use for cooling the building?
( )Yes

3

( ) No

23 Is Natural gas use for water heating in the building?
( )Yes
( ) No

24 Is Natural gas use for cooking in the building?
( )Yes
( ) No

25 What other source or sources of energy is used in the building?
( ) Solar thermal panels
( ) Biomass
( ) None

26 What type of heating equipment is used in the building?
( ) Furnaces that heat air directly, without using steam or hot water
( ) Boilers inside the building that produce steam or hot water
( ) Packaged heating units, other than heat pumps
( ) Individual space heaters, other than heat pumps
( ) Heat pumps
( ) Other heating equipment
( ) No Heating equipment

27 What specific type of heating equipment is used in this building?
( ) Gas Boiler with Radiator
( ) Gas Boiler with Fan Convector
( ) Suspended Gas Radiant Heater
( ) Gas Boiler with Underfloor Heating
( ) Gas fired hot air heating + Electric Radiant Heater
( ) Electric Radiant Heater
( ) Others (please specify)

28 Was any change made to the heating equipment since the building was occupied/or reuse?
( )Yes
( ) No

29 What specific change was made to the heating equipment?
( ) Upgraded since the building was occupied/converted
( ) Replaced since the building was occupied/converted

30 What cooling equipment types are used in the building?
( ) Packaged air conditioning units, other than heat pumps
( )Residential-type central air conditioners, other than heat pumps, that cool air directly and circulate it without using chilled water
( ) Individual room air conditioners, other than heat pumps
( ) Heat pumps for cooling
( ) District chilled water piped in from outside the building
( ) Central chillers inside the building that chill water for air conditioning
( )"Swamp" coolers or evaporative coolers
( ) Other cooling equipment e.g. fans (please specify)
( ) No cooling equipment

31 What Type of centralized water heaters/ "point-of-use" water heaters is used in the building?
( ) One or more centralized water heaters
( ) One or more "point-of-use" water heaters
( ) Both types

32 Is any energy use for generating electricity in the building?
( ) Yes
( ) No

4

33 What energy sources is used for electricity generation in the building?
( ) Natural gas
( ) Fuel oil/Diesel/Kerosene
( ) Bottled gas/LPG/Propane
( ) Solar thermal panels
( ) Other fuel
( ) Not applicable

34 What technologies are used for generating electricity in the building?
( ) Photovoltaic cells
( ) Fuel cells
( ) Microturbines

35 What is the generated electricity in the building used for?
( ) Primarily for emergency backup
( ) During periods of high electricity demand
( ) Whenever electricity was used

36 Is any space used for institutional or commercial food preparation and serving within the building?
( ) Yes
( ) No

37 What type of food preparation or serving areas is done in the building?
( ) Snack bar
( ) Fast food/Small restaurant
( ) Cafeteria/Large restaurant
( ) Food preparation area
( ) Small kitchen area)
( ) Other type of food preparation area

38 Is there any activity in the building that requires the use of large amount of hot water?
( ) Yes
( ) No

39 Is refrigeration, freezer equipment & vending machines use in the building?
( ) Yes
( ) No

40 What type of refrigeration or freezer equipment is use in the building?
( ) Walk-in refrigeration/freezer units
( ) Open refrigerated/freezer cases or cabinets
( ) Residential-type refrigerators/freezers
( ) Closed refrigerated/freezer cases or cabinets
( ) Refrigerated vending machines

41 Are computers use in the building?
( ) Yes
( ) No

42 How many computers are used in the building?

43 What types of computers are used in the building?
( ) Office PC
( ) Laptops

44 Are there printers used along with computers in the building?
( ) Yes
( ) No

45 How many printers are used in the building?

46 What types of printers are used in the building?

5

( ) Inkjet
( ) Laser
( ) Half inkjet, half laser
( ) Some other type

47 Are photocopiers use in the building other than small desktop copiers? ( ) Yes
( ) No

48 How many photocopiers are used in the building?

49 Any FAX machines used in the building?
( ) Yes
( ) No

50 How frequent are the equipment turned off when not in use?

( ) Always turned off
( ) Sometimes turned off
( ) never turned off when not in use

51 How old is the current heating system?
( ) 1 - 5yrs
( ) 6 - 10yrs
( ) 11 - 15yrs
( ) 16 - 20yrs
( ) 21 - 25yrs
( ) Don't know

52 What is the efficiency of the heating system?
( ) 60 - 70%
( ) 71 - 80%
( ) 81 - 90%
( ) 91 - 100%
( ) Don't know

53 How many hours is the building heated during winter?
( ) 1 - 5
( ) 6 - 9
( ) 10 - 14
( ) 15 - 19
( ) 20 - 24

54 How many hours is the building cool during summer?
( ) 1 - 5
( ) 6 - 9
( ) 10 - 14
( ) 15 - 19
( ) 20 - 24

55 What is the approximate number of visitors using the building in a week?

56 How is the building ventilated?
( ) Natural
( ) Mechanical
( ) Hybrid (Natural & Mechanical)

57 What is the mode of lighting in the building?
( ) Natural
( ) Artificial
( ) Combination of both natural & artificial

58 What type of artificial lighting system is used in the building?
( ) Fluorescent tube

6

( ) Compact fluorescent (CFL)
( ) Incandescent
( ) Metal halide
( ) Light emitting diode (LED)
( ) Other

59 What type of fluorescent tube is used for lighting in the building?

( ) T8 25mm diam, wire wound ballast,
( ) T8 25mm triphosphor,
( ) T5 16mm triphosphor, high frequency ballast
( ) others
( ) don't know
( ) none

60 What type of Incandescent is used for lighting in the building?

( ) 100-200W incandescent (220V)
( ) 100-20-500W tungsten glass halogen (220V)
( ) 5-40-100W tungsten
( ) 2.6W tungsten glass halogen (5.2V)
( ) tungsten quartz halogen (12-24V)
( ) others
( ) don't know
( ) none

61 What type of Light Emitting Diode (LED) is used for lighting in the building?

( ) white LED (raw, without power supply),
( ) 4.1W LED screw base lamp (120V)
( ) others
( ) don't know
( ) none

62 What period is lighting used in the building during winter?

( ) 9:00 – 13:00
( ) 14:00 – 19:00
( ) 19:00 – 23:00
( ) 00:00 – 4:00
( ) 5:00 – 8:00

63 What period is lighting used in the building during summer?

( ) 9:00 – 13:00
( ) 14:00 – 19:00
( ) 19:00 – 23:00
( ) 00:00 – 4:00
( ) 5:00 – 8:00

64 What is the number of lighting system used in the building?

65 What mode of lighting control is used in the building?

( ) Manual
( ) Automatic
( ) Daylight (Photocells)
( ) Occupants (Motion sensors)

66 Is there any indoor temp control?

( ) Yes
( ) No

67 Is there any indoor relative humidity control?

( ) Yes
( ) No

68 What is the type of wall construction?

( ) 600mm solid brick wall with lime plaster
( ) 600mm solid brick wall with limestone facing

7

( ) 900mm limestone wall with lime plaster
( ) Flint stone and brick dressing
( ) others

69 Any wall insulation?
( ) Yes
( ) No

70 What type of floor construction?
( ) Stone floor
( ) Timber floor
( ) Concrete floor
( ) floating wooden floor
( ) others

71 Any floor insulation?
( ) Yes
( ) No

72 What type of roof construction?
( ) Pitch roof with slates
( ) Pitch roof with lead

73 Any roof insulation?
( ) Yes
( ) No

74 What window type exists in the building?
( ) Single glazing with glass in lead cames
( ) Secondary glazing
( ) Double glazing
( ) others

75 Was there any measures to improve energy performance of the building?
( ) Yes
( ) No

76 What measures have been taken to improve energy performance of the building?
( ) Underfloor heating
( ) Fitting door closers to external doors
( ) Draught proofing of windows & doors
( ) Installation of new boiler
( ) replacing entire lighting system with a more efficient light source
( ) Others (please specify)
( ) none

77 How will you rate the quality of the maintenance of the building?
( ) Very poor
( ) Poor
( ) Fair
( ) Good
( ) Excellent

78 Do you have any energy management policy for the building?
( ) Yes
( ) No

79 What is the nature of your energy management policy?
( ) unwritten
( ) written but not implemented
( ) written but partially implemented

8

( ) written and extensively implemented
( ) None

80 What are your energy management strategies?

( ) Monitor trends in energy consumption
( ) Consumption records adjusted for weather conditions
( ) Monitoring and targeting scheme employed
( ) Energy use compared to targets for other buildings
( ) Energy use made known to workers to check habits
( ) others
( ) none

81 What are the other ways of controlling energy use in the building?

( ) By turning off electric appliances when not in use
( ) Turn lights out when not in use
( ) Use full loads with dish washer
( ) Use energy saving light bulbs
( ) Buy energy efficient appliances
( ) Other (Specify)

82 What energy management awareness is adopted in the building?

( ) No promotion of energy management awareness
( ) informal awareness used
( ) some ad hoc staff awareness
( ) Program of staff awareness & regular publicity

83 Is there any energy performance certificate and/or operational rating (i.e. EPC/DEC) available for the building?

( ) Yes
( ) No

84 If yes to question 83, what is the operational rating of the building from EPC/DEC?

85 What heating strategy is adopted for the building?

( ) intermittent heating
( ) continuous heating

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Appendice C: Copy of Interview Questions

Anglia Ruskin University
Cambridge & Chelmsford

Faculty of Science and Technology
Dept. of Engineering & the Built Environment
Anglia Ruskin University
Chelmsford
CM1 1SQ

Dear Respondent,
The University is currently funding a PhD research titled **'Towards an Integrated Framework for Operational Energy Management of Public Heritage Buildings'**. Part of the research involves the analysis of selected case studies of reuse/conversion projects involving listed churches. You were selected to participate in this study because of your specialist position; experience and expertise in conversion and/or reuse projects involving listed churches.

The researcher will be grateful if copies of relevant documents in support of your response and some assistance to obtain energy use data from your client could be made available. The documents may include but not limited to detailed reports on the project, drawings and/or picture(s) of the project taken before, during and after conversion, memos and minutes of meetings in relation to the project.

Interview Guide for Design (Architects & Engineers) Professionals

Instructions
The interview involves two parts and will not take much of your time. The first part consists of background information about you. The second part consists of information about the project of your choice you have been directly involved as a professional in heritage building industry. I am asking your permission to use an audio digital recorder for transcription and validation purposes. You may also be asked to provide follow-up information through phone calls or email. I assure you that all responses will remain confidential.

The result of the research will be disseminated in form of written thesis and/or publication in journals. However, if it is okay with you for your name and project identity to be mentioned in the thesis and/or publication in journals, please feel free to contact oluwafemi.akande@student.anglia.ac.uk

Part A: Background Information

Date:.....

Name:.....

JobTitle:.....

Name and location of your organisation:.....

.....

Your primary functions in your job:.....

.....

How long have you been involved in heritage buildings conversion projects:.....

1

Part B: Information on the Project

1. Background information on the project

(a) Could you briefly tell about the success of your selected project giving the following information?

- Name of the project
- Location of the project
- Awards on the project (if any)
- Environmental sustainability of the project in terms of reduction of CO_2 emission

(b) Please could you shed some light about the project on the following?

- How the project budget was determined? (i.e. who decides on the budget and how much?)
- What your capital budgeting process is, and how does it take into account life cycle analysis?
- How sustainable considerations and/or decisions were integrated into the budget? Do upfront costs exist that may affect the project budget? What are the expected pay back times?
- How budgets affect your decisions on environmental sustainability of the projects?

2. Determination of project requirement and goals

(a) Could you please describe how the needs and/or the requirements of the project were identified?

(b) What were the top goals and/or priorities for the project?

(c) What specific target for low energy performance was included in the goal?

(d) At what point were the energy consultants and/or contractors involved in the project?

3. Determination of low energy strategy for the project

(a) What level of assessment and/or analysis was carried out to determine previous energy consumption and to improve energy performance of the building?

(b) What strategies were adopted to reduce energy demand of the building and to enhance its sustainability?

(c) Please could you comment on how your choice of fuel formed part of your low energy strategy?

(c) What would you consider to be the most and least effective strategies adopted to reduce energy demand and why?

(d) How were the ideas for the most effective strategies developed and how were they introduced?

(e) How effective were the strategies adopted? What indicators are used to judge the effectiveness?

(f) What were your main frustrations in implementing the strategies and how were you able to overcome them?

4. Determination of project performance and operational management

(a) Since occupancy, what provision was made to obtain feedback from building operators on current energy performance of the building?

(b) What provision was made to monitor and to more effectively manage the building energy use during the operational phase?

(c) What provision was made to educate the building operators and/or users on how energy could be managed in the building?

(d) What other circumstances do you consider might be contributing to higher or lower energy use than anticipated in your project?

(e) What would you suggest to more effectively manage energy use in future similar projects?

Thank you for your time and help.

2

Appendice D: Re-Use of Closed Churches of England by Ecclesiastical Region from 1969-2011 (Study Author, 2011)

S/N	Diocese	Adjuncts to adjoining eestates	Arts & Crafts	Civic,cultural or Community Purpose	Educationnal purposes	Light Industrial	Monuments	Museums	Music or Drama Centres	Office/Shopping	Parochial & Ecclesiastical	Private School Chapel	Residential Uses	Sports Use	Storage	Worship by other christian Bodies	Others	Total for Diocese
1	Bath & Wells	-	01	04	01	-	05	01	-	-	-	01	19	-	03	04	-	39
2	Blackburn	-	-	13	-	01	-	-	-	07	04	-	09	01	01	01	-	37
3	Birmingham	-	-	04	02	-	-	-	01	01	04	-	03	-	-	09	-	24
4	Bradford	-	-	05	-	03	-	-	01	02	04	-	03	-	-	03	-	21
5	Bristol	-	-	09	02	-	03	-	01	05	04	-	08	01	03	06	-	42
6	Canterbury	-	-	08	07	-	11	02	-	-	-	02	06	-	02	-	-	38
7	Carlisle	-	02	01	-	-	01	-	-	-	-	-	07	02	02	02	-	17
8	Chelmsford	02	04	14	01	02	10	03	-	01	01	01	12	01	-	14	01	**67**
9	Chester	-	-	09	-	-	02	01	-	03	02	-	02	-	01	05	-	25
10	Chichester	-	02	10	03	02	04	06	01	05	11	03	04	01	-	07	-	**59**
11	Coventry	-	-	02	-	-	02	-	-	02	01	02	04	-	-	01	-	14
12	Derby	-	01	01	-	-	-	-	-	02	01	01	-	01	-	03	-	10
13	Durham	-	01	07	-	-	02	01	-	02	02	01	13	-	01	07	01	38
14	Ely	-	-	03	-	-	04	-	-	-	-	01	09	01	-	-	-	18
15	Exeter	-	02	05	-	01	04	-	01	01	02	-	09	01	03	01	-	30
16	Gloucester	-	-	05	01	-	02	-	-	04	01	01	03	-	01	03	-	21
17	Guildford	-	-	02	-	-	-	-	-	-	-	-	04	-	-	01	-	07
18	Hereford	-	01	-	-	-	09	-	-	-	02	01	12	-	01	-	-	26
19	Leicester	-	-	02	02	-	02	-	-	-	-	01	05	-	-	05	-	17
20	Lichfield	-	03	04	-	01	05	-	02	03	02	-	06	01	-	04	02	33
21	Lincoln	-	03	04	01	-	16	-	-	06	01	02	17	-	07	01	-	**58**
22	Liverpool	-	01	01	01	01	-	-	-	01	02	-	01	02	03	02	01	16
23	London	-	03	16	04	02	02	04	03	09	34	-	24	01	02	41	-	**145**
24	Manchester	-	-	07	02	04	04	02	01	09	01	-	14	02	-	17	-	**63**

24	Manchester	-	-	07	02	04	04	02	01	09	01	-	14	02	-	17	-	**63**
25	Newcastle	-	-	01	-	01	01	01	-	01	01	01	06	02	02	04	-	21
26	Norwich	-	01	25	03	01	19	-	01	01	07	-	04	-	-	06	-	**68**
27	Oxford	-	02	10	05	01	06	01	02	02	01	03	16	-	03	03	-	**55**
28	Peterborough	-	02	02	02	-	03	-	-	-	-	-	01	-	01	02	01	14
29	Portsmouth	-	-	01	-	-	02	03	-	01	-	-	01	-	-	01	-	09
30	Ripon & Leeds	-	01	02	03	-	02	01	-	-	-	-	06	02	01	04	-	22
31	Rochester	-	01	02	-	01		01	01	04	01	01	03	-	-	04	-	19
32	Salisbury	05	03	09	01	02	19	-	-	01	02	12	17	-	01	04	-	**76**
33	Sheffield	-	-	01	03	02	01	01	01	01	-	-	02	03	-	05	-	20
34	Southwell & Nottingham	-	-	-	-	-	03	-	-	03	03	-	01	01	02	06	-	19
35	Southwark	-	-	08	05	-	01	02	02	03	13	01	14	-	01	27	-	**77**
36	St Albans	-	02	01	04	-	04	02	01	02	02	02	04	-	-	05	-	29
37	St Edmundsbury & Ipswich	-	01	08	-	-	07	-	-	02	01	-	13	-	01	03	-	36
38	Truro	-	-	02	01	-	-	01	-	-	-	-	04	-	02	-	-	10
39	Wakefield	-	02	02	02	-	04	-	-	06	01	-	10	01	02	03	-	33
40	Winchester	01	02	08	01	-	04	-	01	06	02	01	04	-	01	05	01	37
41	Worcester	-	01	04	-	-	01	-	-	04	05	-	04	-	-	02	-	21
42	York	-	01	05	-	02	12	01	01	01	02	-	06	01	05	03	-	40
	Total for Uses	08	43	**227**	57	27	**175**	34	21	**101**	**120**	38	**310**	25	52	**225**	07	**1469**
Re-Use of Closed Churches of England by Geographical Region from 1969-2011																		
1	**South West**	05	06	**34**	06	03	**33**	02	02	**11**	**09**	14	**60**	02	13	**18**	00	**218**
2	**North West**	00	03	**31**	03	07	**07**	03	01	**20**	**09**	00	**33**	07	07	**27**	01	**158**
3	**West Midlands**	00	05	**14**	02	01	**17**	00	03	**10**	**14**	03	**29**	01	01	**16**	02	**118**
4	**East Midlands**	00	04	**07**	04	23	**21**	00	00	**11**	**05**	04	**23**	02	09	**15**	00	**104**
5	**East England**	02	10	**53**	10	03	**47**	05	02	**06**	**11**	04	**43**	02	02	**30**	02	**232**
6	**York & Humber**	00	04	**15**	08	07	**19**	03	03	**10**	**07**	00	**27**	07	08	**18**	00	**136**