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ADAPTING SUSTAINABLE ENERGY FEATURES TO EXISTING CONDOMINIUM BUILDING STOCK IN SRI LANKA

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Abstract: To achieve a sustainable future, Sri Lankan condominium buildings must be retrofitted with sustainable energy features. As the existing households account for 37% of energy consumption in the building sector considering the existing condominium stock is crucial. However, there is a lack of research on implementing energy conservation methods in Sri Lanka's existing condominiums, including social, financial, and technical challenges. Thus, this study aims to fill this gap by providing practical solutions to address the efficient energy consumption in existing condominium. Using a qualitative research approach, semi-structured interviews were conducted with industry experts. Findings revealed a wide range of adaptable energy features for retrofitting, such as green roofs, LED lighting, tinted glasses, solar systems, and IT applications. Barriers for implementing sustainable energy features were identified and categorized as social, technical, financial, legal, market, and government-related barriers. Strategies to overcome these barriers include raising awareness, modifying policies, offering incentives, involving professionals, and exploring funding options. This research guides the adaptation of sustainable energy features in Sri Lanka's existing condominiums thereby enhancing the efficient energy usage within the condominium sector.

Keywords: *Condominium buildings; Energy retrofitting; Renovations; Sustainable energy features*

1. Introduction

The concept of 'condominium' is much popular and offers a better answer to the urban housing problem when land is scarce, and demand is growing along with population. Regarding Sri Lanka, the condominium project has been in operation for more than 60 years (Prathapasinghe et al., 2018). According to Wickramasinghe and Karunanayake (2018), 727 condominiums were constructed between 2007-2017 in Sri Lanka which consists of 12,643 parcels (units). In 2018, 84 condominiums were constructed, and this number increased to 153 in 2019.

Condominium buildings are a significant contributor to the energy consumption in Sri Lanka. Heating, cooling, ventilation, and lighting are the most energy-consuming functions of a residential building, which needs electricity (Ndiaye & Gabriel, 2011). According to Hamilton et al., (2020) electricity usage in building operations accounts for about 55% of worldwide electricity consumption. Furthermore, Zhou et al (2018) portrayed that, buildings in Sri Lanka, particularly households, account for a large portion of national electricity generation. Most of the electricity generation in Sri Lanka is done with thermal energy (51.65%), on which 43.18% is generated with coal. Electricity generation using coal has detrimental effects on human health and environmental pollution (CEB, 2022; Restrepo et al., 2012). High energy consumption causes environmental impacts such as ozone layer depletion and global warming (Del Río & Burguillo, 2008). This underscores the need for energy optimization in buildings (Yu et al., 2012)

Energy retrofitting is essential for existing condominium buildings to improve energy efficiency and reduce energy consumption (Sharutte, 2014). Energy conservation in the existing building stock is critical to achieving energy conservation targets (Grillone et al., 2020). Sustainable energy features must be implemented, especially in existing buildings. As per Ashraf et al. (2017), sustainable energy feature-adapted buildings are 30-40% more energy-saving than conventional structures. Despite the benefits of energy retrofitting, there are numerous challenges, including uncertainty and complexity, financial barriers, technical, and social challenges (D'Oca et al., 2018a; Noori et al., 2016a). These barriers can impede the successful approval of energy retrofitting initiatives. Nevertheless, it is crucial to address energy conservation methods for existing building stock, particularly in Sri Lanka, which is facing an energy crisis due to the high energy consumption of its building stock.

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2. Literature Review

2.1 SRI LANKAN CONDOMINIUM BUILDING SECTOR.

Sri Lanka has a 0.5% population growth, while urban population growth is estimated to be around 1.86% in 2021, according to the (World Bank, 2022). UN-HABITAT (2008) estimated that 22% of the urban population in Sri Lanka struggles to have shelter, leading to slum dwellings. As per Subasinghe, (2015) Low-income flats have been introduced in Sri Lanka, especially in Colombo, to improve the life welfare of slum dwellers. Paniagua (2002), noted that people migrate to urban areas due to reasons such as fewer opportunities in rural areas, community and connectivity, and infrastructure facilities, leading to urbanization. The growing urban population and land scarcity issue derived an increasing demand for condominiums in Sri Lanka. According to Jayalath, (2016), numerous condominiums have been added to Colombo over the past decades. The data available from the condominium's development authority shows that there were 964 condominiums registered to units of about 15000, indicating many people living in condominiums in Sri Lanka. In Sri Lanka, the demand for high-rise condominium buildings is increasing due to land scarcity and the growing population density of urban areas (Ariyawansa & Udayanthika, 2012)

Identifying factors that affect energy consumption in a building is necessary when seeking energy optimization opportunities. Due to technological advancements, building services can increase comfort levels, leading to increased time spent in a building and which ultimately results in energy demand in condominium buildings (Buranaaudsawakul & Wisaeng, 2021).

2.2 SUSTAINABLE ENERGY FEATURES IN CONSTRUCTION PROJECTS.

According to Finnegan et al. (2018), sustainable energy features are technological features that no longer impact the environment and facilitate the reduction of a building's embodied energy and emission. These features help to reduce the long-term cost and final energy consumption of buildings, as per Kats (2003), Sustainable energy features offer several benefits for the environment, economy, and occupants' health. Eichholtz et al. (2010), mentioned that sustainable energy features reduce CO2 and greenhouse gas emissions, thus decreasing energy consumption. Furthermore, Shah & Ali (2010), stated that sustainable energy features reduce overall energy consumption and cost of operation. In terms of health and safety, Ries et al. (2006), note that buildings with low indoor air quality and hazardous emissions cause sick building syndrome, however green principle-designed buildings have more indoor air quality and lower emissions. Table 1 demonstrates sustainable energy features were identified through a literature survey.

Table 1 Sustainable energy features in the construction industry

Sustainable Energy Feature		Author
Thermal comfort features	Tinted Glasses	1
	Low-E Glasses	2,3
	Double Pane Glasses	4,5,6
	Triple Pane Glasses	7,8
	Opal Glasses	9
	Green Roof	10,11,12,13
	Green Facades	14,15
	Building Shading Devices	16,17
	Building Insulation Material	18,19
Lighting features	Tubular Daylighting Devices	20,21,22
	Fiber Optic Daylighting	23, 24
	LED	25, 26
	HID	27, 28
	Clerestory Windows	29,30, 31, 32, 33
Heating features	Solar Water Heaters	34, 35, 36, 37
	Heat Pumps	38, 39, 40, 41
	Biomass	42, 43
Ventilation features	Roof Ventilator Turbine	44, 45
	Trickle Vents	46, 47, 48
Sustainable on-site renewable energy features	Solar Photo Voltaic	49, 50, 51, 52, 53
	Wind Turbines	54, 55, 56, 57
IT appliances	Sensor-controlled HAVC and luminaires	58
	Automatic Dimming luminaires	59
	Digital Ceiling	60
	AI-integrated Building service	61, 62, 63
1 (Gorantla et al., 2018) 2. (Somasundaram et al., 2020) 3. (Han et al., 2010) 4. (Moreland, n.d.) 5. (Muneer et al., 1998) 6. (Aguilar et al. 2015) 7. (Brdnik, 2021) 8. (Kee et al., 2010) 9. (Carmody & Northern star, 2012) 10. (Magill et al., 2011) 11. (Sebi, 2018) 12. (Theodosiou, 2009) 13. (For et al., 2005) 14. (Manso & Castro-Gomes, 2015) 15. (Elhady et al., 2019) 16. (Shahdan et al., 2018) 17. (Evola et al., 2017) 18. (Huang et al., 2020) 19. (Jelle et al., 2010) 20. (Shuxiao et al., 2015) 21. (Marwaee & Carter, 2006) 22. (Whang et al., 2019) 23. (Sedki & Maaroufi, 2017) 24. (Werring et al., 2009) 25. (Kwon et al., 2013) 26. (Gan et al., 2013) 27. (Farrell, 1975) 28. (Cori et al., 2015) 29.		

(Asdrubali, 2003) 30. (Gashniani, n.d.) 31. (Snyder et al., 2008) 32. (Torcellini et al.,2002) 33. (Xue et al., 2014) 34. (Kakaza & Folly, 2015) 35. (Gong & Sumathy, 2016) 36. (Shamsabadi et al., 2018) 37. (Sadhishkumar & Balusamy, 2014) 38. (Sarbu & Sebarchievici, 2014) 39. (Marini et al., 2014) 40. (Tagliafico et al., 2012) 41. (Bianco et al., 2017) 42. (Chen et al.,2018) 43. (Calero et al., 2018) 44. (Pantaleo et al., 2014) 45. (Dangeam, 2011) 46. (Biler et al., 2018) 47. (Cornaro et al., 2013) 48. (Axley, 2001) 49. (Hantula, 2010) 50. (Bhatia, 2000) 51. (Dominguez et al., 2011) 52. (Sreedevi et al., 2014) 53. (Karthikeyan et al., 2017) 54. (Dayan, 2006) 55. (Francis et al., 2021) 56. (Ahmed, 2013) 57. (Shadmand & Balog, 2012) 58. (Mumma & Jeong,2005) 59. (Loshkarev et al., 2019) 60. (Dounis ,2010) 61. (Yan et al. ,2020) 62. (Merabet et al. ,2018) 63. (Mataloto et al., 2019)

2.3 IMPACT OF SUSTAINABLE ENERGY FEATURES ON THE ENERGY DEMAND OF BUILDINGS

As per Ashraf et al. (2017), sustainable energy feature-adapted buildings are 30-40% more energy-saving than conventional structures, but how well they adapt to sustainable energy features is key. The Department of Energy US (2015), reports that heating, ventilation, and air conditioning (HVAC) account for 43% of the energy consumption of residential buildings, with lighting taking 11% and appliances, including electrical devices, using the remainder. Therefore, HVAC and lighting are critical areas when aiming for energy conservation in residential buildings. Gunvantbhai et al. (2019) explained that sustainable energy features reduce cooling and ventilation energy consumption by using passive environmental controls and enhancing the thermal comfort of the building, leading to less energy required to maintain building comfort. Moreover, green lighting technologies, such as daylighting and energy-efficient luminaires, can also help reduce the energy demand of the building.

2.4 USE OF SUSTAINABLE ENERGY FEATURES IN CONDOMINIUM BUILDINGS

Green building technologies, such as natural ventilation and shading devices, can increase energy efficiency, indoor air quality, and thermal comfort in condominium buildings (Wang et al., 2018). Heating, cooling, ventilation, and lighting are the most energy-consuming functions of a residential building (Ndiaye & Gabriel, 2011). Sustainable ventilation features, such as roof ventilators and louver panel windows, can reduce the energy consumption of HVAC systems (Kotani et al., n.d.). Building shading devices, such as green facades and roof gardens, can reduce solar heat gain and cooling loads (Babota et al., 2013; Jeff Sonne, 2005; Wong & Baldwin, 2016). Thermal insulation and energy-efficient window glazing can further reduce indoor and outdoor temperatures (Amit, 2017; He et al., 2019). Decentralized hot water systems and renewable energy options, such as solar, biomass, and wind power, can reduce the energy consumption of water (Hamza, 2016; J. Huang et al., 2019). Smart technologies, such as IoT applications and motion-sensor-controlled devices, can aid in energy management and reduce energy waste (Casini, 2014; Cheng & Lee, 2016).

2.5 CONSTRAINTS TO ADAPTATION SUSTAINABLE ENERGY FEATURES TO EXISTING CONDOMINIUMS.

Streicher et al. (2017) mentioned that energy retrofitting of existing condominium buildings stock is challenging compared to other types of buildings due to constraints. The following constraints were identified through a literature survey.

Table 2 Constraints to the adaptation of sustainable energy features to existing condominiums.

Constraints		Authors
Social constraints	Owners are less willing to pay.	1-23
	Disturbances to building operations and neighbuors during renovation activities.	
	Relocation issues during renovation activities.	
	Decision-making process.	
	Poor Communication between stakeholders.	
	Resistance to change of stakeholders.	
	Customs, beliefs, and traditions.	
Technical constraints	Lack of building information.	24-42
	Lack of experienced and knowledgeable professionals.	
	Lack of labourer skills	
	Lack of codes and standards, lack of research and development opportunities in green building technologies.	
	Lack of information related to renovation and sustainable energy features.	
	Risks and uncertainties in green building technologies.	
Financi al	High up-front costs and a long payback period	, 43-50
	High cost of sustainable energy features (Initial & maintenance)	
	Lack of financial schemes	
	Split incentives	
Government related	Lack of standards and labeling systems	51-57
	Lack of incentive programs	
	Lack of green building codes and regulations	
	Lack of research and development opportunities	
	Energy codes not covering the whole life of buildings	
	Lack of tax incentives	
Legal constrai	Parties' objections	58-62
	Prevailing laws to prevent from nuisance.	
	Lengthy and complex permissions	
	Lack of legal penalties due to non-compliance	

	No reviewing process for existing policies	
1. (Piro, 1974) 2. (Liu et al., 2021a) 3. (Abreu et al., 2017) 4. (C. Huang et al., 2021) 5. (Moshood et al., 2022) 6. (Sichali et al., 2017) 7. (Huang et al., 2021) 8. (Rothgeb, 2010) 9. (Celik & Budayan, 2016) 10. (Botta, 2005) 11. (D'Oca et al. 2018b) 12. (Greetsema & Sahin 2007) 13. (Baeten et al., 2017) 14. (Ma et al., 2022) 15. (Tiun Ling, 2000) 16. (Reymen et al., 2006) 17. (Aymen et al., 2018) 18. (DuBose et al., 2007) 19. (Du et al., 2014) 20. (Shirazi, 2005) 21. (Othman et al., 2015) 22. (Santangelo & Tondelli, 2017) 23. (Li et al., 2019) 24. (Newman, 2001) 25. (Bean et al., 2017) 26. (Noori et al., 2016) 27. (Juan et al., 2009) 28. (Li et al., 2019) 29. (Moshood et al., 2022) 30. (Chan et al., 2018a)31. (Arditi and Gunaydin 1997) 32. (Zhang et al., 2011) 33. (Gunvantbhai et al., 2019) 34. (Samantha, 2021) 35. (Utting, 2010) 36. (Ho, 2016) 37. (Ahn et al., 2013) 38. (Karlström and Sanden 2004) 39. (Brown & Hendry, 2009) 40. (Gruntová Kolingerová 2018)41. (Darko et al. 2017b) 42. (Y. Wang et al. 2021) 43. (D'Oca et al. 2018) 44. (Sovacool 2017) 45. (Chan et al., 2018) 46. (Kibert ,2008) 47. (WorldGBC 2013) 48. (Samari et al. 2013) 49. (Chan et al. 2018) 50. (Dadzie et al. 2018) 51. (Özdemir 2000) 52. (Chan et al. 2018) 53. (Darko et al. 2017) 54. (Davies& Osmani 2011) 55. (Kensek et al. n.d.) 56. (Okoye et al., 2009) 57. (Gou et al. 2013) 58. (Piro 1974) 59. (Demġrcġefe 2009) 60. (Rahmat n.d.) 61. (Khairi, et al. 2017) 62. (Mansfield 2009)		

3. Methodology

This paper aims to provide a guideline for addressing the barriers to adopting sustainable energy features to existing condominium stock in Sri Lanka. To attain the objectives and establish validity, two rounds of semi-structured interviews were conducted among experts; the preliminary interview round was to validate the data collected from a systematic literature review and the second round of interviews to obtain the outcome of the research. Each interview was semi-structured, to generate rich data to advance understanding and consequently develop empirically and theoretically grounded arguments about the barriers and strategies. Five (05) experts and fifteen (15) experts, who have exposed knowledge and experience in the study area were contacted to collect data for the first and second rounds respectively.

Participants for the first rounds were selected from both industry and academia with experience from five to ten years. Similarly, participants for the second round were selected in the construction industry having experienced from ten to thirty years, who are expertise in the following field: Architecture, Quantity Surveying, Facilities Management, Mechanical, Electrical and Plumbing Engineering, and Project Management. This above combination was used to maximize the value and originality of the data from the Interview. All interviews were conducted face to face having an Interview duration from 30 to 90 minutes. To increase the reliability of the data and minimize bias and errors, all interviews were recorded, notes were taken by the researcher during the interview, and manual content analysis was used for data analysis. Finally, the findings were used to identify the most impactful constraints with the process and to propose strategies to overcome constraints specifically to the condominium building stock in Sri Lanka.

4. Research Findings and Discussion

4.1 ADAPTABLE SUSTAINABLE ENERGY FEATURES TO EXISTING CONDOMINIUM BUILDINGS STOCK IN SRI LANKA.
Table 3 demonstrates the level of adaptability of sustainable energy features to existing condominium buildings in Sri Lanka

Table 3 Adaptability of sustainable energy features to existing condominium building stock.

Sustainable energy features	***E01***	***E02***	***E03***	***E04***	***E05***	***E06***	***E07***	***E08***	***E09***	***E10***	***E11***	***E12***	***E13***	***E14***	***E15***
Tinted Glasses	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Low E Glasses	✕	✕	✕	✕	☆	✕	✕	✕	✕	☆	☆	✕	✕	✕	☆
Double Pane Glasses	✕	✕	✕	✕	☆	✕	✕	✕	✕	☆	☆	✕	✕	✕	☆
Triple Pane Glasses	✕	✕	✕	✕	☆	✕	✕	✕	✕	☆	☆	✕	✕	✕	☆
Opal Glasses (Opaque)	✕	✕	✕	✕	☆	✕	✕	✕	✕	☆	☆	✕	✕	✕	☆
Green Roof	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Green Facade	✓	✓	☆	✓	✓	✓	✓	✓	✓	✓	✓	☆	✓	✓	✓
Building Shading Devices	☆	✓	✓	✓	✓	☆	✓	☆	☆	☆	☆	✓	✓	☆	☆
Building Insulation Materials	☆	✓	✓	☆	☆	✓	☆	✓	✓	☆	☆	☆	☆	✓	☆
Tubular Daylighting Devices	✕	☆	☆	✕	✕	✕	☆	✕	✕	☆	✕	✕	✕	✕	✕
Fiber Optic Daylighting Devices	✕	☆	☆	✕	✕	☆	☆	✕	✕	✕	☆	☆	☆	✕	✕
LED	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HID	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Clerestory Windows	☆	☆	✕	☆	☆	✕	☆	☆	☆	✕	☆	☆	☆	✕	☆
Solar Heaters	☆	✓	✓	✓	✓	✓	✓	☆	☆	✓	✓	✓	✓	✓	✓
Heat Pumps	☆	✓	☆	☆	☆	☆	✓	☆	☆	☆	☆	☆	☆	✓	☆
Trickle Vents	☆	✓	✓	✓	✓	✓	✓	☆	☆	✓	✓	✓	✓	✓	✓

Solar Photo Voltaic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wind Turbines	✓	☆	☆	✓	✓	✓	☆	☆	✓	✓	☆	✓	☆	✓	☆
Digital Ceiling	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	☆	☆	☆	✓
Automatic Dimming Luminaires	✓	☆	✓	✓	✓	✓	☆	✓	✓	✓	✓	✓	✓	✓	✓
AI Integrated Building Services	✕	✕	☆	✕	✕	☆	✕	✕	✕	✕	✕	✕	✕	✕	✕
Sensor-Controlled Luminaires/ HVAC	☆	☆	✓	☆	✓	✓	✓	✓	☆	☆	☆	✓	✓	☆	☆
Double Skin Facades	✓	✓	✓	✓	✓	☆	✓	✓	✓	✓	✓	✓	✓	✓	✓
Green Walls	✓	✓	☆	✓	✓	✓	✓	✓	✓	✓	✓	☆	✓	✓	✓
Passive Solar Techniques	✕	✕	☆	✕	✕	☆	✕	✕	✕	✕	☆	✕	✕	✕	☆
Natural/Cross Ventilation	✕	✕	☆	✕	✕	☆	✕	✕	✕	✕	☆	✕	✕	✕	☆
Skylights	✕	✕	☆	✕	✕	☆	✕	✕	✕	✕	☆	✕	✕	☆	☆
Energy submetering/monitoring/BMS	✕	✕	☆	☆	☆	✕	☆	☆	☆	☆	✕	☆	☆	☆	☆

✓	Highly adaptable
☆	Adaptability is medium
✕	Difficult to adapt

Highly adaptable sustainable energy features are those that can be easily integrated without major alterations to buildings, building elements, or deep structural changes. Medium adaptability refers to sustainable energy features that can be incorporated with minor modifications and limited structural adjustments, while difficult-to-adapt features require extensive structural changes and significant effort.

The findings of the study indicate that following sustainable energy features are highly adaptable for existing condominium building stock in Sri Lanka: tinted glasses, green roofs, green facades/walls, LED lighting, high-intensity discharge (HID) lighting, digital ceilings, solar water heaters, solar panels, double skin facades, automatic dimming luminaires, and sensor-controlled luminaires/HVAC systems, as affirmed by 15 industry experts who participated in the secondary interview round. While building shading devices, heat pumps, wind turbines, clerestory windows, and energy submetering/BMS were identified as moderately adaptable.

4.2 THE SEVERITY OF CONSTRAINTS TO ADAPTING SUSTAINABLE ENERGY FEATURES IN EXISTING CONDOMINIUM BUILDINGS IN SRI LANKA

The study's secondary interview round with 15 industry experts identified lack of interest from unit owners, reluctance to pay for sustainable energy features, limited knowledge among society, poor communication among stakeholders, stakeholders' resistance to change and new ideas, lack of awareness of sustainable energy practices, potential disturbance to the neighborhood during renovations, relocation issues during renovations, and disturbance to occupants during renovations/modifications as the most impactful social constraints to the adoption of sustainable energy features in existing condominium building stock in Sri Lanka. While split incentives, high up-front costs and a long payback period, high cost of sustainable energy features (Initial & maintenance), and lack of financial schemes were identified as the most impactful financial constraints.

The experts mention the lack of green building technologies suppliers, lack of market demand, professionals and contractors' lack of experience regarding procurements of renovation projects and sustainable construction projects, poor after-sales services for appliances and systems, lack of long-term warranties for energy-efficient equipment and materials, and lack of long-term warranties for energy-efficient equipment and materials were highly impactful market-related constraints to the process. On the other hand, difficulties in doing structural changes, the extra burden associated with some green features, and incompatibilities of existing buildings/systems with new technologies were identified as highly impactful technical constraints whereas lack of incentive programs, lack of research and development opportunities, and lack of tax incentives identified as highly impactful technical constraints and parties' objections to renovation were the major legal constraints as per the experts.

4.3 STRATEGIES TO MITIGATE THE IMPACT OF CONSTRAINTS TO ADAPTING SUSTAINABLE ENERGY FEATURES TO EXISTING CONDOMINIUM BUILDING STOCK IN SRI LANKA

The interviewees provided suggestions to mitigate the impact of various constraints to adapting sustainable energy features in existing condominium building stock in Sri Lanka. The majority of interviewees identified the lack of interest in the unit owners, unit owners' less willingness to pay, lack of knowledge within society, poor communication among stakeholders, lack of green building technologies suppliers, and lack of market demand as the major constraints that arise due to the lack of awareness and education. The interviewees suggested conducting awareness programs, team-building activities, and social media campaigns to create awareness among the public and professionals. Additionally, they proposed developing professionals' awareness conferences, training programs, and financial incentives to increase interest in sustainable energy features. Pilot projects were also recommended to demonstrate the outcomes and benefits of adopting sustainable energy features. To address stakeholders' resistance to change and root ideas, the interviewees suggested providing a cost-benefit analysis through leaflets campaigns.

The experts proposed several ways to mitigate the impact of disturbance caused to the neighborhood during renovations, relocation issues, and disruption to the occupants during the renovations/modifications. All the experts suggested arranging proper time slots for the renovations and taking necessary precautions to reduce the disturbance. A few experts also suggested using sinking funds for temporary residences and doing the renovation systematically in parts without doing a complete renovation.

To address the difficulties in doing structural changes, the extra burden associated with some green features, and the incompatibilities of existing buildings/systems with new technologies, all experts recommend selecting sustainable energy features that do not require deep structural changes and are compatible with existing systems. Proper studies should be conducted before choosing sustainable energy features. Additionally, to tackle the high up-front costs and long payback periods associated with sustainable energy features, experts suggest conducting cost analyses to select features that provide maximum benefits while avoiding those with high costs. Finally, the high cost of sustainable energy features can be addressed by selecting features that require lower initial and maintenance costs.

Experts provide strategies to mitigate the impact of the following constraints lack of financial schemes, lack of incentive programs, lack of research and development opportunities, and lack of tax incentives. All experts emphasized the importance of government involvement in adopting sustainable energy features for existing condominium buildings in Sri Lanka. Most experts mentioned that government financial concessions and low-interest credit facilities for energy-efficient renovations are effective strategies for the lack of financial schemes and incentive programs. Further, providing tax concessions is recommended by all interviewees.

To mitigate the impact of constraints related to sustainable energy features in existing condominium buildings in Sri Lanka. To address the low quality of equipment and materials, experts suggested selecting high-quality equipment and materials and conducting proper research before making a purchase. For maintainability issues, some experts suggested hiring a maintenance company, while others recommended training and forming a maintenance team within the management corporation. Additionally, all experts emphasized the importance of proper agreements with equipment and system providers to ensure good after-sales service and long-term warranties for energy-efficient equipment and materials. Overall, it is important to conduct thorough research, select high-quality equipment and materials, and establish proper agreements to mitigate the impact of these issues on sustainable energy features in existing condominium buildings in Sri Lanka.

5. Conclusion

This study has identified sustainable energy features that can be adapted to existing condominium buildings in Sri Lanka and assessed their adaptability through two interview rounds with experts. The study identified constraints to adapting sustainable energy features and proposed strategies to overcome them. The findings suggest that while certain sustainable energy features, such as tinted glasses, green roofs, LED lights, and solar water heaters, are highly adaptable to existing condominium buildings, several constraints need to be addressed, including a lack of interest among unit owners, unwillingness to pay for energy-efficient renovations, risks and uncertainties, and difficulties in doing structural changes. Strategies such as creating awareness through workshops and social media, appointing accredited professionals, and purchasing insurance policies to transfer risks were proposed to overcome these constraints. Overall, this study provides useful insights for stakeholders in the construction industry in Sri Lanka who are interested in promoting sustainable energy features in existing buildings.

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