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Barriers to Adoption of Sustainable Technologies for Energy-Efficient Building Upgrade—Semi-Structured Interviews

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Abstract: Globally, only 2% of existing building stock is built yearly; the remaining 98% already exist. Energy consumption and indoor thermal comfort of the existing building stock are not encouraging. This is due to many challenges associated with existing buildings; the challenges range from cracks, leakages, poor insulation, heat losses and high rate of unsustainable technologies. This paper investigates possible barriers facing the adoption and application of sustainable technologies (STs) for sustainable or energy-efficient upgrade of existing buildings. New STs are manufactured on a regular basis to meet improved energy efficiency standards, yet there are minimal actions/attempts to adopt and apply improved technologies in existing buildings for energy efficiency. Indeed, there are limited studies focused on the use of qualitative approaches to identify barriers to adoption and use of STs. Thus, a semi-structured interview approach was adopted and applied using sustainability/energy efficiency professionals, building services engineers, project managers, architects, and facility managers in Australia. The results indicate that barriers to the adoption and application of sustainable technologies are perceived benefits in demolish-and-build, age of building, cost of STs, perceived poor payback time, unreliable energy-savings projections, existing design, hidden and overall cost of renovation, and cost of STs.

Keywords: energy consumption; indoor thermal comfort; energy efficiency; barriers; sustainable technology; sustainable upgrade; existing buildings; semi-structured interviews

1. Introduction

Existing buildings are increasing every year; however, they are faced with many defects because of exposure to severe weather conditions and usage. These defects include cracks, dead holes, and high level of infiltration, which affect energy consumption. According to the Australian Sustainable Built Environment Council (ASBEC) [1], energy consumption in existing buildings is close to 19% with 23% of carbon dioxide (CO_2) emissions. Sustainable technologies (STs) are technologies used in the building envelope and its insulation, for space heating and cooling systems, water heating, lighting, and controlling, for passive actions to reduce energy consumption and indoor thermal comfort [2]. Specific ones include double glazing, triple skin, smart glazing and e-glazing, solar hot water systems, solar panels, underfloor air distribution (UFAD) systems, chilled beams, variable speed drives, LED lighting and sensors etc. Undeniably, the application of sustainable technologies to improve energy savings of existing buildings can lead to substantial reductions in greenhouse gas (GHG) emissions. These technologies lead to the creation of environmentally sound and resource-efficient environments, high performance of buildings and a reduction in GHG emissions [2,3].

Buildings improved with sustainable technologies and other construction procedures reduce the ecological, human health and environmental life-cycle implications of a project [4]. The upgrade of technologies in existing buildings has been increasing over time through sustainable upgrade. Indeed, STs have been adopted and installed through renovation to improve the energy consumption of existing buildings [5,6].

Unlike new buildings, existing buildings are not improved regularly to match or incorporate newly developed technologies [7]. For example, over decades, heating and cooling systems and smart envelope technologies have undergone extensive revolution, yet renovation of existing buildings with STs is still low. Thus, the expected energy savings from sustainable upgrade are often not achieved. This is due to the adoption of low energy-saving STs, which contributes minimally to energy reduction targets [8]. To date, only a few studies have addressed the sustainable upgrade of existing buildings with a specific focus on barriers affecting the adoption, using a detailed qualitative approach. This study seeks to use semi-structured interviews to investigate barriers affecting the adoption and installation of STs in existing buildings in Australia. The rest of the paper is organized as follows: a review of the nature of existing buildings, STs used for sustainable upgrade, and barriers to the adoption of STs. This is followed by methods applied to generate qualitative data, and content analysis of data. The article concludes with discussion and concluding remarks.

2. Literature Review

2.1. Existing Buildings

New buildings contribute only 2% to existing building stock in Australia. Accordingly, old buildings comprise approximately 98% of the nation's total building stock [9]. The United Kingdom (UK) Office for National Statistics estimated that new buildings account for approximately 1% of the stock each year and in the United States of America (USA), the Energy Information Administration (EIA) reports that existing buildings make up close to 99% of the total building stock. These cases are not different from other developed and developing countries [10]. This is a source of concern because the vast majority of the buildings to be occupied in the next thirty years or so have been built already [11]. It is often argued that, as this large stock is to cater for the increase in population, a large proportion end up consuming more energy, thereby negatively affecting the environment [12]. Unfortunately, these buildings are associated with several defects such as cracks [13], corrosion of steel components in old buildings [14], heat losses because of poor insulation [15], highly unclassified [16], high level of air infiltration [17], and leakages [18]. The leakages can be attributed to differences in design and workmanship [19]. These have generated concerns about possible energy and environmental impact of existing buildings.

Indeed, energy consumption of existing buildings has been highly argued, with available estimates and projections indicating that energy demand could rise by 50% in 2020. Global energy use of existing buildings is about 40% [20] of which a significant proportion might be wasted due to various faults in building design, construction and particularly in operation stages [21]. Additionally, existing buildings are responsible for 41% of energy consumption and 36% of carbon dioxide (CO_2) emissions in the EU, and 39% of total energy use and around 38% of CO_2 emissions in the USA. Similarly, Australian cities have approximately 21 million square meters of commercial office space spread across nearly 4000 buildings most of which, if measured by net lettable area, consists of low-grade office buildings [22].

According to Australian Government Department of Climate Change and Energy Efficiency (DCCEE) [23], energy consumption in standalone offices is estimated to be 26.4 PJ in 1999; this increased to 33.6 PJ in 2009 and further projected to reach 38 PJ by 2020. This presents a margin of 14% from 1999 to 2009 and over 29% comparing 1999 and 2020 projections. This pattern is similar to other types of buildings studied by DCCEE [23]. Thus, the need for improvement of existing buildings through renovation with STs is very high [11]. Fortunately, energy use in existing buildings can be reduced significantly through effective renovation or retrofitting [24].

2.2. Definition and Types of Sustainable Technologies for Sustainable Upgrade

A sustainable technology (ST) is any well-designed technology capable of addressing high energy demands without posing negative effects to the environment. Any technology that exceeds the benchmark of conventional systems in reducing energy can be classified as a sustainable technology [25]. There are many types of these technologies. Thus, Smith [26] provides a range of various sustainable technologies. They include solar thermal, low-energy techniques for cooling, geothermal, wind energy, photovoltaic cells, and bioenergy. However, Syed [25] improved the various types of sustainable technologies for new and existing buildings provided by Smith [26]. They include the underfloor air distribution system, radiant cooling, displacement ventilation, chilled beams, and displacement induction unit. Others are high-performing envelope, solar energy, geothermal systems, and cogeneration. Also, Goswami and Kreith [27] improved the studies on the HVAC systems conducted by Syed [25] and provided detailed descriptions of the functions of each component required for energy efficiency. Although these studies were extensive, key technologies such as lighting and lighting control systems were not addressed by Syed [25] and Goswami and Kreith [27].

These gaps relating to lighting and lighting control systems were earlier filled by DiLouie [28] and Atkinson et al. [29]. There are other types of sustainable technologies: the green roof [30], and renewable technologies such as solar panels and solar hot water systems [31]. The green roof technology is generally considered a passive approach used to reduce energy consumption in buildings. The passive approach is consistent with building retrofitting actions in existing buildings [32,33]. A simple framework for adoption of STs has been shown in Figure 1. This framework proposes a simple way of adopting STs for energy improvements in existing buildings. Under this structure, attention is given to the building envelope as the main driver for technology adoption decisions due to its relationship with the outside environment.

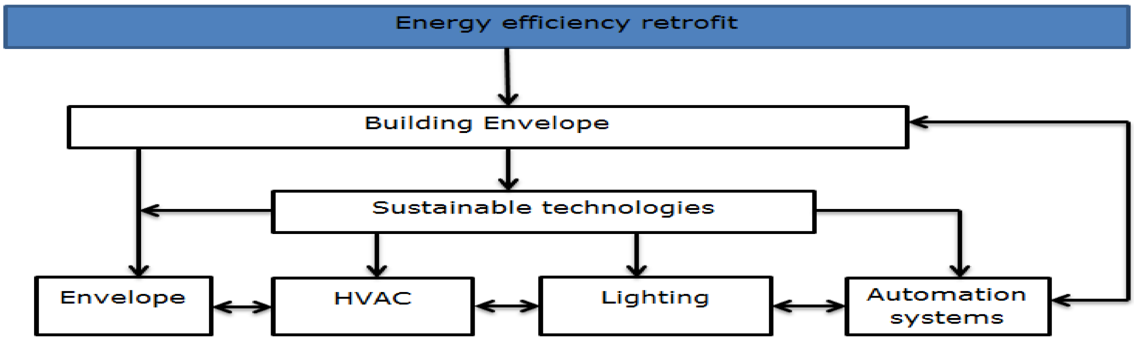

Figure 1. Framework of sustainable technology application adopted from [8].

2.3. Barriers to the Adoption of Sustainable Technologies for Sustainable Upgrade

Despite the use of STs to improve energy consumption of existing buildings, there are challenges. This is surprising, particularly when energy use and its impact on the environment is on the rise. The barriers are generally broad and thus unorganized. Studies in this field tend to associate barriers to the adoption of STs to the barriers to sustainable construction. In many instances barriers to adoption of STs are considered as barriers of sustainable construction as shown by Chan et al. [34], although there are specific barriers to adoption of STs. These are grouped under various headings: cost, inadequate marketing strategies, lack of knowledge about the technology and many others.

In relation to cost, the initial cost of investment is a deterrent to investors, thus affecting the rate of adoption and application to reduce energy consumption of existing buildings [34]. This is consistent with similar findings established by Hirmer and Cruickshank [35]. Often, high cost of investment also affects the rate of adoption particularly where the STs are not available on the local market, thus imported [36]. Indeed, high cost drives potential buyers away irrespective of the need to address energy consumption in existing buildings [37]. Manufacturers are concerned with the ability to recover cost of investment; often this condition affects pricing [38]. The implication is that clients or investors are unable to adopt expensive technologies particularly those targeting HVAC systems and the envelope. This means that energy-saving actions are unlikely to meet the drive towards environmental sustainability. Consequently, potential investors are forced to apply other inferior technologies leading to high energy consumption in existing buildings.

Similarly, sales and marketing are closely related, particularly where diffusion and adoption of technology are concerned. Thus, there is a relationship between sales and marketing strategies [39]. This implies that, where good marketing strategies are not adopted, the rate of adoption and use of STs can be affected. This is often related to the lack of a defined and proper supply chain in the distribution line. In many instances, there is a breakdown in the supply chain line, thus affecting marketing of STs [35]. This could be due to lack of a large or broad market base [40] and inadequate marketing strategies linked to STs [41]. Certainly, lack of good marketing strategies could be a factor in the low level of awareness associated to STs [38], thus affecting sustainable construction [42]. Also, it can be attributed to the main stakeholders in the energy efficiency industry [43]. Indeed, where consumers, clients and investors are not aware of perceived energy-saving potentials of a particular technology, actions towards adoption and application are often low [44].

Furthermore, lack of awareness affects the adaptability of technology [42] usually perceived as a result of insufficient information about the technology and its potentials [45]. In addition, Kennedy and Basu [45] stated that, in many instances, there is insufficient replacement for some of the technologies thus affecting rate of use, largely due to the complexity of the design of the technologies [46]. The technologies have their efficiencies, which are, in many cases, doubted. There is the perception that these technologies are not able to meet specified energy-saving targets [38]. In some instances, lack of energy efficiency policies contributes to slow adoption of energy-saving technologies [42]. These policies are often not rigorous enough to restrict the use of conventional technologies [34].

However, these discussions are not focused on qualitative methods. Thus, ref. [47] used interviews to supplement survey questionnaires to identify barriers to green technology adoption. The authors identified cost as the main barrier. Similarly, ref. [48] used interviews as part of a case study research and identified lack of promotion and incentives from governments and maintenance cost as barriers to adoption of green roof strategies. In addition, ref. [49], through interviews, provided empirical evidence of barriers to energy-efficient technology adoption to include the low influence of highly motivated stakeholder on the decision of adoption. Inadequate financial resources, low grid capacity, delays in the issuance of building permits, opposition from local communities and the lack of a stable institutional framework are among the most important barriers that inhibit the diffusion of wind and PV solar power [50]. However, in these studies, the selection of participants is restricted to only the cases, thereby reducing the depth of the responses and findings. Also, the majority of these studies are used to supplement other quantitative methods. It is further contended that there could be barriers affecting the application of STs particularly through sustainable building upgrade.

3. Research Methodology

Interview is one of the popular tools for data gathering and has been widely used in the built environment. It is easily modelled into various types and very useful for quantitative questions studies as well [51]. A qualitative research interview is a form discussion where the interviewer obtains information from participants relating to personal views about a specific area, usually regarded as a conversation with a purpose [52]. Also, Denzin and Lincoln [53] supported the views raised by Kvale [52] referring to interview as a conversation; it is the art of questioning and listening. However, there are various types: structured, semi-structured and unstructured [53,54]. The semi-structured interview, which is the focus of this paper, provides a different approach compared to the structured and unstructured methods. Under this approach, the questions are somewhat structured yet participants have the freedom to introduce new ideas during the interview. They are open-ended in nature where the questions allow creativity and flexibility. This is because it involves the use of open-ended questions or topics designed before data is collected thereby introducing some degree of flexibility into a study [55]. This could be the reason semi-structured interviews are considered one of the most effective and convenient ways of collecting qualitative scientific data [56].

Data Collection

The main methods for conducting semi-structured interviews include face-to-face conversation, email, video conference and telephone [57]. However, the choice of a particular approach is based on several reasons. They include the availability of participants, the location, work load and closeness to past documents for referrals [58]. In line with the aim of the study, two approaches out of the four proposed by Denzin and Lincoln [57] were used: face-to-face and telephone for all the eleven (11) participants. The semi-structured interviews followed Patton's [59] general interview guidelines. Consequently, the interview guide was grouped into two main sections, each addressing STs and barriers to adoption of STs. Also, a list that shows the topics and questions to be covered was developed as proposed by Kvale and Brinkmann [56]. The potential respondents were identified through personal contacts or referrals, company websites and professional associations as shown in Figure 2. Thereafter, invitation letters were sent to the professionals who had the required training and experience. Those recommended by other professionals were given the option to accept or reject the invitation to participate in the interview process.

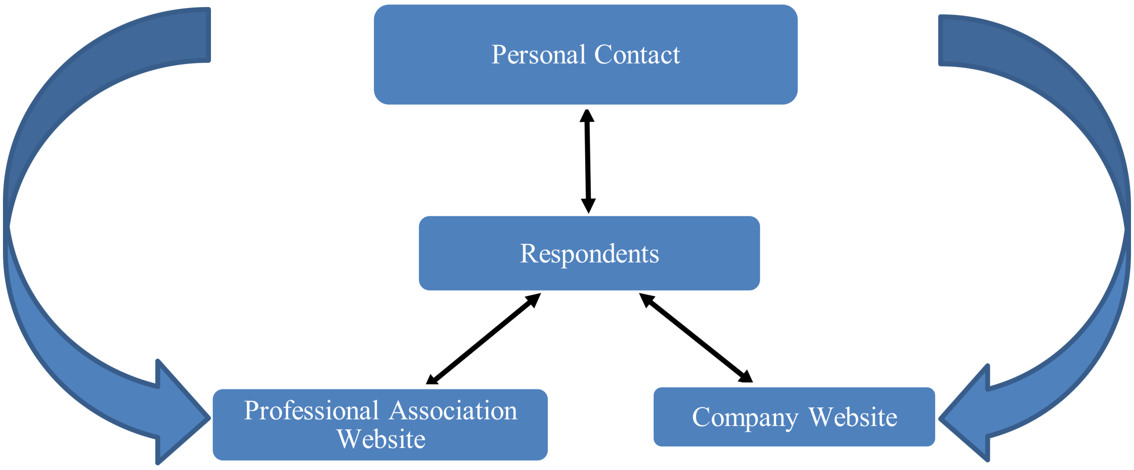

Figure 2. Respondent selection and survey distribution.

Subsequently, the interview process followed with all the participants. The open-ended section of the interview addressed background information of the interviewees or participants and their past experience, and reviewed some projects related to the use of STs to improve energy performance. This step essentially provides a good support in relation to the validity of the interview process. That is, whether those interviewed had the required experience adequate to support the data. The second section focused on the existing buildings renovated and the challenges facing adoption of STs.

The interview process for the face-to-face started with an introduction of the interviewer. This process was followed by questions on all the headings relating to sustainable technology and building existing buildings. Starting with open questions allowed participants to identify and expand their thoughts, thus having a general idea of what the interview could likely entail. This also created an encouraging and friendly environment which improved the level of confidence of participants. However, the order of the topics as stated in the guide were not strictly followed. This is because for semi-structured interviews, participants are allowed the freedom to contribute without strictly following the guide by Robson [60]. As such, not all the questions followed the order in which they appeared, and the wording was not strictly followed. This was because the semi-structured interviews approach requires a mix of structured questions and other open questions. Indeed, the main aim was not to cover all the questions developed but to seek the knowledge of the experts [61]. During this process the recorder had been set to record all the proceedings. Also, the main points raised by the interviewees were written down. The main themes were introduced after the earlier ones were fully explained. This process takes some time to fully conclude. In addition, the composure and actions of the participants were jotted down in a notebook. The average time of the face-to-face interview was 56 min. Almost 60% of all the interviewees were taken through the face-to-face approach.

Similarly, the second phase of the interview adopted the telephone approach. Unlike face-to-face interviews, telephone interviews have a large coverage [62,63]. The steps to conduct a telephone interview introduced by Patton [64] were adopted. Key words relating to energy efficiency and sustainable technologies were abbreviated. This facilitated writing and listening processes in order not to miss any key points raised by the interviewees. On average, the interviews were conducted weekly, due to availability and willingness of participants. Thus, after each process of the interview, records or notes were fully transcribed to keep intact all relevant and salient points established during the conversation. This helped to easily recall other missing words or lines. It also helped in the follow-up with the interviewee for clarification on areas that were not clear after the transcription was done. This is because a quick way of keeping records of telephone interview is to do a follow-up with interviewees for further clarification [65]. During the interviews, several steps were taken to ensure proper conduct and avoid any possible biases from creeping in as proposed by Patton [64]. They are:

- asking one question at a time;
- remaining neutral as far as possible by trying not to show strong emotional reactions to responses, for instance;
- taking control of the interview by sticking closely to questions of interest.

This adopted approach is consistent with studies conducted in energy efficiency renovation with sustainable technologies by Achtnicht and Madlener [66]. Also, there are similar studies in built environment research on energy studies where interviews were used to supplement survey or case studies. In addition, semi-structured interviews were used by Andersen et al. [67] to supplement an experimental study. The interviews were conducted with 10 occupants. Similarly, Wamuziri [68] undertook six interviews with senior safety/project managers in various construction organizations. Table 1 provides details of the participants interviewed.

Table 1. Details of participants.

Snr	Position	Firm	No. of Participants
1	Sustainability/Energy efficiency experts (S/EEE)	Consultants	4
2	Service/mechanical engineers (S/ME)	Consultants	3
3	Project Managers (PM)	Construction	2
4	Architects (ARC)	Self-employed	1
5	Facility Managers (FM)	Public institution	1

4. Analysis of Results

Stake [69] stated earlier that qualitative data analysis essentially involves separation of data into units, understanding the components and how they relate to each other. Miles and Huberman [70] summed up the idea of qualitative data analysis in the following words: “to review a set of field notes, transcribed or synthesized, and to dissect them meaningfully, while keeping the relations between the parts intact”. Creswell [71] argues that, regardless of the type of qualitative methodology employed, a common process to qualitative data analysis involving six steps. Thus, Creswell's [71] approach was found useful and thus adopted for the study. The analysis of the interviews followed 6 main steps:

- organization and preparation of data for analysis;
- reading the data repeatedly to get the general sense of the data;
- coding;
- description of setting;
- contextualizing and finding linkages between the themes;
- interpretation of data.

In qualitative data analyses, coding can be done manually or by computer [59,67]. This study adopted manual color coding proposed by Creswell [71].

4.1. Challenges Faced Introducing Sustainable Technologies for Sustainable Building Upgrade

4.1.1. Perceived Gains in Demolish and Rebuild

For the analysis, buildings over 45 years old were considered very old. A Project Manager and an Architect agreed that to demolish and build an old building is economically beneficial than energy-efficient retrofit.

> *[Using past experiences … It is somehow better than investing millions of capital into whatever kinds of technologies to improve … energy consumption whereas the building is still old … . with many faults...]*

These sentiments are, as a result of the economic benefits, fewer CO_2 emissions and the overall environmental gains attached to actions targeting rebuilding old buildings, deemed a better option compared to upgrades with STs. They further added that:

> *[Pull down and rebuild, it is less expensive … it is likely to save in excess of 20% of the cost of investing in STs for energy efficiency … even 5% gains is still a good margin … ..]*

They argued that fairly new buildings are sometimes considered partially efficient and may require minimal upgrade with STs to improve energy performance compared to the very old buildings. This is not the same for the very old buildings especially those over 45 years old. The cost of rebuilding is generally less compared to undertaking huge retrofit with expensive STs. However, some Engineers were firm on heritage buildings.

> *[… there are reasons for restoring or keeping old buildings … .usually for heritage purposes else demolish-and-build presents a better economic option … .]*

Additionally, some of the participants agreed that for heritage purposes, old buildings can be maintained because of what they represent as well as the economic gains attached to heritage buildings. Heritage buildings attract tourists, and this translates into economic gains through job creation.

4.1.2. Unreliable Time to Recoup Investment

Almost all the Sustainability Consultants agreed that perceived time of recouping investment is a barrier to adoption of STs. Often, this depends on the formula used to calculate the Internal Rate of Return (IRR).

> *[Most of the clients are interested in short-term returns … .the new Energy Efficiency Policy seeks to address this shortfall by putting a limit to the repayment time - the maximum allowable as of 2014 is 4 years or less …]*

However, some of the Engineers, Project Managers and the Architect were of the view that limiting the return on capital invested is a barrier to adoption of high energy-saving technologies.

> *[Limiting the years to recoup investment is a disadvantage; it will not encourage clients to adopt expensive technologies which are likely to have long-term return on investment. Those less expensive technologies can be recovered under 2 years in most cases . . .]*

The Engineers further stated that one of the problems facing STs installation in existing buildings is the lack of a defined approach to improve capital savings.

> *[. . . the 2014 Energy Efficiency Policy is a good start although there are some limitations . . . . . . .there should be a well-designed, tested and acceptable approach to address this shortfall to improve investment...]*

Indeed, the focus of many investors is often not the capital invested, but the rate at which gains from investments can be recouped. Generally, investors turn to avoid actions or strategies which have long rate of return. The reason is that such long periods turn to lock the capital invested as well as increased interest repayment.

4.1.3. Sustainable Technologies Do Not Yield Calculated Energy Savings

The participants unanimously agreed that some clients perceived energy-savings targets as unachievable, particularly for existing buildings improved with STs. This confirms the general perception that clients are skeptical of estimated energy savings. They doubt the figures, and often think they are unachievable. This reflects the lack of appreciation of the environmental impact and climate change concerns because of excessive energy consumption of existing buildings.

> *[There are too many assumptions during energy auditing . . . some of them are because of lack of sub metering systems to effectively record energy consumption . . .] [Some clients try to upgrade to satisfy the regulations or policies governing energy efficiency, and not because they trust that STs are saving energy . . .]*

This is consistent with similar findings indicating challenges facing sustainable technology adoption include a general lack of belief. In addition, the Sustainability Consultants agreed that there is a general lack of trust which can be directly or indirectly linked to issues of sustainability and climate change.

> *[People do not believe. Some do not even believe climate change exist. The level of awareness is low . . . this has to improve though . . . .]*

This can be attributed to lack of data on energy-saving potentials of existing buildings. To achieve this requires publishing of energy savings achieved through renovations with STs. This will stimulate demand and actions towards the use of STs.

4.1.4. Age of Building

A Project Manager was concerned with the age of existing buildings. This is because the age reflects the level of defects and related cost of upgrade. Age of a building is known by observing the exterior and interior components of a building. It is often argued that the older the building the more the defects, particularly where there is a lack of planned maintenance.

> *[. . . Old buildings sometimes have less or no energy savings features . . . this makes them expensive and uneconomic to upgrade. It is sometimes difficult as monies are obtained from banks with interest...]*

The Facility Manager added that:

> *[. . . .Old buildings are old and very expensive to renovate. We hardly expect that clients can repay most of the monies spent over a short time...]*

These positions were collaborated by the Sustainability Consultants and the Architect during the discussions. Indeed, due to minimal education on such actions, these assertions do not take into consideration situations where old buildings can be improved with simple STs capable of achieving substantial energy reductions with minimal or no additional extra cost to the client.

> *[Irrespective of the nature of the building client and cost of refurbishment, the age of a building is critical to a client who has to take decisions on whether to invest or not. The general perception is that, old buildings are economically unattractive . . .]*

The perception is that old buildings have achieved their economic usefulness and value, thus investing heavily in terms of STs is usually considered uneconomical since the gains might not exceed losses. The Sustainability Consultants were firm in their assertions that buildings under 10 years old may not require the injection of high volumes of STs.

> *[. . . .Existing buildings under 10 years may not require renovation, it is not common to find many of such buildings . . . It is unusual to find very old buildings with poor energy consumption improved with STs. . . . it is very difficult for investors to improve such buildings . . . .]*

The clients consider upgrade of old buildings as unprofitable due the obvious deep-rooted defects such as roof leakages, air infiltration, heat losses, cracks, dead holes, and energy losses. With such defects, the most appropriate condition available is to demolish and rebuild.

4.1.5. Perceived Hidden Cost

There is a hidden cost in almost everything, from construction to retailing. This is high in renovation of existing buildings as they are deemed unpredictable and often uncoordinated. This position was expressed by some of the participants, especially the Architect and some Engineers.

> *[. . . Hidden cost of ceiling, lighting, flooring pipe works and painting associated with such improvements might not be considered but for economic reasons . . . .] [. . . .the moment a particular technology is chosen, it comes with components which might need replacement as well. In some cases, the additional cost are not estimated or anticipated at all . . . .]*

Generally, there are certain hidden costs associated with the improvements of existing buildings which tend to throw the initial budget for the refurbishment out of control. This is because some of the components are difficult to identify at the early stages of the cost analysis.

> *[Contingency budget are provided but not always sufficient . . . efficient renovations are likely to bring about extra cost . . . . . . .clients encountered had the idea that additional changes are likely to be effected and so are firm to stick to old estimates rather than accept any unexpected cost . . . [They (clients) are really reluctant to discuss issues relating to additional works which occur during renovations due to the cost implications.]*

The Sustainability Consultants shared similar views—renovations of an external wall with a sustainable façade or wall could lead to the removal of the windows, frames and doors and the introduction of cracks. These conditions contribute to additional cost, often unexpected.

4.1.6. Overall Cost of Refurbishment

The hidden cost associated with refurbishment is not the only reason some clients show lack of interest in the energy efficiency improvements/upgrades with STs. This position was highly articulated by professionals interviewed. Some of their quotes include:

[The cost of the STs combined with the actual cost of doing the refurbishment is a source of concern to some client . . .] [Some of the sustainable technologies are expensive . . . plus the cost of renovations . . . this requires thousands of dollars . . .][Some clients consider the cost as a problem . . . they often request detailed engineering estimates . . .]

Obviously, this does not present a good economic position to invest in expensive technologies without working to improve the other parts of the building particularly, sections that contribute to heat losses and poor energy management. Indeed, such renovations will include other sections or elements of the building, although may not be part of the general schedule.

[Renovation is renovation, whether for energy efficiency or for something else . . . .the main aim is to improve the value of the buildings . . . the cost of renovation is always compared to cost of new designs . . . this makes it difficult to use STs because of the perceived high economic returns attached to new buildings . . . .]

Installation of STs in existing buildings does not necessarily attract prospective investors or buyers. Thus, the concerns of investors and owners is how to reduce the cost of refurbishment, otherwise they are forced to adopt and install conventional technologies.

4.1.7. Type and Location of Building

In describing the barriers to the adoption of STs, the majority of the participants were convinced that location and type of building is an obstacle. There are different types of buildings—residential, commercial, educational, health, heritage, religious etc. Depending on the type and where they are located, decisions to upgrade with STs are accepted or rejected. Obviously, not all the buildings have the same level of economic demand; unfortunately, this tends to reflect in decisions relating to STs adoption and application.

[. . . STs investments in commercial buildings are usually preferred compared to other building types known to have poor investment recovery rate . . . ..sometimes the recovery of capital invested can take many years or not recovered at all . . . ..office buildings in the city are considered better than residential or retail buildings, ...]

Many investors in the energy efficiency sector often consider the gains in improving a particular type of building before deciding to invest. For instance, they consider the short-to long-term gains before taking any decisions to improve a particular building type. This implies that different types of buildings have different returns on capital invested.

[. . . ..Not all investors will invest millions into a residential building which presents poor returns or yield and also located in an area that attracts less rental charges . . .]

It is clear that, irrespective of the energy and environmental gains associated with the use of STs, the type and location of a building is a barrier to adoption of STs for energy-efficient upgrade. However, this can be improved with rigorous energy efficiency policy which can deal with the deficiencies caused by the cost of investment. This can encourage clients to upgrade with STs, without necessarily considering the type of build and location.

4.1.8. Nature of Existing Building Components/Design

A major factor that was common and constantly mentioned by the Project Managers, some Engineers and the Facility Manager was the nature of existing building elements. They indicated that some existing buildings have complex designs, thereby affecting the selection and installation of certain key STs.

> *[. . . .Room heights in the late and early 40s and 50s have changed. Those buildings had certain heights which make them difficult to improve with modern technologies irrespective of the expected thermal comfort and energy savings benefits...]*

The existing buildings have certain design characteristics in relation to the position of columns, beams and slabs, air conditioning systems and other building services, as well as the internal designs or dimensions. The Architect mentioned that sometimes these components or elements are difficult to replace, thus any decision to improve with new and efficient technologies becomes a challenge.

> *[. . . Spacing . . . spacing . . . .old buildings have spacing problems . . . sometimes with too many columns and concrete partitioning walls which attract extra work in order to install new STs . . . ...]*

According to the Sustainability Consultants, certain components of existing buildings make it difficult for the introduction of STs. This touches on the availability of space for extra pipe and duct works as well as other fixtures for telephone, internet, and water distribution.

> *[The underfloor is good for thermal and energy savings but cannot work in a space with very small room height. To fix the technology requires breaking all the floors and constructing new ones . . . .]*
> *[. . . . . . there could be resistance to the adoption of the LED technology because it could introduce massive overhaul of the existing conduit systems in the building . . .]*

The lighting systems are not the same; for example, the fittings of incandescent bulbs are not the same as that of LED bulbs. This means adopting LED bulbs demands a complete overhaul of the fittings as well. This was the position of the Facility Manager.

4.1.9. Cost of Sustainable Technologies

Cost drives decisions to adopt and use STs. According to majority of the participants, HVAC systems and façade upgrades of existing buildings present the most viable option for high energy savings in existing buildings. However, these are not often adopted because of the cost.

> *[The energy efficient technologies are expensive, this discourages clients and potential investors. For example chillers and smart glazing technologies . . . .]. [For large buildings this becomes a problem considering cost involved . . . .] . . . [Cost is a major challenge . . . .many clients have expressed the desire to adopt some solar PV panels...yet are unable to, because of the cost . . . .]*

The Sustainability Consultants added that:

> *[Some are too expensive to install....they can reduce energy consumption but too expensive . . . it becomes more expensive when added to the overall cost of renovation . . . .]*

This implies that cost is a major barrier to the adoption of STs for energy-efficient upgrades. This often leads to the adoption of alternative technologies with lower energy-saving potentials. Thus, attempts to link economic gains in the future to rate of adoption should be addressed, as some clients are interested in the initial cost and not the expected gains.

5. Discussion and Conclusions

Sustainable technologies are to a large extent installed in existing buildings through renovations to improve energy savings. However, the results indicate that clients and potential investors are interested in perceived gains from demolish-and-build against upgrading with STs. Indeed, this position is inconsistent with earlier studies conducted by Power [72] where reasons for maintenance instead of demolition of a whole building were elaborated. Also, Ding [73] argues that the concept of demolish-and-build leads to many environmental challenges. Energy-savings estimates are often undertaken to project payback time. This helps clients and investors to take decisions on whether to invest in a sustainable technology or not. Unfortunately, some of the technologies are expensive, thus affecting payback times. This discourages clients from investing due to the long period required to recoup capital invested as well as interest on capital invested. Poor payback periods lead to a situation whereby energy efficiency renovation measures are often avoided due to costs and unacceptable economic returns. This affects energy savings in old buildings thus attempts should be made to improve payback time [74]. This is important because unacceptable long payback periods make it difficult to recover the economic investment as well [75]. There is the perception that energy efficiency improvements do not achieve estimated energy savings. This affects actions towards adoption and use of STs. Indeed, this is a major barrier to adoption of STs and the related impact on environmental sustainability. There is the perception that these technologies are not able to meet specified energy-saving targets [38]. In some instances, lack of energy efficiency policies contributes to slow adoption of energy-saving technologies [43], thus forcing the Energy Efficiency Council in Australia to introduce various levels of sustainable renovations/upgrade. The first type of energy-efficient renovation is not detailed, requiring minimal action towards adoption and installation of high energy-saving technologies. This is an attempt to stimulate demand for STs.

In addition, the nature of existing building designs is a major source of concern, hindering attempts to adopt STs. The underfloor air distribution system, for example, requires a complete change of the flooring system of an existing building. These extra works add to the cost of renovation thus often avoided by clients and investors. The same applies to the nature of existing façade of a building where attempts to introduce high energy-saving technologies are avoided because of the nature and construction of existing façade. In some instances, the building envelope requires complete demolition to pave way for newly developed technologies. However, such actions are expensive thus hindering the introduction of new STs.

Accordingly, the findings can assist energy efficiency experts, government agencies, and academia to take a critical look at possible ways of improving energy reduction strategies for existing buildings. This study has elaborated nine challenges affecting adoption and use of STs to improve energy savings of existing buildings in Australia.

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