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THE KEY CONSTRAINTS UNDERLYING ENERGY RETROFIT OF THE RESIDENTIAL BUILDINGS IN MALAYSIA

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Abstract

The residential sector in Malaysia consumes 6% of the overall energy consumption. Energy retrofit of the existing residential buildings contributes as a significant carbon reduction measure in response to the overall sustainable development. The energy retrofit of the existing residential buildings is not considered under the existing GBI rating tools GBI and other energy guidelines in Malaysia. Thus, this study aims to investigate the key constraints underlying energy retrofit of the existing residential buildings in Malaysia, focusing on building envelope improvements. The study used a quantitative research methodology, using an online survey questionnaire. A total of one hundred and twenty (120) respondents completed the online survey. The descriptive statistical analysis was used to identify the key constraints faced by the house owners. Findings from the study revealed the critical factor affecting the consideration of Malaysian house owners or occupants towards energy retrofit is the financial factor (FF) which includes the cost of the retrofitting, the return or profit earned, and the payback period of the energy retrofits. Based on the findings, the policy factor is suggested to constitute a positive influence on financial aspects in affecting house owners or occupants' consideration towards the topic of this study. As a result, a consistent and effective policy tool is suggested in Malaysia to encourage the energy retrofitting of existing residential buildings.

Keywords: Energy retrofit, Key constraints, Malaysia, Residential building.

1. Introduction

Forty per cent (40%) of the world's primary energy Mari et al. [1] is consumed by buildings, with the residential sector accounting for 6 per cent of the total energy consumption [2]. Existing buildings make up most of the building stock in Malaysia, with 5,611,673 existing housing units as of 2019 [3]. Around 86.5 per cent of Malaysia's total building stock consists of existing residential homes. However, most present buildings are constructed without or with little regard for energy efficiency or environmental impact years or decades ago. Consequently, it is essential to retrofit existing residential buildings to improve energy efficiency, as these buildings consume more energy over time.

In 2009, the Malaysian Institute of Architects (PAM) and the Association of Consulting Engineers Malaysia (ACEM) established the Green Building Index (GBI). New green buildings cannot yet offset the detrimental impact of existing residential buildings on Malaysia's sustainable development. Given Malaysia's high density of residential buildings with high energy consumption, the energy retrofitting of existing residential buildings will be an essential carbon-saving measure for sustainable development. However, Malaysia’s existing GBI rating tools do not assess the energy retrofitting of existing residential properties. The house owner's perspective and intention remain the driving force in the start phase of energy retrofit. To encourage global sustainable development, it's essential to examine how residents in Malaysia make decisions on energy retrofitting. For this purpose, below is how five widely used projectile shapes are investigated. The geometry and total dimensions of these projectile shapes are shown body station. The supersonic Mach number range is from 1.6 to 5 for zero-angle of attack.

Most Malaysian buildings are built decades ago without concern for resource, energy, or environmental efficiency. "Ageing" residential buildings increase energy demand and reduce energy efficiency. Energy retrofits improve existing residential buildings' energy and environmental performance, declining health, and ecological consequences. Improving existing buildings’ environmental performance and energy efficiency can contribute to global sustainable development. "Energy retrofit" refers to changing a building's envelope (passive retrofit) or installing energy-efficient fixtures (active energy retrofit measure). Existing non-residential and industrial buildings can be retrofitted to reduce energy use and improve occupant health and productivity [4]. Most construction firms and Organizations disregard existing residential buildings. Sustainable development goals prioritise green building construction. However, the Malaysian green construction projects do not include low energy efficiency and environmental performance housing stock.

Energy upgrading existing buildings is more sustainable than developing new green buildings [4]. New construction produces more waste than retrofitting. A high volume of building waste causes water, soil, and air pollution, habitat destruction, and global warming. Construction and demolition (C&D) waste management is a crucial challenge for global sustainable development. Considering the resources required to build a new green building, particularly embodied energy for material manufacturing, contradicts the goal of green initiatives to promote sustainable development. In evaluating Malaysia's sustainable development, embodied energy in existing and new buildings should be addressed.

As a result of the rising global environmental catastrophe, massive energy retrofitting is required. It is also worth noting that existing residential structures can

contribute to the overall sustainable development in Malaysia through energy retrofitting. Furthermore, most existing residential buildings were built decades ago, regardless of resource efficiency, energy efficiency, or environmental performance. Environmentally, this situation emphasises the necessity for energy retrofitting existing residential structures to reduce their impact on human health and the environment. Hence, energy retrofitting an existing building is a more cost-effective and sustainable solution than developing a new building.

Malaysia's present economic expansion prioritises new green building construction, particularly as global sustainable development becomes increasingly critical. However, the number of new green buildings in Malaysia remains small compared to the overall number of existing buildings. Furthermore, constructing new green buildings is insufficient to address Malaysia's long-term sustainable growth. Existing buildings account for the vast bulk of Malaysia's total building stock [3], and their significance should not be disregarded. Overall, sustainable growth necessitates prioritising energy retrofitting existing buildings, Malaysia's primary sources of excessive energy consumption.

New buildings require more time to achieve life-cycle energy reductions than existing ones. Jackson [5] compared embodied and operational energy between a building retrofit and a new building. The study revealed that a new building typically takes 57 years to achieve life-cycle energy savings, while a retrofitted building will take about 53.3 years. Retrofitting existing buildings takes less energy than building green from fresh. The Synthesis Report from the Intergovernmental Panel on Climate Change identified energy retrofitting as an essential contributor to carbon reductions by 2030 (IPCC). The above findings emphasise the significance of renovating existing residential buildings to ensure energy efficiency and environmental performance in response to Malaysia's sustainable development.

Energy retrofitting existing buildings is more cost-effective than developing new green buildings. The Malaysian GBI has a set of rating tools and guidelines for existing non-residential and industrial building retrofits in Malaysia to reduce energy consumption, improve occupant health, and increase productivity. Malaysia has 513 GBI-certified buildings as of September 2019. Furthermore, only 20 of the 513 GBI-certified buildings are classified as existing non-residential and industrial buildings [6], and GBI has yet to develop a rating tool or guideline for existing residential building energy retrofits. This suggests that the Malaysian construction industry has overlooked the possibility of retrofitting existing residential buildings for energy efficiency to achieve overall sustainable development. As a result, a sustainable and comprehensive framework is required to regulate the residential sector's energy consumption.

1.1. Statement of the problem

Scholars debated the effectiveness of energy retrofits in terms of social, financial, and environmental factors. Considering Malaysia's vast number of existing residential buildings consume a significant amount of energy, energy retrofitting existing residential buildings will be an effective carbon reduction technique. Furthermore, the GBI rating tool in Malaysia does not consider energy retrofitting existing residential buildings into account in its rating tools and guidelines. Malaysian construction has disregarded energy retrofitting existing residential buildings in its pursuit of sustainable development. While various construction industry stakeholders

are expected to participate in implementing sustainable energy retrofits, the perception and intent of the owner and occupant remain the key factor in the initial stage. It is critical to investigate the factors influencing house owners' attitudes toward energy retrofitting existing Malaysian houses to promote holistic, sustainable development. As a result, the study aims to examine the underlying constraints underpinning energy retrofit of existing residential buildings in Malaysia:

- To explore energy retrofit of the existing residential buildings.
- To investigate factors affecting the consideration of house owners towards energy retrofit of the existing residential buildings in Malaysia.
- To suggest a simple framework to promote energy retrofit of the existing residential buildings as part of the green initiatives in Malaysia.

1.2. Significance of the study

The study highlights house owners and occupants' awareness of the global environmental issue and energy retrofitting of existing residential buildings in Malaysia. It identifies the factors house owners or residents consider in energy retrofitting existing residential buildings. The survey questionnaire was also developed to collect and assess the respondents' perception of sustainable energy retrofit of existing residential buildings in Malaysia. The survey outcomes can measure the extent to which house owners or tenants disregard existing building energy retrofits. The findings of this study can assist green consultants, architects, and the Malaysian government in addressing and bridging the sustainability gap, encouraging Malaysians to undertake energy retrofits to existing residential properties by recommending the government or private organisations with appropriate and effective policy instruments.

1.3. Significance of the study

This study, however, has certain limitations. Different residential building typologies may influence the owner's or residents' intentions for energy retrofit. The amount of solar heat gain varies by building type; for example, the facade or windows of a high-rise building gain the most solar heat. Since a landed building receives the bulk of its solar heat from its roof, high-rise building owners will adopt different energy-saving measures than landed house owners. Furthermore, existing residential buildings within UNESCO-protected historical conservation areas, such as Malacca and, Georgetown, Penang, are not permitted to alter their physical appearance or façade. As a result, data from owners or residents of conserved houses are not used in the descriptive statistical data analysis of the study.

1.4. Importance of energy retrofits of existing residential buildings

The concept "energy retrofit" refers to changing an existing building's envelope or installing energy-efficient fixtures and fittings to improve its energy efficiency, environmental performance, and indoor air quality. Existing buildings can be retrofitted to leverage their embodied energy and thus minimise operational energy consumption [5]. Baldwin et al. [7] defined "retrofit" as "increasing the environmental performance of existing buildings, reducing energy use, and generating renewable energy sources. This is an approach to improving an existing building's energy efficiency, environmental performance, and spatial quality [8].

All the above descriptions emphasised the importance of retrofits in enhancing the energy efficiency, environmental performance, and interior environmental quality of existing buildings.

Retrofitting existing residential buildings with energy-efficient technologies is critical to addressing the rising global ecological problem caused by Carbon Dioxide (CO_2) emissions. Thus, "energy retrofit" is defined in this study as upgrading an existing building's envelope (passive energy retrofit) or installing energy-efficient fixtures and fittings (active energy retrofit measure).

As part of Malaysia's national sustainable programme, the Malaysian government has undertaken a variety of retrofit strategies to reduce energy usage in existing government buildings. However, there is no long-term plan to retrofit existing residential buildings. Existing buildings can gain social, environmental, and occupant benefits through energy retrofits [9-11]. Besides energy efficiency and environmental performance, the occupants' well-being and productivity are critical, particularly when energy retrofitting existing residential buildings. Energy retrofitting existing residential buildings can improve indoor thermal comfort and environmental quality.

Improving the internal atmosphere and thermal comfort can save energy and improve tenant health, especially in residential buildings. Furthermore, energy retrofitting existing houses can help to improve overall sustainability and environmental benefits by reducing construction waste compared to developing new green buildings [12]. Construction, renovation, or demolition of buildings and infrastructures generate C&D waste. The construction waste generated by retrofitting is lower because waste materials can be recycled rather than manufactured and transported, which consumes a lot of energy. Besides, energy retrofitting residential buildings can be more cost-effective and profitable than developing new green homes Shilei and Yong [11] and minimises overall energy usage, operation, maintenance, and life-cycle expenses Husain et al. [12].

Existing buildings can be retrofitted to produce life-cycle energy savings with a high investment return and a short payback period. According to Mari et al. [13] life-cycle study, creating a new building takes a lot longer time than renovating an old building to save energy. The life-cycle energy savings for new installations can take up to 57 years relative to existing buildings which can take up 53.3 years. To achieve energy efficiency in existing buildings, it is necessary to conduct well-designed monitoring and analysis of energy consumption and performance.

1.5. Importance of energy retrofits of existing residential buildings

Buildings consume a substantial amount of energy for cooling and ventilation to generate the ideal thermal environment; hence, most environmental efforts in architecture, particularly in the tropics [13], aim to minimise operating energy related to cooling. Thus, increasing the energy efficiency of existing buildings can reduce global energy use and its detrimental environmental effects. Existing buildings that lack energy efficiency and thermal comfort are inefficient. Age and scale of a building, design of the building envelope, materials, glazing materials, and human behaviour also impact energy use [11, 12]. Nevertheless, climate, building layout, orientation, and window-to-wall ratio (WWR) are additional significant elements that may influence energy use [14, 15]. Therefore, the tropical environment in Malaysia should

not be disregarded when constructing energy-efficient buildings, as it may be integrated into the building's layout, orientation, and window-to-wall ratio to provide natural sunlight and airflow throughout. Similarly, internal design conditions such as the use of electrical lighting and other electrical equipment influence the energy consumption of an existing building. In addition, building design restricts energy retrofits; for example, it is not viable to reorient an existing building to reduce solar exposure or increase the rate of natural ventilation.

1.6. Factors affecting energy retrofit of existing residential buildings

Existing building energy retrofitting has been extensively researched. Despite continued promotions, many owners and residents are unaware of the benefits of energy retrofits. Most studies emphasized social concerns as critical barriers to residential energy retrofits [16-18]. The rationale is that energy retrofitting existing residential buildings requires the owners' consent. Hence, awareness of energy retrofits among owners or occupants is critical for its implementation.

Nevertheless, policy barriers also contribute to homeowners' or occupants' awareness. The government makes no concerted efforts to encourage homeowners or occupants to undertake energy modifications. Based on the literature, financial incentives encourage homeowners to make energy upgrades. Providing incentives or subsidising interest is another step toward improving overall sustainability [16, 19].

Identifying the key factors considered by house owners or occupants while investigating the restrictions affecting energy retrofit of existing residential buildings in Malaysia is critical. Based on a literature review, social, policy, and financial factors that influence energy retrofit of existing residential structures are identified and employed in this study. Building ownership, education, environmental awareness, and energy retrofitting of existing residential buildings are aspects of social factors. The financial factors include external funding, public subsidy or incentives, investment costs, profit margins, payback periods, and house owners or occupants' income. At the same time, the policy includes a consistent framework, incentives or interest subsidies, and professional assistance for house owners. The policy aspect assesses how much house owners care about energy retrofitting existing Malaysian houses. Below is the theoretical framework for the study based on literature (Table 1).

Table 1. Theoretical framework. Factors affecting energy retrofit of existing residential buildings

Framework	Instrument
Social Aspect	- building ownership. - degree of information and awareness. - education level. - degree of interest.
Policy Aspect	- availability of a consistent framework. - provision of incentives or interest subsidy. - provision of professional energy advice.
Financial Aspect	- availability of external funding. -availability of public subsidy or incentives. - investment cost. - the amount of profit earned. - payback period. - household income.

2. Research Methodology

The study employs a quantitative research method. The key constraints affecting energy retrofitting existing residential buildings in Malaysia were investigated using a self-administered survey questionnaire, one of the most often used quantitative research techniques. The use of a survey questionnaire in this study has the advantage of covering a large quantity of information across many participants in a brief period [18].

The questionnaire was developed to assess respondents' perspectives on energy retrofits using a consistent increment of difference ranging from strongly agree (5) to disagree (1) strongly. The self-administered survey questionnaire includes two (2) sections: (1) respondent demographic information and (2) factors influencing energy-related retrofits. The online survey questionnaire was developed in Google Form and shared with respondents via e-mail and other social media platforms. The survey questionnaire results were collected in Microsoft Excel after three (3) months of data collection.

The factors influencing house owners' or occupants' decision of energy retrofit of existing residential buildings in Malaysia were analysed using descriptive statistics and the Statistical Package for Social Sciences (SPSS) V25 programme. This survey included one hundred and twenty (120) participants. More than half of the respondents (50%) are from Penang, with another half (50%) from Selangor, Melaka, Pahang, and Johor. 13% of respondents own one house, 84% are renters, and 3% own more than one house.

3. Findings and Discussion

The study includes three (3) primary variables that assess the social factor (SF), the policy factor (PF), and the financial factor (FF) (Table 2). The seventeen (17) criteria have been grouped under the three variables.

Multiple mean analyses were performed on factors to assess house owners' or occupants' level of agreement with energy retrofits. To discuss the study's findings, scoring was divided into three (3) main interpretation levels: 1.00 to 2.33 as low, 2.34 to 3.66 as a medium, and 3.67 to 5.00 as high. Table 2 shows the respondents' mean scores on the SF, PF, and FF. A higher mean score indicates more respondents considered the factor.

Table 2. Summary of overall descriptive statistics for variables.

	Variables	Mean	Standard Deviation
SF	**Social Factor**	1.25	0.49
PF	**Policy Factor**	3.54	0.19
FF	**Financial Factor**	3.58	0.46

The FF was scored highest, followed by the PF, and SF was scored the lowest. In general, the mean score ranges from 1.25 (SD = 0.49) to 3.58 (SD = 0.46) (Table 2). Findings suggest that the FF with the highest mean score of 3.58 (SD= 0.46), making it the most significant factor in influencing house owners or occupants' consideration of energy retrofits of existing residential buildings in Malaysia. This finding contradicts Achtnicht and Madlener's [16] and Caputo and Pasetti's [17]

study which identified social issues as the primary barriers to initiating energy retrofits of existing residential structures. This implies that financial constraints, such as monthly household income, retrofit costs, a lack of funding, and uncertainty about the repayment period, are regarded as the primary constraint across any project, contributing to significant challenges to energy retrofit of existing residential buildings.

The findings show that the PF was scored the second highest, with a mean score of 3.54 (SD = 0.19). The results confirm the assertions made by Achtnicht and Madlener [16] and Caputo and Pasetti [17] that householders are more likely to execute energy retrofits when policies give incentives or subsidised financial aid. This finding highlights the significance and necessity of an effective and consistent framework that guides and motivates owners and occupants to implement energy retrofits. The availability of bank loans, incentives, subsidies, green certificates, and professional energy advice from relevant parties, agencies, or the government contributes significantly to the energy retrofit of existing residential buildings.

However, the SF was scored significantly lower among all three (3) factors with a mean score of 1.25 (SD= 0.49) (Table 2). the findings suggest that SF, such as owners' and occupants' education level, house ownership, degree of awareness towards global environmental impacts, and level of interest and attention towards energy retrofits, do not significantly affect their interest in energy retrofits of existing residential buildings in Malaysia. This study contradicts Achtnicht and Madlener's [16] and Caputo and Pasetti's [17] findings, indicating owners or occupants are aware of the significance of energy retrofits and are prepared to make necessary retrofits to their houses provided supported by policies and financial aid.

A descriptive statistical analysis of seventeen (17) criteria was performed to determine the level of agreement among homeowners or residents toward energy retrofits (Table 3). The means are reported separately for the Owner (single owner), multi-owners (more than one owner), and tenants (who do not own the house) to determine the influences of different house ownership on energy retrofits of the existing residential buildings.

As indicated earlier, the financial factor (FF), with a mean score of 3.58 (SD=0.46), is the most influential factor driving Malaysian homeowners or residents to perform energy retrofits. The influence of financial factor (FF) measures such as C2- "cost of renovation" and C3- "amount of profit obtained from energy-saving" is acknowledged as the most significant in all three types of house ownership. Consequently, the study's results imply that the cost of renovation and the amount of profit obtained from energy-saving significantly influence Malaysian house owners or occupants' consideration of energy retrofitting of existing residential buildings, regardless of house ownership.

In addition to the FF, the PF with a mean score of 3.54 (SD=0.19) is a critical factor. Measure B3- "availability of government subsidies on energy bills" scored the highest under the PF across all categories of house ownership. This was followed by measures B2- "availability of incentive from building authorities" and B1- "availability of bank loans". Surprisingly, studies show that SF with a considerably low mean score (M=1.25, SD=0.49) was the least significant factor for Malaysian owners or occupants considering energy retrofits.

C2- "cost of renovation," C3- "amount of profit earned from energy-saving," and C4- "the time needed to earn profit from energy-saving" are the three (3) most frequently agreed-upon measures within FF, regardless of kind of ownership. Findings revealed that Occupants scored C2- "cost of renovation" with the highest mean (M=4.16, SD= 1.21), followed by single owners with a mean score of 4.07 (SD= 1.33) and numerous owners with a mean score of 4.00 (SD= 1.0). Single house owners scored the highest (M=3.87, SD=1.25) on measure C3- "amount of profit earned from energy-saving," followed by tenants (M=3.80, SD=1.01) and multiple owners with a mean score of 3.33 (SD= 0.58).

Furthermore, single owners scored the highest mean (M=3.80, SD=1.21) on the measure C4- "the time required to achieve a profit from energy-saving," followed by tenants (M=3.55; SD=0.91) and numerous owners (M=3.00; SD=1.00). Existing residential buildings with multiple ownership had the lowest mean scores for all three categories. As stated, the decision of homeowners or occupants is essential for initiating and implementing energy retrofits on existing residential buildings.

Single owners scored highest (M=3.80, SD=1.21) on the measure C4- "the time required to earn a profit from energy-saving," followed by tenants (M=3.55; SD=0.91) and multiple owners (M=3.00; SD=1.00). Existing residential buildings with multiple owners scored the lowest mean scores for the three (3) measures, as indicated by the findings. The decision of house owners or occupants is critical for initiating and implementing energy retrofits on existing residential buildings. However, it was found that the availability of expert energy-saving advice and financial assistance favoured the retrofitting of existing residential buildings for energy efficiency. In contrast, Caputo and Pasetti [17] revealed that insufficient tax incentives or expenditures that encourage energy retrofit of existing residential buildings have a negative effect and do not reduce the high acquisition costs required for extensive energy retrofits. Therefore, a practical framework or policy instrument that provides financial assistance for energy retrofits, such as the availability of bank loans, incentives, or subsidies, is vital to encouraging the implementation of energy retrofits in residential buildings.

The SF was scored significantly lower (M=1.25, SD= 0.49) among the three factors. In this study, SF includes education level, house ownership, level of awareness of greenhouse gas (GHG) and urban heat island (UHI) impacts, global warming (GW), level of interest in energy saving, and level of awareness of energy retrofits. The education level of house owners or occupants, the level of understanding of the global environmental crisis, and the significance of energy retrofits might affect their decision and determination to implement energy retrofits. Findings show that awareness of environmental issues was moderately scored across all types of house ownership ranging from M=1.33 (SD= 0.58) to M= 1.87 (SD= 0.35).

The level of interest in energy conservation of houses was relatively low, ranging from a mean score of 1.86 (SD= 0.51) to 2.00 (SD= 0.52). Also, their level of awareness towards energy retrofits of houses was scored relatively low, ranging from M=0. 93 (SD= 1.03) to M= 1.33 (SD= 1.54). Furthermore, social constraints, such as a lack of knowledge or educational programmes to increase public awareness of energy-environmental issues, hinder the growth of residential building energy retrofits [17, 19]. Although the SF has been considered the least important, it is essential to raise public knowledge of global environmental issues

and the significance and value of energy retrofits in response to the global sustainability drive. In conclusion, the FF has the greatest impact on the decision-making of Malaysian owners and tenants on the energy retrofitting of existing residential buildings.

Table 3. Descriptive statistics for items of different factors.

Factor		Item	Single Owner (N=16)		Multiple Owners (More than one owner) (N=3)		Tenants (N=101)	
			M	SD	M	SD	M	SD
SF	A1	Level of Education	1	0	1	0	1	0
	A2	House ownership	2	0	1	0	0	0
	A3	Degree of awareness towards greenhouse effects (GHG)	1.87	0.35	1.33	0.58	1.4	0.81
	A4	Degree of awareness towards urban heat island effects (UHI)	1.87	0.35	1.33	0.58	1.25	0.84
	A5	Degree of awareness towards global warming (GW)	1.87	0.35	1.33	0.58	1.71	0.61
	A6	Degree of interest towards energy conservation of houses	1.87	0.52	2	0	1.86	0.51
	A7	Degree of awareness towards energy retrofits of houses	0.93	1.03	1.33	1.54	1.15	0.99
PF	B1	Availability of bank loans	3.13	0.92	3.67	0.58	3.6	1.05
	B2	Availability of incentives from building authorities	3.47	0.83	3.67	0.58	3.75	0.89
	B3	Availability of subsidies on energy bills from the government	3.73	1.03	3.67	0.58	3.79	0.92
	B4	Availability of green certificate by building authorities	3.07	0.96	3	0	3.26	1.03
	B5	Provision of professional energy advice	3.6	1.06	3.33	0.58	3.46	0.97
FF	C1	Household monthly income	2.67	1.4	3.33	0.58	2.75	1.55
	C2	Cost of renovation	4.07	1.33	4	1	4.16	1.21
	C3	Amount of profit earned from energy saving	3.87	1.25	3.33	0.58	3.8	1.01
	C4	The period needed to earn profit from energy saving	3.8	1.21	3	1	3.55	0.91
	C5	Investment return	3.6	1.06	3.33	0.58	3.66	1.01

4. Discussion

Based on the study's findings, it can be concluded that the FF is the most influential factor in considering energy retrofits for existing residential buildings in Malaysia. The descriptive statistical data analysis suggests that the financial factor has the highest mean score, followed by the policy and social factors.

In addition, the study identifies monthly household income, the cost of energy-related retrofits, profit uncertainty, the payback period required to achieve life-cycle energy savings, and investment return as the primary constraints to energy retrofit of existing residential buildings in Malaysia. C2- "cost of refurbishment" is identified by respondents as the most significant aspect of all FF measures. The most implemented energy retrofit measures by Malaysian house owners or occupants are retrofits that require a relatively lower cost, such as the adoption of energy-saving electrical appliances and LED lighting fixtures.

Passive energy retrofit strategies, such as green roofs and green wall designs, are the least utilised by Malaysian house owners and occupants in achieving energy

efficiency. Financial issues, including cost and budget, often limit energy retrofitting, considering that passive energy retrofit strategies involve significant expenses and budget before implementation. Similarly, the findings of this study indicate that more than half of respondents regard the cost of energy retrofits as a significant obstacle to implementing energy retrofits.

This study reveals that C3- "amount of profit earned from energy-saving" and C4- "time required to achieve profit from energy-saving" are the second and third most important considerations for energy retrofitting existing residential buildings in Malaysia. Before the energy retrofit of existing residential buildings in Malaysia, the cost savings from energy conservation and the return on the investment required to achieve life-cycle energy savings are the primary concerns. This is consistent with the findings of Achtnicht and Madlener [16] found that 51% of respondents considered the uncertainty of the payback period to be a significant concern in the energy retrofitting of existing residential buildings. The respondents choose active energy retrofit strategies since they are significantly less expensive than passive retrofitting. However, it is less likely that these dynamic energies retrofit techniques will result in a significant difference in terms of the savings generated by the improved energy efficiency of the existing residential buildings.

Therefore, passive energy retrofit strategies, such as green roofs and green wall designs, are recommended to produce a more significant change in terms of profit. Many owners and occupants were apprehensive about whether the energy retrofit measures would be economical [19]. Passive energy retrofit techniques are essential for improving existing buildings' energy efficiency and thermal comfort. Still, they are expensive and have a more extended payback period than active energy retrofit solutions [14]. Due to the unpredictable nature of cost savings from energy conservation and the relatively long payback period required to achieve life-cycle energy savings, Malaysian house owners and tenants are hesitant to invest in passive energy retrofit strategies that demand a larger budget and investment cost.

The study findings indicate that financial concerns are the primary factor influencing Malaysian house owners or occupants' motivation in energy retrofitting existing residential buildings. The study’s results imply that financial and policy considerations influence people's decisions to perform energy retrofits. A consistent and effective policy tool is essential to guide efforts toward removing hurdles and encouraging Malaysian homeowners or occupants to improve the energy efficiency of their residential properties. Criteria B1- "availability of bank loans," B2- "availability of incentive from building authorities," and B3- "availability of government subsidies on energy bill" were rated house owners and occupants as the most critical factors in energy retrofitting of existing residential buildings. These outcomes support the assertion of Caputo and Pasetti [17], Stieß and Dunkelberg [19] and Choi et al. [20] that policy instruments should include the introduction of a consistent green certification system, the provision of financial support, and professional energy advice, which are critical drivers in promoting energy retrofit of existing residential buildings.

The lack of external financings, such as incentives from the government or appropriate institutions to assist house owners or occupants, is a significant constraint to the energy retrofitting of existing residential buildings. According to Achtnicht and Madlener [16], more than half of respondents (59 %) perceive a lack of financial resources to be a significant factor in the energy retrofit of existing

residential buildings. Therefore, the availability of financial assistance, including bank loans, incentives from building authorities, and government subsidies on energy bills, shall be considered for inclusion in the policy instrument to promote Malaysia's energy retrofit of existing residential buildings.

Findings also reveal that the social factor has been regarded as the least influencing factor in the energy retrofit of the existing residential buildings in Malaysia. Measures A7- "degree of awareness towards energy retrofits of houses", A1- "education level", and A2- "house ownership" of SF scored the lowest mean. This contradicts study findings by Achtnicht and Madlener [16], which reported that well-educated house owners and those with a higher level of awareness of the global environmental issues are more likely to perform energy retrofits of their houses. Hence the education level of the respondents does not appear to affect the level of awareness towards energy retrofit of the existing residential buildings in Malaysia.

5. Conclusions

This study investigated the key constraints underlying energy retrofit of existing residential buildings in Malaysia. A quantitative method using a survey questionnaire to investigate factors affecting the consideration of residents towards energy retrofit of the existing residential buildings in Malaysia.

The findings of this study confirm earlier studies, highlighting financial constraints as the critical constraint on the progress of energy retrofit of the existing residential buildings. Surprisingly, the social factor appears to be the least important consideration towards energy retrofit of the existing residential buildings in Malaysia contradicting one of the earlier studies which reported that well-educated house owners and those with a higher level of awareness of global environmental issues are more likely to perform energy retrofits of their houses. This shows that the residents, irrespective of their educational background and awareness, are willing to perform energy retrofits to their houses if they have solid financial support.

Finally, policy factors must be addressed to resolve financial constraints and encourage homeowners or occupants to perform energy retrofit energy to existing residential buildings in Malaysia. The financial factor, which includes the cost of energy retrofits, uncertainty about the profitability earned, and the payback period required to achieve life-cycle energy savings, has been regarded as one of the key constraints to energy retrofitting of existing residential buildings in Malaysia. The findings of this study posit that policy factors can positively influence the financial factor in encouraging the house owners or occupants' consideration of retrofitting for energy efficiency.

Therefore, a consistent and effective policy tool is suggested in Malaysia to encourage the energy retrofitting of existing residential buildings. This policy instrument should include the standards or rating tools for green certification systems for existing residential buildings, the provision, and guidelines of financial assistance for passive energy retrofitting, and professional energy advice.

Therefore, it is proposed that future research should explore the possibility and relevance of policy instruments to address the financial constraints to energy retrofitting of existing residential buildings in Malaysia. Existing buildings can

contribute to Malaysia's sustainable development's green initiatives through effective energy retrofitting.

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