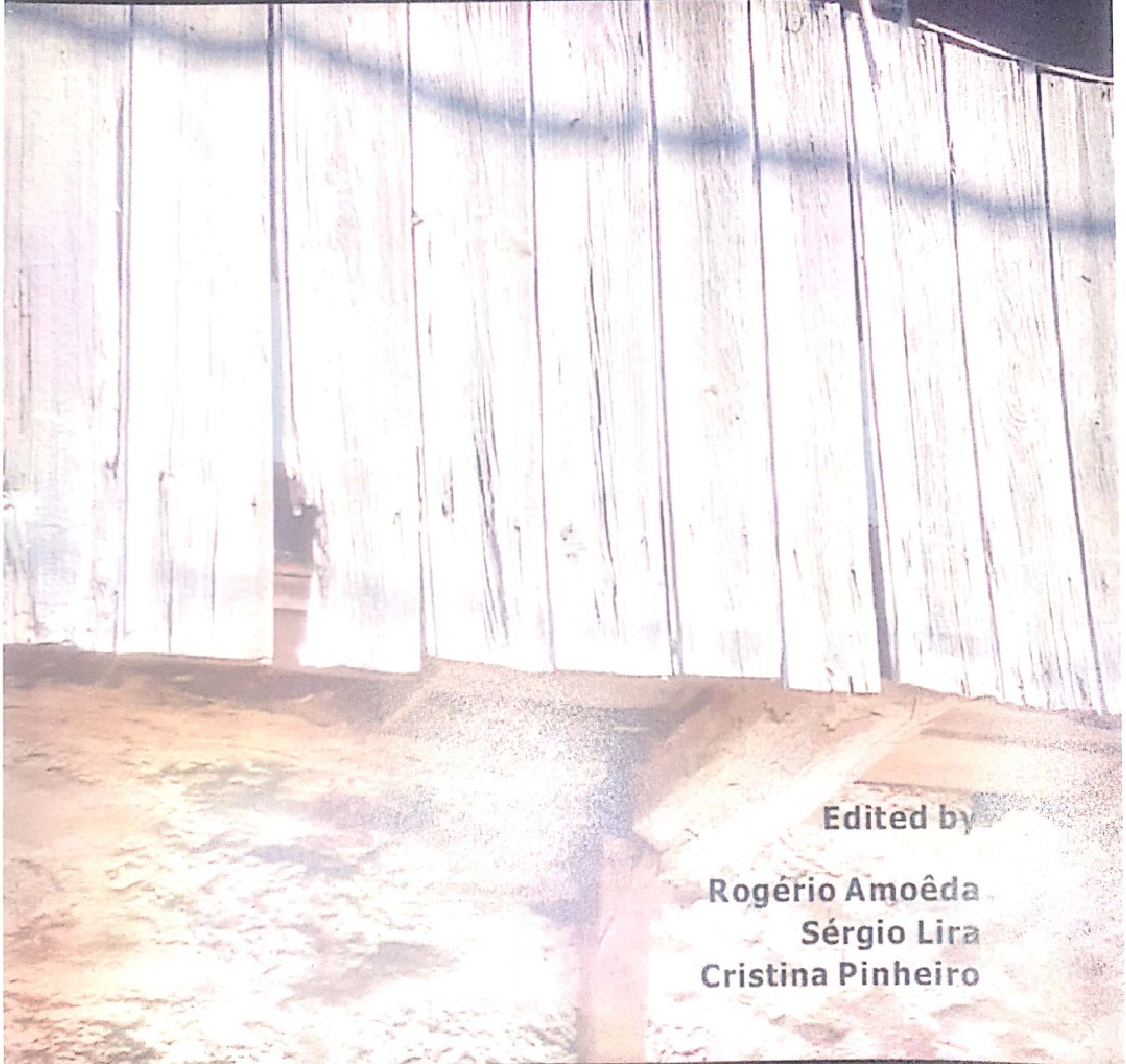
REHAB 2015

2nd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures



Edited by

Rogério Amoêda
Sérgio Lira
Cristina Pinheiro

Volume 2

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We would like to express our gratefulness to all the partners and sponsors of REHAB who joined efforts to make it a significant Conference. Our special word or recognition to the Municipality of Porto, to the Youth Foundation (Fundação da Juventude) and to the Bureau of Tourism of Portugal - Porto and North.

A special word of gratitude to all Members of the Scientific Committee who reviewed the papers and made suggestions that improved the quality of the individual works and the overall quality of the event.

The Editors

Rogério Amoêda
Sérgio Lira
Cristina Pinheiro

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Energy use reduction for sustainable reuse of public heritage buildings: the stakeholders' perspectives

O. K. Akande, D. Odeleye, A. Coday & C. Jimenez Bescos
Department of Engineering & the Built Environment, Anglia Ruskin University, Chelmsford, UK

ABSTRACT: The influence of global climate change on the environment has necessitated continuous utilization of various possibilities to reduce energy consumption in buildings. Heritage buildings are not left behind in the global drive towards environmental sustainability. Observation shows the prevalence of current energy performance is still low and often been attributed mainly to their thermal performance. Using survey method, this paper investigated stakeholders' perception of energy use reduction in reuse of public heritage buildings (PHBs) projects. The objective is to identify critical factors influencing their energy consumption. Operational energy management; institutional/government role and caution on technical approach were identified as critical factors to address to effectively manage their energy use. It concludes that though it is challenging to attain energy efficiency in reuse of PHBs when compared to the requirements in modern buildings; nevertheless, the factors identified could be effectively addressed as a drive to achieving their long term sustainable reuse.

1 INTRODUCTION

1.1 *Building energy use*

Globally, it is acknowledged that the building sector and existing building stock has 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 tonne oil equivalent (TOE) fuels for direct combustion and 0.84 billion TOE in the form of electricity and heat (IEA 2010). Considering the significance of climate change, considerable importance is now attached to incorporating energy saving measures to new buildings and improving energy efficiency of existing buildings. Energy consumption in the built environment is predicted to increase by 34% in the next 20years at an average rate of 1.5%. By 2030, the trend of the increase ascribed to dwellings and non-domestic sectors is anticipated at 67% and 33% respectively (Perez-Lombard *et al.*, 2008).

The UK set an ambitious target of reducing greenhouse gas emissions by 80% of 1990 levels by 2050 to address the issues of climate change. To meet this target, the UK Budget 2009 set carbon budgets equivalent to a 34% reduction in carbon emissions with respect to 1990 levels by 2020. The Climate Change Act allows the Government to meet its carbon budgets through the purchase of carbon credits, meanwhile the Government aims to meet the first three carbon budgets by changing the way energy and resources are used and as well encourage the development of low carbon technologies.

Currently, many existing research place less attention on the stock of existing public buildings, which could be a key to reducing emissions from buildings. Rather, most research tends to focus on new build and domestic buildings. This study identified other areas such as the adaptive reuse of existing buildings where energy use problems in buildings could also be addressed. Among adaptive reuse of existing buildings are public buildings of heritage value. The utmost concern for these historical buildings is the question of how their energy use could be curtailed, their efficiency maximised and their carbon footprint reduced to improve their environmental sustainability without undermining their historical value?

1.2 *Adaptive reuse and sustainability of heritage buildings*

Adaptive reuse is a notable change made to an existing building function when former function has become obsolete (Douglas, 2006) and a special form of refurbishment that presents great challenges for designers 'as changing the class (i.e. functional classification) of a building will introduce new regulatory conditions and perhaps require planning consent' (Langston & Shen, 2007: p.3). As part of the strategy to promote sustainability within the built environment, many buildings of cultural and historical significance are being adapted and reused. A key and notable potential area for adaptive reuse in the UK is in non-domestic sector of public PHBs.

In the UK, historical buildings are some of the most beautiful fixtures of the towns and cities. However, some PHBs (e.g. industrial, churches etc.) have become redundant and converted to other functions either for private or for public use. Although, 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 still remain a source of energy consumption. In addition, their conservation is faced with many challenges of meeting global challenge of coping with climate change without affecting their special character.

Langston *et al.* (2007) argued that adaptive reuse has become an essential strategy to improve the environmental, financial and social performance of buildings. This view is supported by other authors (Stubbs, 2004; Bullen & Love, 2010) stating that the incorporation of historic conservation with environmental issues has become an inherent feature of an agenda to support sustainability. Given the indisputable importance of adaptive reuse of historic buildings as vital to sustainable development and its relevance to climate change adaptation agenda, and because of its ability to recycle resources in place (Conejos *et al.*, 2012); the level, scope, and boundaries of research into maximizing their energy efficiency remain poorly understood.

Several studies (Remoy & van der Voordt, 2007; Bullen, 2007; Martin *et al.*, 1978) have documented numerous factors to consider when initiating adaptive reuse project; however, few studies have addressed the issues of energy use reduction for environmental sustainability of these projects. A significant study found in the literature related to this aspect is a survey conducted by Bullen (2007). The results indicated that environmental sustainability, heritage significance and effectiveness in meeting sustainability benchmarks are the most important factors that should be given consideration in the decision-making process involving adaptive reuse projects. While there is increasing awareness of the role adaptive reuse could play in sustainable development, there is limited studies investigating how energy use reduction as perceived by the project stakeholders for environmental sustainable of adaptive reuse of PHB projects.

Heritage industry comprises of diverse stakeholders related to properties belonging to a person (s) to voluntary and public sector organizations concern and involve with heritage building projects. The stakeholders could be referred to as "key influencers" as a result of being involved in project development that relate to heritage buildings. According to stakeholder theorists (Project Management Institute, 2004; Post *et al.*, 2002; Pinto, 2000), the support of key stakeholders is essential for any project to be successful. Other theorists pointed out that what is done in the world is related to how it is perceived and the thought about the world (Proshansky *et al.*, 1976). This theory thus formed the basis for investigating what the stakeholders perceived to be the most sustainable approach to energy use reduction in heritage building projects.

This paper presents part of a doctoral research on energy management in reuse of PHB projects from stakeholders' perspectives on energy use reduction conducted in the United Kingdom using a questionnaire based assessment. The outcomes of the study should provide valuable information to heritage building stakeholders on the factors to address which could play a significant role towards appropriate strategies for energy management for sustainable reuse of PHBs.

2 APPROACH AND METHODOLOGY

2.1 *Stakeholder's online perception survey (OPS)*

Survey method was considered appropriate for this study due to the size of population which covered the entire country and as a way to obtain standard and stable collection of data from a specific population (Robson, 1993). The respondents comprised of heritage building stakeholders consisting of architects, conservation officers, engineers, energy consultants, planning and development control officers, and surveyors. Two hundred and eleven respondents consisting of 121 practicing professionals and 90 policy makers participated in the survey. The practicing professionals group include; architects, energy consultants, engineers and surveyors. The policymakers include; conservation officers, planning and development control officers, regulatory bodies' officers. The respondents were selected randomly across United Kingdom (Table 1).

Table 1. Distribution of Study Participants, professional role and number of projects.

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

2.2 *Instrument*

The use of a questionnaire was identified as the most suitable instrument through which the respondents could be easily reached in the most economical (Sarantakos, 1988) efficient and popular method to collect the required information. A structured questionnaire to determine reliably the stakeholders' perceptions was developed by the researcher incorporating 28 factors obtained from a review of relevant literature relating to energy use in PHBs. The respondents were to indicate their response and degree of agreement on an ordinal five-point Likert scale of choices using a number value assigned to each choice (i.e. 5- strongly agree, 4 - agree, 3- neutral, 2 - disagree, and 1 - strongly disagree).

The questionnaire was first administered to a group of 35 professionals in heritage industry who were not included in the sample used for the study to obtain reliability of the instrument before it was finally administered online using SurveyMonkey platform. The scores on Cronbach's Alpha were used to obtain the internal consistency and reliability coefficients of the respondents' responses. It indicated a score of 0.76 which is considered adequate compared to an accepted value for alpha at the least of 0.60 for new scales (Nunnally, 1978).

2.3 *Data collection and procedure for analysis*

2.3.1 *Data collection*

The survey comprised of six parts which covered questions on information about the respondent' role and experience; professional values and priorities on their projects; drivers guiding their decisions and actions on projects; perceived barriers to energy efficiency improvements in the projects and current practice and strategies adopted for energy efficiency improvements of the projects. Each part was designed to analyse the stakeholders' perception of energy use reduction.

2.3.2 *Data analysis*

Data analysis was based on 211 total responses obtained from the survey. 57% of the respondents were practising professionals while 43% were policymakers. Higher numbers of the responses (86%) were obtained from England: 10% from Scotland. 3% from Wales and 0.5% from Northern Ireland providing a response rate of 29%.The data were analysed with SPSS 20.0 using a number of descriptive and inferential statistics techniques to ascertain response consensus from the respondents. Exploratory factor analysis was employed to analyse the responses in order to determine the critical factors to be addressed.

3 RESULTS

Research Question 1: What critical factors arising from stakeholders' perceptions of energy use reduction needs to be addressed to improve energy performance in reuse of PHBs? To answer this research question. responses on the OPS were obtained and the results are presented in the following sections.

3.1 *Professional values and priorities applied to conversion projects*

In investigating the respondents' values and priorities. 68.6% of the respondents considered modernisation (ranked 2nd) a priority at conversion to other use. Majority of the respondents (74%) agreed that energy management (ranked 1st) is very paramount to modernisation of PHBs conversion projects. 61% agreed that taking advantage of current technologies (ranked 3rd) and incorporating secondary glazing would facilitate minimal energy use to achieve it. Table 2 show the most compelling result from the respondents unanimous rejection of reducing U-value (ranked 6th) of heritage building and economic pay-back period if less than 10 years (ranked 7th).

Table 2. Perceived factors based on professional values and priorities.

	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 ([illegible])	53 ([illegible])	70 (36.0%)	25 (13.0%)	1.10	3.31	5
Building energy management	2 (1%)	[illegible] (3%)	[illegible] ([illegible])	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 pay-back	26 (13%)	89 (45%)	54 (27%)	19 (10%)	9 (5%)	0.99	2.47	7

3.2 *Perceived factors based on decision-making*

In order to identify the drivers guiding the respondents' decisions on refurbishment of PHBs for change in use. the survey requested the respondents to rate the factors that influence their decision using a 5-point scale (5 being the highest). The results from Table 3 indicate how the stakeholders perceive the aspects of energy efficiency for sustainable reuse of PHBs. From the four propositions. conservation policies (mean=4.44. SD=0.80) ranked the highest. performance for intended use (mean=3.50. SD=1.11) ranked second. life cycle cost (mean=2.97. SD=1.13) ranked third. Surprisingly. the decision factor associated with sustainability in terms of energy efficiency (mean=2.71. SD=1.08) ranked the lowest.

Table 3. 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

In order to determine whether or not the two categories (i.e. professionals and the policy-maker's) of respondents agree in their ratings, Spearman Rank-Difference Correlation Coefficient was used. Table 4 indicate the divergence of opinions among the respondents in relation to the drivers guiding the respondents' decisions on refurbishment of PHBs. The level of significance set at 0.05 yielded ρ value (<0.01) which indicate the significant difference in respondents' rating. The result of the rank correlation indicates the respondents rated conservation policies very high which signify their agreement and its priority over energy efficiency. While it could be seen that no other factor appears to be more important to the policymakers, performance for intended reuse appears to be the drivers influencing the decisions of the professionals (mean ratings = 3.824).

Table 4. Spearman's rank Correlation Coefficient test result on decision factors.

Decision influencing factors	Mean		Spearman's Correlations	
	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

3.3 *Perceived barriers to energy efficiency improvements*

The technical and policy barrier statement provided were collected from literature related to energy use reduction and formulated similarly to the statements on values and priority. From the review in Table 5, 'building complexity' (mean = 3.85, SD = 0.99) ranked the highest perceived technical barrier. The next major perceived barrier was 'risk of insulation'. Whilst the general perception of the respondents on other technical barriers appears to be neutral, surprisingly, they rejected that they give little consideration for low energy consumption (mean=2.627, SD=0.98). The responses of both the practicing professionals and policymakers in relation to perceived policy and regulatory barriers indicate their agreement to limited resources (ranked 1st) as a major barrier Following this is the absence of operational energy management policy for building operation (ranked 2nd).

Table 5. Perceived technical barriers to energy efficiency improvements.

Technical barriers	Frequency of response					Descriptive statistics		
	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

According to the result presented in Table 6, the respondents agree that government regulations and policies on refurbishment projects along with the listed status of the buildings (ranked 3rd) influence energy efficiency measures for sustainable projects.

Table 6. Perceived policy and regulatory barriers to energy efficiency.

Policy and Regulatory Barriers	Frequency of response					Descriptive statistics		
	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

3.4 *Strategies implemented for energy use reduction by heritage professionals in their projects*

To determine the strategies implemented for energy use reduction, the survey allowed the selection of more than one strategy adopted by the professionals. The descriptive analysis was limited to presenting responses to those who adopt or do not adopt given strategies. Table 7 show "Building services upgrade" (ranked 1st) as the most popular strategy used by heritage professionals (55.5%). "Improvements to the building fabric to reduce U-value" ranked 2nd while renewable technologies ranked 3rd. Surprisingly, among the less invasive and intrusive approach such as "smart metering" (ranked 7th) and others (passive design features, etc.) appear to be the least popular strategies implemented by the least proportion of the respondents.

Table 7. Current strategies implemented for energy use reduction by heritage professionals.

Strategies	Yes Implemented by		No Not implemented by		Ranking based on % Yes
	f	%	f	%	
Improvements to building fabric to reduce U- value	114	54.0	97	46	2
Building services upgrade	117	55.5	94	44.5	1
Energy management system	63	29.9	148	70.1	6
Smart lighting control	75	35.5	136	64.5	4
Smart metering	36	17.1	175	82.9	7
Renewable technologies (solar, geothermal, biomass)	76	36.0	135	64.0	3
Operational energy management policy & awareness	68	32.2	143	67.8	5
Others (careful attention to air leakage; draughtproofing of windows, passive design features, secondary glazing, voltage reduction, etc.)	14	6.6	197	93.4	8

3.5 *Critical factors responsible for energy use in reuse of PHBs*

To identify the critical factors, exploratory factor analysis was used. This allows for the investigation of the strongest factors; starting with the original data matrix and using multiple correlations as the estimates of communalities, principal factors were extracted after interacting of communalities. Factors with eigenvalue greater than 1 were retained for rotation. The procedure yielded two factors seven factors components presented in Table 8.

Table 8. Rotated Component Matrix[a] 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	
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 factors extracted were identified using the features of the items loaded under each of them and labelled according to their groupings as follows: Energy management (1); Design decision (2); Government regulations (3); Limited resources and grants(4); Risks of condensation and building complexity (5); Heritage visual impact and secondary glazing (6) and Fabric U-value (7). The labelled factors indicate the critical factors to be addressed to achieve energy use reduction for sustainable reuse of PHBs.

4 DISCUSSION

Findings from this study show that the practicing professionals and the policymakers are significantly different in their perception of energy use reduction in reuse of PHB projects. This difference can be attributed to the lack of common direction among the respondents. This might have resulted from the impulse to protect the delicate fabric of the buildings especially among the policymakers. And with conservation rules seemingly so fastidious, it is not surprising that the respondents perceive this as a barrier to improving the energy efficiency of these buildings. Hence, they are less inclined to reducing the environmental impact of the buildings. Findings show that for most respondents, an improvement in energy efficiency is not a driving factor for these projects. Clearly, the most significant driver is non-energy related decisions like performance for intended reuse and users' comfort and external appearance while less attention is focused on environmental benefits of reducing their energy consumption.

The top three most implemented strategies to reduce energy use in practice was identified as building services upgrade, improvements to building the fabric to reduce U-value and renewable installations. Meanwhile, findings from respondents who have achieved energy efficiency improvements to a significant and moderate extent indicated that energy management system, smart metering and operational energy policy and awareness topped the most effective strategies for energy use reduction. This is in contrast to the findings in Table 7 which showed that these strategies ranked 5th, 6th and 7th which have only been implemented by few of the respondents. It is evident from these findings that the cause of failure, in achieving the benefits of the sustainable approach to heritage building projects is connected to the current approach in practice. Thus revealing the major shortcomings in many designs and planning efforts in recognizing appropriate strategies compatible for sustainable reuse of PHBs.

Similarly, the findings from the factor analysis show the leading factors classified into three to address energy use reduction in reuse of PHBs are energy management in operational practices, governments' regulations in relation to resources and grants for refurbishment project and caution on technical approach (Fig. 1). It is clear that heritage building industry perceives energy management to be the appropriate strategy that should drive and top the decision of designers and facilities managers to achieve more effective and efficient reduction of energy consumption in PHBs. Given that energy use reduction is growing in importance as a core sustainability issue for heritage buildings, the design professionals and the operators of PHBs have a great responsibility to add sustainability value to their projects and service delivery. This is could be done by tackling equally important issues like improved design decisions that incorporate energy management at the planning level and implementation of operational energy management policy at the operational level.

Much emphasis seems to have been on many traditional energy efficiency measures applicable to modern buildings. However, due to the statutory conservation requirements for listed buildings, application of these measures remains a challenging constraint on their sustainable energy refurbishment options. Nonetheless, technology is catching up with the demand for better energy management in listed buildings. For instance, information technology can help to manage, reduce energy consumption and increase energy efficiency in PHBs through energy data collection systems such as the installation of automatic monitoring and targeting (AMT). In addition, there are energy management systems (EMS) (e.g. eSight M&T /EMS, EnergyCap) capable of collecting energy data through the use of sub-meters. This is in line with Carbon Trust (2008) view that existing EMS have been shown to reduce energy use by 5%.

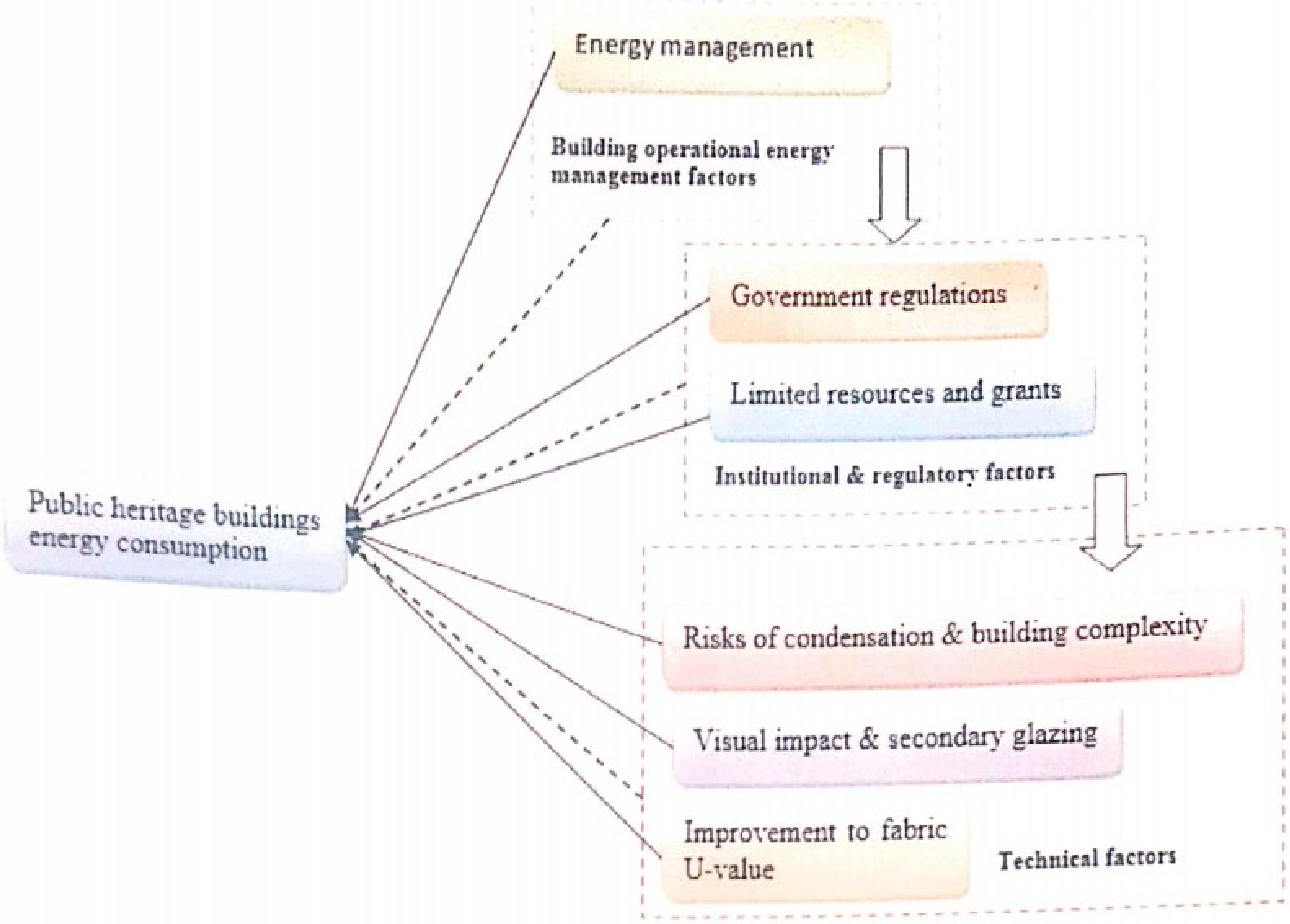

Figure 1. Critical factors influencing energy consumption in reuse public heritage buildings.

The EMS systems could be used to identify and monitor daily energy use along with other range of sensor technologies to analyse energy use data and display relevant information that could be useful to reduce energy use and consequently improve energy efficiency.

4.1 *Implications for practice*

The implication of these finding is that if energy use reduction is to be adequately addressed in PHBs, energy management should top the priority for designers and facilities managers. The pattern of use and/or activity, hours of occupancy, control settings etc. could vary enormously and represent the greatest unknown factors at the design stage. Therefore, designers have to take into account this variability through improved design that incorporate energy management at the planning level to ensure minimum environmental impact of their projects. Facilities managers' should pay greater attention to developing written and effective implementation of operational energy management policies at building operation level. Meanwhile, the idea of insulating the historic fabric should be limited to certain areas (e.g. the floor and roof) only and with great caution when occasion demand but put aside in favor of preservation of cultural values whenever conflicts arise.

5 CONCLUSIONS

The purpose of this paper was to identify critical factors influencing energy use in reuse of PHBs that needs to be addressed from stakeholders' perspectives. To achieve the objective of this paper, adaptive reuse literature and stakeholders' theory guided the study to identify the stakeholders' priorities, drivers, barriers and perception of energy use reduction for sustainable reuse of PHB projects. Drawing on an online questionnaire survey, broad understandings that evoke the critical factors for sustainable reuse of PHBs is provided. This study underscores the need for environmental sustainability planning incorporated early into the design to accommodate unknown non-generic factors influencing energy use in PHBs. In conclusion, energy use reduction in refurbishment of heritage building assets would require greater consideration to be given to energy management and improved operational practices. Improved government and institutional involvement through adequate funding and VAT reduction would also encourage sustainable reuse of PHBs. Realistically, heritage buildings might not attain a high sustainability rating when compared to their modern building counterparts. However, energy use could be minimized if the critical factors identified are adequately addressed.

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