FACTORS AFFECTING THE SUCCESSFUL ADOPTION AND IMPLEMENTATION OF ENERGY RETROFITS IN EXISTING HOTEL BUILDINGS

M.F.F. Fasna* and Sachie Gunatilake

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Energy Efficiency (EE) of the existing buildings is identified as an important focal point for the reduction of total energy consumption and greenhouse gas emissions. Though there is a huge room for EE improvement in existing buildings, still the level of the adoption and implementation of Energy Retrofits (ER) in existing buildings is comparatively low. In fact, it has been ascertained that retrofitting existing buildings is more strenuous than constructing a new green building from scratch due to numerous factors at work that can either facilitate or hinder ER projects. Hence, this research explores the enablers and barriers for the adoption and implementation of ER projects.

Three case studies were conducted among hotel buildings that have implemented ER projects. Selected cases included two ER projects led by in-house teams and one project outsourced to an external Energy Service Company (ESCO). Altogether, 14 semi-structured interviews were conducted with different stakeholders to collect data. Findings of the research revealed 24 enablers and 42 barriers for the adoption and implementation of ER projects in existing hotel buildings. The enablers and barriers were identified for each of the three main phases of ER project implementation; i.e. pre-retrofit, retrofit implementation and post retrofit phases. 'Commitment, engagement and support from the involved parties' in all three phases of the project is ascertained as a crucial enabler that could support the successful adoption and implementation of any ER project. Conversely, 'lack of transparency about energy cost and use', 'lack of skills and experience', 'difficulties in establishing communication between parties' and 'occupancy type of the facility' were identified as the barriers that impede the ER project success in all three phases. Further, this paper argues that the party who execute the ER projects have significant impact on the enablers and barriers for the adoption and implementation of ER project. By providing a thorough understanding of the enablers and barriers, it is hoped that the findings of this study will provide a basis for more successful adoption and implementation of ER projects in the hotel sector.

Keywords:*Barriers; Enablers; Energy Retrofits (ER); Existing Buildings; Hotel Buildings.*

1. INTRODUCTION

In the contemporary world, importance of energy conservation and the reduction of greenhouse gas (GHG) emissions are stressed globally (Choi et al., 2017). Since, existing buildings encompass the largest segment of the built environment (European Climate Foundation (ECF), 2013), enhancement of Energy Efficiency (EE) in existing buildings through Energy Retrofits (ER) is crucial to attain a timely reduction in global energy usage (Ma et al., 2012). Energy retrofitting involves changing or modifying the systems, equipment or parts of a building to enhance the energy performance (Ashrafian et al., 2016; Chunduri, 2014). ER can also result in other benefits such as upgraded functionality, improved architectural quality, increased aesthetic value (Kalc, 2012), reduced resource consumption and improved indoor air quality (Alm et al., 2005).

Despite the existence of a large number of approaches and recognised benefits of retrofitting, regulating and improving the EE of the existing buildings is still considered to be a challenging issue (Hou et al., 2016). As

*Corresponding Author: E-mail – fasna.fm2013@gmail.com

highlighted by Miller and Buys (2008), retrofitting existing buildings can often be considerably more strenuous than constructing a new green building from scratch. Indeed, retrofitting existing buildings involves many challenges and opportunities (Ma et al., 2012) and there are numerous factors at work that has the potential to either facilitate or hinder ER projects (Beillan et al., 2011). This research aims to shed light on this issue by investigating the enablers and barriers for the adoption and implementation of ER in existing buildings. This paper brings together the existing literature as well as the results of the case study findings with respect to the enablers and barriers for the adoption and implementation of ER projects.

2. ENABLERS AND BARRIERS FOR THE ADOPTION AND IMPLEMENTATION OF ER

Generally, the decisions on ER are affected by several economic and non-economic motivations (i.e. enablers) and barriers (Friege and Chappin, 2014). Since still ER projects have not been implemented on a significant scale (UNEP, 2014), a number of previous researches have been carried out to determine the barriers for the adoption and implementation of ER (Moder, 2013). As the barriers of ER can be analysed at several levels, going from a broad category (e.g. financial barrier) to a more detailed and specific category (e.g. high interest rate), different authors have classified ER barriers in numerous ways. Painuly (2009) has classified ER barriers as financial, technical, information, managerial, and institutional, whereas International Energy Agency (IEA) (2003) has categorised ER barriers as information, behavioural, market, organisation and technological. On the other hand, Bruce *et al.* (2015) have classified the ER barriers as economic, regulatory and social barriers. Additionally, Zuhaib *et al.* (2017) have mentioned that ER projects encounter many social barriers throughout their adoption and implementation. So, it is clear that so far scholars have not reached a consensus on the standard classification of ER barriers. Hence, based upon the review of literature, in this research, barriers to the adoption and implementation of ER are classified as financial, technical, informational, managerial, institutional, behavioural, market, regulatory, and social.

Similarly, in the existing literature, though several authors have identified the enablers for ER projects, no one has come up with the proper classification of the enablers of ER projects. Hence, in this study, enablers of ER identified through the review of literature are categorised into several groups based upon the classification of barriers of ER projects made in some of the past researches. Table 1 provides a snapshot of the key enablers and barriers of ER projects identified through the review of literature under respective category.

Table 1: Enablers and Barriers to the Adoption and Implementation of ER

	Enabler or Barrier category								
	Financial	***Technical***	***Informational***	***Managerial***	***Institutional***	***Behavioural***	***Market***	***Regulatory***	***Social***
Barriers	Lack of funding	Immature technologies	Lack of information	Inappropriate ER project management practices	Split incentives	Reluctance to invest in ER projects	Perception of risk or uncertainty	Lack of competent regulatory body	Low level of public awareness & understandings
	Lack of access to finance	Lack of availability, reliability, knowledge on efficient technologies	Unawareness of federal & state incentives related to EE upgrades	Lack of synergy with managerial goals & incentives in business	Lack of leadership for ER projects	Inertia of current practices & attitudes	Market capacity	Lack of comprehensive national energy policy & targets	Social norms in relation to thermal & acoustic comfort, light, air quality
	Lack of incentives	Lack of access to efficient technologies	Lack of transparency about energy cost & use	Unfavourable administrative conditions	Lack of repairs or maintenance supply chain	Lack of commitment & engagement to ER	High level of uncertainty of future energy prices	Lack of legislation to support ER	Cultural change
	Lack of explicit financing mechanism & debt constraints	Lack of knowledge and know-how (Lack of technical knowledge & expertise on ER technologies/ measures & how to deploy them)		Building owners' lack of motivation to connect building performance to a clear business case for EE	Unstructured decision making or limited decision-making frequency	Occupants' resistance	Diverging priorities	Lack of willingness of the government to adequately mobilize and sensitize the public towards EE	
	Effects of lock-in	Technological incapability due to lack of adequate experts in the area of EE		Lack of skills & experience	Communication between parties is tedious & complex	Intense inter-disciplinary collaboration	Market fragmentation	Recent developments in building codes or new regulations	

	High up-front capital expenses	Difficulties in calculating the payback periods	Building operational & management constraints	Lease structures		Changing energy
	Profit sacrifices or insufficient ROI	Difficult to convince the management to undertake ER projects		Lack of proper programme design & monitoring expertise		
	Elevated payback periods	Lack of predictable roadmap for opportunities		Low versatility for intervention in existing buildings		
		Difficult to evaluate & quantify the benefits of ER		Lack of coherent green workforce development		
		Lack of inter-operability		Lack of staff training		
		Complexity of technologies		Occupancy type		
Enablers	Client resources	Availability of retrofit technologies /solutions	Awareness programmes	Building energy labelling programme	Organisation's commitment	Government policies & targets
	Financial assistance	Technical support	Demonstration programmes	Energy performance certification systems	Willingness & skills of stakeholders	Building codes & energy acts
			Knowledge of stakeholders	Green leases	Cooperation among stakeholders	

Sources: (Beillan *et al.,* 2011; Bruce *et al.,* 2015; Choi *et al.,* 2017; Davies & Osmani, 2011; Dixon *et al.,* 2014; Friege and Chappin, 2014; Hou et al., 2016; Liang et al., 2016; Ma et al., 2012; Miller and Buys, 2008; Painuly, 2009; Rhoads, 2010; Wilcox, 2010; Zuhaib *et al.,* 2017)

Although it was possible to identify the aforementioned enablers and barriers from the review of existing literature, there has been a lack of focus so far on investigating the specific enablers and barriers during each different phase of ER project implementation.

Among the available processes for the adoption and implementation of ER projects, the process suggested by Ma *et al.* (2012) has classified the overall process of a building retrofit into five major stages: namely, project setup and pre-retrofit survey; building energy auditing and performance assessment; identify possible retrofit measures or options; site implementation and commissioning; and validation and verification. Conversely, Hwang *et al.* (2015) have defined 'pre-retrofit' as the state prior to the implementation of a retrofit project and 'post-retrofit' as the state after the retrofit completion. Hence, it is possible to derive that the activities which comes prior to the implementation of selected ER measures is 'Pre-retrofit phase' whereas the activities to be performed after the implementation of ER project is 'Post-retrofit phase'. So, through careful analysis this study postulated the five major stages identified by Ma et al. (2012) into three different phases as pre-retrofit phase (i.e. project set-up and pre-retrofit survey, building energy auditing and performance assessment, and identification of ER measures), retrofit implementation phase (i.e. site implementation and commissioning) and post-retrofit phase (i.e. validation and verification). Hence, the enablers and barriers for the adoption and implementation of ER projects for each of these identified phases of ER process will be elicited in this study via the empirical investigation.

3. RESEARCH METHODOLOGY

This research adopted a qualitative case study strategy. Since hotel buildings use as much as 50% of their total expenses on energy mainly due to their 'extended operation' (Sri Lanka Energy Managers Association (SLEMA) 2009); and as the implementation of EE initiatives in the Sri Lankan hotel industry is urgently necessitated to reduce dependency on fossil fuels and meet future demand for resources like energy (International Finance Corporation Sri Lanka (IFCSL), 2013), this study has limited its focus to existing hotel buildings. Three cases (IH1, IH2 and ES1) were selected from existing hotel buildings that have successfully completed ER projects within the last five years.

In selecting cases, the focus was limited to shallow (i.e. adopting measures that are relatively easy to install and have low upfront cost) and medium (i.e. focusing on individual systems to achieve the potential energy savings of each building system) retrofits (See Chunduri 2014) only. This was because, in practice, hotel buildings rarely undertake deep retrofit projects due to their operation type. Among these selected cases, Cases IH1 and ES1 are medium retrofit projects while Case IH2 is a shallow retrofit project. In addition, in order to capture the enablers and barriers from different settings, ER projects purely handled by in-house teams as well as handled with the assistance of an external Energy Service Company (ESCO) are selected as case studies. Among the selected cases, Cases IH1 and IH2 are led by the in-house teams while Case ES1 is led by an ESCO.

In order to investigate the enablers and barriers, altogether fourteen (14) semi-structured interviews were conducted with the stakeholders involved in the adoption and implementation of ER in the selected cases. The details of the respondents are presented in Table 2.

Table 2: Details of the Respondents

Case	Respondents	Profile of the respondent	Role(s) in ER project	Experience (years)
IH1	IH1R1	General Manager of the particular hotel	Owner/Client	40
	IH1R2	Manager – Engineering of the hotel group	Facilities Manager (throughout the project)	10
	IH1R3	Chief Engineer of the particular hotel	Facilities Manager (in implementation phase & Post-retrofit phase)	39
	IH1R4	Engineer of the particular hotel	Building Services Engineer	14
	IH1R5	Engineer of another hotel attached to the particular hotel group	Energy Auditor	12
	IH1R6	Assistant Manager	Specialist Contractor, Supplier, and Architect	05
	IH1R7	Chief technical advisor – energy	Financial Institutions	25
ES1	ES1R1	Chief Executive Officer (CEO)	ESCO, Supplier, Energy Auditor, Cost Consultants	18
	ES2R2	Chief Engineer	Facilities Manager	26
	ES3R3	BMS and Facilities engineer	Building Services Engineer	03
IH2	IH2R1	Chief Engineer	Facilities Manager, Energy Auditor	30
	IH2R2	Senior Foreman	Electrical Engineer	36
	IH2R3	Foreman	Electrical Engineer	15
	IH2R4	Cost Controller	Cost Consultant	08

Code based content analysis using NVivo computer software was used to analyse the qualitative data collected through semi-structured interviews.

4. CASE STUDY ANALYSIS AND DISCUSSION OF THE FINDINGS

Case study findings revealed twenty-four (24) enablers and fourty-two (42) barriers for the adoption and implementation of ER projects in existing hotel buildings. A key gap identified in the literature review was the lack of focus on identifying enablers and barriers for the different phases of ER projects. Hence, Tables 3 and 4 presents the identified enablers and barriers for each ER project phase as well as classified into the groups given in Table 1. To present the results of the case studies (both enablers and barriers), the format presented in Figure 1 was adopted.

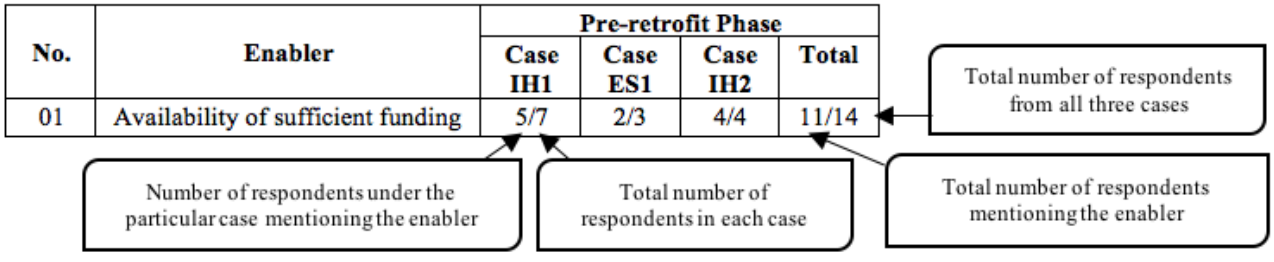

Figure 1: Presentation of the Results

The findings are presented and further discussed in the following sections.

4.1. ENABLERS FOR THE ADOPTION AND IMPLEMENTATION OF ER PROJECTS

As given in Table 3, out of the total twenty-four (24) enablers, twenty-one (21) enablers were identified in the pre-retrofit phase highlighting the importance of the pre-implementation phase in ensuring the success of ER project implementation. Comparatively, only eight (8) and nine (9) enablers were identified in the retrofit implementation and post-retrofit phases respectively. The identified enablers represent five (i.e. Financial, Technical, Informational, Institutional, and Behavioural,) out of the total six groups of enablers identified in Table 1. Besides, through the case study analysis 'Managerial' and 'Market' enablers were also elicited.

During the **pre-retrofit phase**, 'availability of technical knowledge and expertise to perform the assigned tasks' was identified as a key enabler by all 14 respondents from the three cases. Similarly, 'availability of sufficient funding', 'past experience with similar projects', 'availability of retrofit technologies/solutions', 'commitment, engagement, and support from the involved parties' and 'willingness and skills of stakeholders' were identified as the other enablers common to all three cases (despite whether the project was led by an in-house team or outsourced) which facilitated the effective adoption of ER in the pre-retrofit phase.

On the other hand, 'commercial guarantees provided by ESCO', ESCO's 'ability to invest in the project' and 'availability of technical support' emerged as enablers specifically when an outside contractor was involved, as was the case in ES1.

Additionally, 'financial assistance from funding agencies', 'adoption of energy performance certification schemes or standards', and 'quality of service provision' are specified as enablers only by Case IH1 in pre-retrofit phase. This would be due to certain reasons that have motivated them to adopt the ER project i.e. obtained financial assistance for the particular ER project from an international funding agency; adopted energy management standards like ISO 50001 for the facility; and quality of service provided by the specialist contractor which provided enough confidence of successfully proceeding with the implementation. Conversely, the respondents of Case IH2 disclosed that though this was their first ER project, existence of 'good project leadership for the ER project' is a unique enabler which facilitated them to successfully proceed with the pre-retrofit phase.

In **retrofit implementation phase**, findings revealed that 'availability of technical knowledge and expertise to perform the assigned tasks', 'past experience with similar projects', 'commitment, engagement and support', and 'cooperation among the stakeholders' are the enablers which assisted all three cases in successful implementation of the selected ER measures despite the party who led the project. The latter two factors were particularly stressed by the respondents from Case ES1 as crucial enablers when ER is being implemented by an external party. In contrast, Case IH2 has revealed that though at first most of the stakeholders had their own perceptions on the project, they have managed to proceed with the project implementation successfully due to the existence of sufficient 'cooperation among stakeholders'.

It was interesting to note that 'adoption of good project management practices' and 'good project leadership for the ER project' were identified as enablers during this phase only in Case ES1, which was led by ESCO. This could be mainly due to ESCOs past experience and expertise with the execution of ER projects. Conversely, 'establishment of proper communication' is an enabler ascertained in retrofit implementation phase only from Case IH1. In-house led cases i.e. Case IH1 and IH2 have divulged 'willingness and skills of the stakeholders' and 'availability of the technical support in the local context' as the enablers in the retrofit implementation phase.

In **post-retrofit phase**, case study analysis revealed that 'provision of training via conducting demonstration programmes or training programmes' and 'commitment, engagement and support from the involved parties' are the enablers unitedly disclosed by the selected cases in post-retrofit phase. Among these enablers, training/ demonstration provision is necessary in order to for the technicians to properly conduct post Measurement and Verification (M&V) once a project is implemented. This is especially crucial in organisations with little or no prior experience with ER projects as highlighted by the respondents of Case IH2.

Table 3: Enablers for the Adoption and Implementation of ER projects

No.	Enabler	Number of respondents											
		Pre-retrofit Phase				Implementation Phase				Post-retrofit Phase			
		Case IH1	Case ES1	Case IH2	Total	Case IH1	Case ES1	Case IH2	Total	Case IH1	Case ES1	Case IH2	Total
Financial enablers													
01	Availability of sufficient funding	5/7	2/3	4/4	**11/14**				**0/14**				**0/14**
02	Financial assistance from funding agencies	3/7			**3/14**				**0/14**	2/7			**2/14**
03	Commercial guarantees provided by ESCO		3/3		**3/14**				**0/14**				**0/14**
Technical enablers													
04	Availability of technical knowledge and expertise to perform the assigned tasks	7/7	3/3	4/4	**14/14**	6/7	3/3	3/4	**12/14**	6/7		1/4	**7/14**
05	Availability of retrofit technologies/ solutions	2/7	2/3	3/4	**7/14**				**0/14**				**0/14**
06	Existence of up to date knowledge on available efficient retrofit technologies	2/7	3/3		**5/14**				**0/14**				**0/14**
Informational enablers													
07	Conducting awareness programmes		1/3	4/4	**5/14**				**0/14**				**0/14**
08	Availability of sufficient information on energy consumption (i.e. historical data and consumption data after retrofitting)	1/7	1/3		**2/14**				**0/14**	1/7			**1/14**
Managerial enablers													
09	Past experience with similar projects	7/7	3/3	3/4	**13/14**	2/7	3/3	3/4	**8/14**				**0/14**
10	Adoption of good project management practices		1/3	1/4	**2/14**		2/3		**2/14**				**0/14**
11	Past experience with the maintenance of similar systems				**0/14**				**0/14**	1/7		1/4	**2/14**
Institutional enablers													
12	Intense need to reduce costs	3/7	1/3		**4/14**				**0/14**				**0/14**
13	Adoption of energy performance certification schemes or standards	3/7			**3/14**				**0/14**				**0/14**
14	Brand value and reputation of the particular stakeholder i.e. particular hotel, specialist contractor, ESCO	1/7	2/3		**3/14**				**0/14**				**0/14**
15	Maturity level of the specific stakeholder	1/7	3/3		**4/14**				**0/14**				**0/14**
16	Client's ability to invest in the ER project		3/3		**3/14**				**0/14**				**0/14**
17	Good project leadership for the ER project			4/4	**4/14**		1/3		**1/14**				**0/14**
18	Establishment of proper communication channels				**0/14**	1/7			**1/14**	1/7			**1/14**
19	Provision of training via conducting demonstration programmes or training programmes				**0/14**				**0/14**	4/7	3/3	4/4	**11/14**
Behavioural enablers													
20	Commitment, engagement and support from the involved parties	5/7	1/3	1/4	**7/14**	4/7	3/3	2/4	**9/14**	5/7	3/3	2/4	**10/14**
21	Cooperation among stakeholders	4/7	1/3		**5/14**	5/7	3/3	4/4	**12/14**	1/7			**1/14**
22	Willingness and skills of stakeholders	3/7	2/3	3/4	**8/14**	3/7		3/4	**6/14**			1/4	**1/14**
Market enablers													
23	Availability of the technical support		2/3		**2/14**	5/7		2/4	**7/14**				**0/14**
24	Quality of the service provision	1/7			**1/14**				**0/14**				**0/14**

Besides, 'financial assistance from funding agencies', 'availability of sufficient information on energy consumption', 'establishment of proper communication channels', and 'cooperation among stakeholders' are the enablers mentioned only by Case IH1 in post-retrofit phase. This was because, availability of sufficient information on energy consumption would facilitate the proper assessment of saving through retrofitting, while other factors are useful in ensuring the continuous operation of the retrofitted system. Conversely, 'availability of technical knowledge and expertise' and 'past experience with the maintenance of similar systems' are the enablers stated by both in-house led cases i.e. Case IH1 and IH2.

By summing up the findings on enablers, it can be derived that among the enablers which facilitated the proper adoption and implementation of ER projects, 'availability of enough technical knowledge and expertise', 'commitment, engagement, and support', 'cooperation among stakeholders', and 'willingness and skills of stakeholders' are the enablers which are crucial for the successful completion of the activities throughout the project as ER projects are huge endeavours undertaken by the organisations which necessitates the participation different stakeholders to perform various roles. Since 'commitment, engagement and support from the involved parties' is highlighted by all three cases in all three phases, it can be deduced that for any ER project despite the party who plans and execute the project, existence of 'commitment, engagement and support' throughout the project would facilitate the successful project execution (Refer Table 3). Besides, 'availability of technical knowledge and expertise' and 'past experience with similar projects' are crucial for any ER project mainly in both pre-retrofit phase and retrofit implementation phase to ensure the project success. On the other hand, if the project is led by in-house team, 'availability of technical knowledge and expertise' throughout the project is crucial to ensure the project success (Refer Table 3).

In literature, most of the authors have specified 'financial assistance' and 'government policies and targets' as the key enablers for the adoption and implementation of ER project (Refer Table 1). However, findings revealed that 'availability of sufficient funding', 'availability of technical knowledge and expertise' and 'past experience with similar projects' are the enablers that played a key role in pre-retrofit phase. Besides, 'availability of technical knowledge and expertise' and 'cooperation among stakeholders' were elicited as the main enablers in retrofit implementation phase whereas 'provision of trainings via conducting demonstration programmes or training programmes' and 'commitment, engagement and support from the involved parties' were disclosed by most of the respondents as the key enablers in post-retrofit phase. As depicted in Table 1, though 'government policies and targets', 'building codes and energy acts', 'building energy labeling programme' and 'green leases' are identified as enablers in literature, none of the respondents' have specified these as enablers for the adoption and implementation of ER projects. This could be due the lenience of country's legislations which induce low level of influence to adopt ER projects.

4.2. BARRIERS FOR THE ADOPTION AND IMPLEMENTATION OF ER PROJECTS

Through case study analysis, fourty-two (42) barriers that could hinder the adoption and implementation of ER were identified (Refer Table 4). The most number of barriers (i.e. 27) were identified in the pre-retrofit phase, while seventeen (17) and sixteen (16) barriers each were identified in retrofit implementation phase and post-retrofit phase respectively. The identified barriers represent eight (i.e. Financial, Technical, Informational, Managerial, Institutional, Behavioural, Market and Social) out of the total nine groups of barriers identified in Table 1.

In **pre-retrofit phase,** 'difficult to evaluate and quantify the benefits of retrofitting' is the key barrier specified by Case IH1 in pre-retrofit phase due to lack of up to date information on cost and benefits of different ER measures. Similarly, Case ES1 has revealed that 'lack of technical knowledge and expertise' of the in-house team is a key barrier that they have encountered due to which they have decided to obtain the assistance of ESCO for the ER project while 'lack of trust and confidence on ESCOs' is another the key barrier they have faced due to which they had to investigate the sustainability credential of the particular ESCO. Conversely, 'lack of commitment and engagement to ER project' is the key barrier highlighted by Case IH2 in pre-retrofit phase due to their employees' lack of prior experience with ER projects and poor understanding of the benefits that could be gained through retrofitting.

Table 4: Barriers for the Adoption and Implementation of ER projects

No.	Barrier	Number of respondents											
		Pre-retrofit Phase				Implementation Phase				Post-retrofit Phase			
		Case IH1	Case ES1	Case IH2	Total	Case IH1	Case ES1	Case IH2	Total	Case IH1	Case ES1	Case IH2	Total
Financial barriers													
01	High up-front capital expenses	3/7			3/14				0/14				0/14
Technical barriers													
02	Lack of knowledge on efficient retrofit technologies	1/7	1/3		**2/14**				**0/14**				**0/14**
03	Lack of technical knowledge and expertise	1/7	3/3		**4/14**				**0/14**	1/7			**1/14**
04	Difficult to convince the top management to undertake ER projects	1/7	1/3	3/4	**5/14**				**0/14**				**0/14**
05	Lack of predictable roadmap to identify the opportunities	4/7			**4/14**				**0/14**				**0/14**
06	Difficult to evaluate and quantify the benefits of retrofitting	5/7			**5/14**				**0/14**	1/7	1/3	4/4	**6/14**
07	Lack of access to certain technological platforms or software				**0/14**				**0/14**	1/7			**1/14**
08	Difficulties in attaining the expected savings									1/7	1/3		**2/14**
Informational barriers													
09	Lack of information (lack of availability of energy consumption data)	2/7			**2/14**				**0/14**	1/7			**1/14**
10	Lack of transparency about energy cost and use	2/7	1/3	3/4	**6/14**	1/7			**1/14**	1/7			**1/14**
11	Unawareness of locally available incentives for energy conservation projects	4/7	1/3		**5/14**				**0/14**				**0/14**
12	Lack of accuracy and reliability of available data	1/7			**1/14**				**0/14**				**0/14**
Managerial barriers													
13	Poor project management practices				**0/14**	4/7		3/4	**7/14**				**0/14**
14	Delays in getting the ordered equipment		1/3		**1/14**			3/4	**3/14**				**0/14**
15	Delays in getting the approval from the local authority				**0/14**	5/7			**5/14**				**0/14**
16	Interruptions to building operation and management				**0/14**	4/7	2/3		**6/14**				**0/14**
17	Lack of skills and experience			3/4	**3/14**	2/7	2/3	4/4	**8/14**	4/7	2/3		**6/14**
Institutional barriers													
18	Unsystematic way of making decisions	4/7		2/4	**6/14**	4/7			**4/14**				**0/14**
19	Lack of leadership for ER projects	3/7			**3/14**				**0/14**			1/4	**1/14**
20	Difficulties in establishing communication between parties	1/7	1/3		**2/14**		1/3		**1/14**	1/7			**1/14**
21	Lack of programme design expertise		1/3	3/4	**4/14**				**0/14**				**0/14**
22	Lack of proper programme monitoring expertise				**0/14**				**0/14**		3/3	4/4	**7/14**
23	Low versatility for intervention in existing buildings	4/7			**4/14**				**0/14**				**0/14**
24	Lack of staff training				**0/14**				**0/14**	2/7			**2/14**
25	Occupancy type of the facility which caused, ▪ Difficulties in conducting the audits ▪ Difficulties in properly identifying the energy saving from the retrofitted system	1/7			**1/14**	3/7	3/3	4/4	**10/14**	1/7			**1/14**
26	Lack of time		2/3		**2/14**				**0/14**				**0/14**
27	Lack of proper coordination				**0/14**	1/7	2/3		**3/14**				**0/14**
28	Non-conductance of post occupancy assessment				**0/14**				**0/14**			3/4	**3/14**

Behavioural barriers												
29	Reluctance to invest in ER projects	1/7			**1/14**				**0/14**			**0/14**
30	Lack of commitment and engagement to ER projects		1/3	4/4	**5/14**			2/4	**2/14**		2/4	**2/14**
31	Difficult to change the attitude of the staff			3/4	**3/14**			4/4	**4/14**			**0/14**
32	Intense inter-disciplinary collaboration				**0/14**	4/7	2/3		**6/14**			**0/14**
33	Negligence of the stakeholders which caused system errors				**0/14**	3/7	1/3		**4/14**			**0/14**
Market barriers												
34	Perception of risk or uncertainty		2/3		**2/14**				**0/14**			**0/14**
35	Lack of trust and confidence on ESCOs	2/7	3/3		**5/14**				**0/14**			**0/14**
36	Difficulties in finding reliable source of advice			2/4	**2/14**				**0/14**			**0/14**
37	Difficulties in selecting the most suitable supplier			1/4	**1/14**				**0/14**			**0/14**
38	Difficulties in finding certain ancillaries needed for the implementation				**0/14**	2/7			**2/14**			**0/14**
39	Uncertainty of the availability of the needed resources to run the retrofitted system				**0/14**				**0/14**	2/7		**2/14**
Social barriers												
40	Low level of public awareness and understandings				**0/14**	3/7			**3/14**			**0/14**
41	Social norms with respect to the thermal and acoustic comfort, light and air quality			1/4	**1/14**				**0/14**			**0/14**
42	Negative perception regarding the project				**0/14**	1/7			**1/14**	4/7		**4/17**

Analysis of the findings revealed that, 'difficult to convince the top management to undertake ER projects' and 'lack of transparency about energy cost and use' are the barriers mentioned by all three cases in pre-retrofit phase. Since Case IH1 had to develop the needed support infrastructure for the retrofitted system and as this particular ER project was initially led by head office team as a whole, in this phase 'high up-front capital expenses' and 'lack of leadership for ER project' are the unique barriers faced by this case. Conversely, 'lack of time' of the in-house staff to plan and execute the ER project, and 'perception of risk or uncertainty' are the distinctive barriers which led Case ES1 to plan and execute their ER project using ESCO. On the other hand, Case IH2 has disclosed that 'lack of skills and experience', 'difficult to change the attitude of the staff', 'difficulties in finding reliable source of advice', 'difficulties in selecting the most suitable supplier', and 'social norms with respect to the thermal and acoustic comfort, light and air quality' are the barriers uniquely faced by them in pre-retrofit phase mainly owing to their lack of previous experience with ER projects. Besides, 'unsystematic way of making decisions' is the one and only barrier faced by both in-house led projects i.e. Case IH1 and IH2, which insist the vitality of mapping the decisions to be made throughout the project and get the needed consultations from the respective parties in in-house led projects prior to make decisions.

In **retrofit implementation phase**, Case IH1 which had to get certain approvals from local authority, has faced certain 'delays in getting approval from the local authority' due to the negligence of the respective authorities. Case ES1 which is led by ESCO has specified that 'occupancy type of the facility' is the barrier that they have encountered while retrofitting the facility. Equally, Case IH2 has mentioned that 'lack of skills and experience' of the in-house staff with implementation of the selected ER measures, 'occupancy type of the facility', and 'difficult to change the attitude of the staff' were the key barriers that they have encountered.

Since all three ER projects are being done in hotel facilities which have 24/7 operation and as in-house team of the selected cases did not have enough expertise with the implementation of particular ER measures, 'lack of skills and experience' and 'occupancy type of the facility' are being highlighted as the barriers encountered by all three cases in retrofit implementation phase. On the other hand, 'poor project management practices' is the barrier faced only by both in-house led cases i.e. Case IH1 and IH2 in retrofit implementation phase, which indirectly implies the existence of lack of knowledge with the in-house staff about the way to run an ER project and thereby insist the need of adopting a good approach to manage the ER project. Besides, 'difficulties in establishing communication between parties' is the barrier highlighted by Case ES1 in retrofit implementation phase since in this case the project is mainly led by an ESCO but along with the involvement and consultation of the in-house employees.

As the total cost of the project and most suitable financing options are determined in pre-retrofit phase and as in retrofit implementation phase physical implementation of selected ER measures takes place, the possible influence of financial and technical aspects in implementation phase would be very low. Similarly, in this phase, none of the cases have specified financial and technical barriers while 'lack of transparency about energy cost and use' is the one and only informational barrier reported by Case IH1.

In **post-retrofit phase**, 'lack of skills and experience' for the staff to properly operate the newly implemented system, and neighbourhood's 'negative perception regarding the project' (i.e. neighbourhood's fear of boiler explosion) are the key barriers highlighted by Case IH1. Similarly, the key barrier faced by Case ES1 in post-retrofit phase is 'lack of proper programme monitoring expertise' which has insisted the ESCO to establish a proper M&V protocol as well as to assist the client in doing M&V. Case IH2 which did not have prior experience with retrofitting have specified that 'difficult to evaluate and quantify the benefits of retrofitting' and 'lack of proper programme monitoring expertise' are the key barriers that they have faced.

Since in hotel buildings occupancy pattern tend to change time to time, all three cases have found 'difficulties in evaluating and quantifying the benefits of retrofitting'. Conversely, 'lack of technical knowledge and expertise', 'lack of access to certain technological platforms or software', 'lack of information (lack of availability of energy consumption data)', 'lack of transparency about energy cost and use', 'difficulties in establishing communication between parties', 'lack of staff training', 'occupancy type of the facility', 'uncertainty of the availability of needed resources to run the retrofitted system', and 'negative perception regarding the project' are the barriers which hindered the effective execution of the tasks only in Case IH1 in post-retrofit phase. On the other hand, the barriers faced only by Case IH2 in post-retrofit phase mainly due to their lack of prior experience with execution of ER are 'lack of leadership for ER projects', 'non-conductance of post occupancy assessment', and 'lack of commitment and engagement to ER projects'.

Financial barriers were not being encountered by any of the selected cases in post-retrofit phase since in post-retrofit phase no any significant amount of cost needed to be incurred. Technical barriers and institutional barriers are the barriers highlighted by selected cases in post-retrofit phase while the other types of barriers were being rarely mentioned. For instance, 'lack of skills and experience' is the one and only managerial barrier faced by selected cases i.e. Cases IH1 and ES1 in post-retrofit phase. Similarly, 'lack of commitment and engagement to ER project' faced by Case IH2 is the only behavioural barrier affirmed in this phase. Equally, 'uncertainty of the availability of the needed resources to run the retrofitted system' is the one and only market barrier ascertained in this phase while 'negative perception regarding the project' is the only social barrier identified in this phase and are faced by Case IH1.

In brief, though some regulatory barriers were elicited through the review of existing literature (Refer Table 1), the case study analysis did not identify any barriers relating to the regulatory aspects and thereby disclosed their lack of impact on the project success. As given in Table 1, 'high up-front capital, 'lack of information', 'lack of access to finance' and 'lack of knowledge and know-how' are highlighted by most of the authors in the existing literature as the main barriers for the adoption and implementation of ER projects. However, the analysis of the findings disclosed that these barriers impact the retrofit projects in different ways during the different project phases. For instance, 'lack of transparency about energy cost and use' and 'unsystematic way of making decisions' are the barriers highlighted by most of the respondents in pre-retrofit phase, while 'poor project management practices', 'interruptions to building operation and management', 'lack of skills and experience', 'occupancy type of the facility', 'intense inter-disciplinary collaboration' are being stressed by the respondents in retrofit implementation phase. Conversely, 'difficult to evaluate and quantify the benefits of retrofitting' and 'lack of skills and experience' were divulged by respondents as the key barriers in post-retrofit phase.

As a whole, among the derived enablers in this study, thirteen (13) enablers are consistent with the literature while rest of the enablers are purely ascertained through the case study analysis (Refer Tables 1 and 3). Conversely, among the barriers identified through the case study analysis, most of the barriers i.e. twenty-eight (28) barriers seem to be in-line with the barriers compiled from the literature review, while rest of the fourteen (14) barriers are identified mainly via the case study analysis (Refer Tables 1 and 4). Besides, among the barriers derived through the literature, most of the barriers i.e. thirty-one (31) are not being divulged by the case study respondents and thereby clearly distinguishes the barriers that can impede the success of ER projects in the local context (i.e. Sri Lankan context).

5. CONCLUSIONS

This paper identified the enablers and barriers that influence the adoption and implementation of ER projects using three case studies. In total, seven (7) groups of enablers and eight (8) groups of barriers were identified (Refer Tables 3 and 4).

Among the 24 enablers identified, the research suggests that for any ER project, 'commitment, engagement and support from the involved parties' throughout the project is crucial to facilitate the successful project execution while 'availability of technical knowledge and expertise' and 'past experience with similar projects' are crucial in both pre-retrofit and retrofit implementation phases to ensure the project success. Further it has been ascertained that in in-house led ER projects 'availability of technical knowledge and expertise' throughout the project is vital to ensure the project success.

Altogether, forty-two (42) barriers that can impede the successful adoption and implementation of ER projects in existing hotel buildings was also identified. Herein, 'lack of transparency about energy cost and use', 'lack of skills and experience', 'difficulties in establishing communication between parties' and 'occupancy type of the facility which caused difficulties in conducting the audits and difficulties in properly identifying the energy saving from the retrofitted system' are the barriers which had significant impact in impeding project in all three phases. Besides, the possibility of encountering commitment issues (i.e. lack of commitment and engagement to ER projects) in all three phases of ER project by the organisations who do not have prior experience with retrofitting is also being ascertained through case study analysis.

Further, this research has made it vivid that the pathways to the implementation of ER project is complex and insisted that the further research in this arena should investigate the strategies that can be used to overcome the identified barriers. Although this research was limited to only three cases, valuable insights gained provide

industry practitioners with a set of enablers and barriers to be considered when pursuing ER projects. This research can help industry practitioners in understanding the enablers and barriers for the adoption and implementation of ER projects and accordingly ensure success.

6. ACKNOWLEDGEMENT

The authors would like to acknowledge the support received from the Senate Research Committee of University of Moratuwa, Sri Lanka under the Grant SRC/LT/2017/18.

7. REFERENCES

Alm, E., Boland, I., Cobb, V., Eaton, E., Newcomer, M., Pajkowska, J., Perl, Y., Wallentine, L. and Zeller, A., 2005, "Workshop in applied earth system policy analysis", paper presented at Final Workshop Report, Columbia University, New York, NY.

Ashrafian, T., Yilmaz, A. Z., Corgnati, S. P. and Moazzen, N., 2016. Methodology to define cost-optimal level of architectural measures for energy efficient retrofits of existing detached residential buildings in Turkey. *Energy and Buildings*, *120*, 58-77.

Beillan, V., Battaglini, E., Huber, A., Mayer, I., Goater, A. and Trotignon, R., 2011. Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. In *Energy efficiency first: The foundation of a low-carbon society*. Available from http://www.irbnet.de/daten/iconda/CIB_DC23299.pdf

Bruce, T., Zuo, J., Rameezdeen, R. and Pullen, S., 2015. Factors influencing the retrofitting of existing office buildings using Adelaide, South Australia as a case study. *Structural Survey*, *33(2)*, 150-166.

Choi, B. E., Shin, J. H., Lee, J. H., Kim, S. S. and Cho, Y. H., 2017. Development of Decision Support Process for Building Energy Conservation Measures and Economic Analysis. *Energies*, *10(3)*, 324.

Chunduri, S., 2014. *Development of planning and design phases of an integrative building life-cycle process model for advanced energy retrofit projects*. Thesis(PhD). Available from: https://etda.libraries.psu.edu/files/final_submissions/9943

Davies, P. and Osmani, M., 2011. Low carbon housing refurbishment challenges and incentives: Architects' perspectives. *Building and Environment*, *46(8)*, 1691-1698.

Dixon, T., Britnell, J. and Watson, G. B., 2014. *'City-wide' or 'City-blind?' an analysis of emergent retrofit practices in the UK commercial property sector* (ISSN 2052-1618). PSRC Retrofit 2050, Cardiff.

European Climate Foundation (ECF), 2013. Assessing Europe's Building Stock. Available from https://europeanclimate.org/bpie/

Friege, J. and Chappin, E., 2014. Modelling decisions on energy-efficient renovations: A review. *Renewable and Sustainable Energy Reviews*, *39*, 196-208.

Hou, J., Liu, Y., Wu, Y., Zhou, N. and Feng, W., 2016. Comparative study of commercial building energy- efficiency retrofit policies in four pilot cities in China. *Energy Policy*, *88*, 204-215.

Hwang, B. G., Zhao, X., See, Y. L. and Zhong, Y., 2015. Addressing Risks in Green Retrofit Projects: The Case of Singapore. *Project Management Journal*, *46(4)*, 76-89.

International Energy Agency (IEA), 2003. Creating Markets for Energy Technologies. OECD/IEA, Paris.

International Finance Corporation Sri Lanka (IFCSL), 2013. *Ensuring sustainability in Sri Lanka's growing hotel industry*. International Finance Corporation World Bank Group. Available from: https://www.ifc.org/wps/wcm/connect/30f331004fddd89eb9d8ff23ff966f85/Mapping+Report++-+Ensuring+Sustainability+in+Sri+Lanka%E2%80%99s+Hotel+Industry.pdf?MOD=AJPERES

Kalc I., 2012. *Energy Retrofits of Residential Buildings – Impact on Architectural Quality and Occupant's Comfort*. Thesis (MSc). Norwegian University of Science and Technology, NTNU.

Liang, X., Peng, Y. and Shen, G. Q., 2016. A game theory based analysis of decision making for green retrofit under different occupancy types. *Journal of Cleaner Production*, *137*, 1300-1312.

Ma, Z., Cooper, P., Daly, D. and Ledo, L., 2012. Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, *55*, 889-902.

Miller, E. and Buys, L., 2008. Retrofitting commercial office buildings for sustainability: tenants' perspectives. *Journal of Property Investment & Finance*, *26(6)*, 552-561.

Moder, E., 2013. *A Decision-Making Model for Building Energy Retrofits*. Thesis (BSc). Princeton University

Painuly, J. P., 2009. Financing energy efficiency: lessons from experiences in India and China. *International Journal of Energy Sector Management*, *3(3)*, 293-307.

Rhoads, J., 2010. Low Carbon Retrofit Toolkit—A Roadmap to Success. Available from: http://climatechangeecon. org/index. php.

Sri Lanka Energy Managers Association (SLEMA), 2009. *Energy management guide* (version 1). Sri Lanka Sustainable Energy Authority.

UNEP, F., 2014. Commercial Real Estate-Unlocking the energy efficiency retrofit investment opportunity. United Nations Environment Programme Finance Initiative, Geneva. Available from: http://www. unepfi. org/fileadmin/documents/Commercial_Real_Estate. pdf).

Wilcox, P., 2010. *Existing Building Renewal: Deep Energy Renovation - Planning Workshop Summary Report*. Northwest Energy Efficiency Alliance.

Zuhaib, S., Manton, R., Hajdukiewicz, M., Keane, M. M. and Goggins, J., 2017. Attitudes and approaches of Irish retrofit industry professionals towards achieving nearly zero-energy buildings. *International Journal of Building Pathology and Adaptation*, *35*(1), 16-40.