The following publication Tan, Y., Luo, T., Xue, X., Shen, G. Q., Zhang, G., & Hou, L. (2021). An empirical study of green retrofit technologies and policies for aged residential buildings in Hong Kong. Journal of Building Engineering, 39, 102271 is available at https://dx.doi.org/10.1016/j.jobe.2021.102271.

An Empirical Study of Green Retrofit Technologies and Policies for Aged Residential Buildings in Hong Kong

Abstract: Given the ever-increasing number of aged residential buildings in Hong Kong, green retrofit provides a sustainable solution for improving existing aged residential buildings' performance instead of constructing new buildings. Studies on green retrofit technologies (GRTs) and green retrofit policies (GRPs) have received great attention globally. However, few studies have been done to understand the applicability and importance of GRTs and GRPs, and the impacts of GRPs on the application of GRTs in a particular region, such as Hong Kong. Therefore, based on a questionnaire survey conducted in Hong Kong, this study aims to further examine the GRTs and GRPs that have been identified in a previous study. The applicability of the GRTs and the importance of the GRPs for green retrofit of aged residential buildings in Hong Kong were studies, the correlations between the GRTs and GRPs were analyzed, and a priority guide was developed for promoting green retrofit of aged residential buildings in Hong Kong. The findings can help various stakeholders to have a better understanding of the GRTs and provide valuable references for the local government to develop future GRPs. Furthermore, this study also provides a fundamental guide for future green retrofit research and development in the local and global contexts.

Keywords: Green retrofit technologies (GRTs); Green retrofit policies (GRPs); Aged residential building; Priority guide; Hong Kong

1. Introduction

Sustainable development has been challenged by the increasing energy consumptions and carbon emissions caused by buildings [1]. According to existing data, the building sector contributes to 35% of global carbon emissions and 40% of global energy consumption [2], which makes it the key contributor to climate change [3]. Besides, the global building sector is responsible for 40% of the raw materials (stone, sand, and gravel) [4], 67% of solid waste, and 13% of potable water [5]. Furthermore, comparing with existing buildings, new buildings constructed every year still account for a small portion of the total building stocks [6]. Therefore, to reduce the environmental impacts caused by buildings, green retrofit of existing buildings would be a better option to achieve various energy efficiency targets set by many countries [7].

Hong Kong is one of the densest modern cities in the world [8, 9]. A number of existing buildings in Hong Kong were built during the 1970s to 1980s, driven by the industrial expansion [10]. According to the Housing in Figures 2019 published by the Hong Kong Housing Authority, the residential buildings aged over 30 years in Hong Kong accounts for 42.50% [11]. Due to the limited amount of development land (accounting for 24% of the total land area) [12], most aged residential buildings are high-rise with low energy efficiency [12]. To improve these aged residential buildings' performance, especially energy efficiency [13], green retrofit provides a sustainable solution instead of construction of new buildings, which may take many years [14, 15].

Retrofit is the "change" of elements or components of a building [12]. Wherein, the "change" for green retrofit is limited to the "upgrade", which can improve a building's performance [16]. Many studies use interchangeable terms associated with the retrofit, such as refurbishment, rehabilitation, renovation, improvement, adaptation, repair, and renewal on existing buildings [17]. Furthermore, according to the U.S. Green Building Council (USGBC), "*green retrofit is any kind of upgrade at an existing building that is wholly or partially occupied to improve energy and environmental performance, reduce water use, and improve the comfort and quality of the space in terms of natural light, air quality, and noise*". As such, green retrofit provides a prominent opportunity for reducing energy consumption and carbon emission in the building sector. It is also considered as an effective strategy to achieve sustainability for the built industry at relatively low cost and in a relatively short period of time [18]. Green retrofit also can increase the satisfactory service level and indoor environmental quality of existing buildings [19]. Moreover, retrofitted buildings are more livable and comfortable for occupants [20]. Green retrofit can also preserve the cultural, aesthetic, and heritage value of aged buildings [21].

Technologies and polices play important roles in the development of building green retrofit [12]. Many studies have been done on green retrofit technologies (GRTs), such as research on green roof technology [22], HVAC systems retrofit [23]. Furthermore, another prominent issue is how polices can effectively promote and support the adoption of GRTs. In this context, green retrofit policies (GRPs) refer to guidelines, regulations, technical supports, financial supports, and schemes that are used to guide, regulate and support green retrofit of existing buildings. Many studies have been done on green retrofit policies (GRPs) to promote GRTs adoption [7, 12, 24]. In practice, many governments and international organizations have provided various financial supports to building retrofit, such as the Building Retrofit Energy Efficiency Financing (BREEF) Scheme in Singapore [25], Renewable Heat Incentive (RHI) by the International Energy Agency (IEA) [26].

However, few studies have been done on examining the applicability and importance of relevant GRTs and GRPs with empirical evidence, and the different impacts of GRPs on the application of GRTs in a particular region. Li et al. [14] studied the sustainable refurbishment solutions of multi-story buildings in Hong Kong. Guo Liu et al. [24] examined 191 green retrofit policies in China and grouped them into six policy categories, including command and control, economic incentives, information, certification, technology, and organization and professional. These studies didn't examine the relationship between GRTs and GRPs. Therefore, this paper aims to examine the applicability of GRTs and the importance of GRPs for aged residential buildings through a questionnaire survey and identify the different impacts of GRPs on GRTs. Finally, a priority guide was developed to provide a valuable reference for the local government to develop new policies for green retrofit of aged residential buildings. Furthermore, this study also provides a useful reference for the development of green retrofit in other countries or regions that have similar contexts and building features with Hong Kong.

2. Literature review

2.1 Green retrofit technologies for building retrofit

GRTs refer to those technologies that can be used to improve existing buildings' sustainability performance, such as energy efficiency, carbon emission reduction, indoor air quality, safety [14, 18]. There are many green retrofit technologies. For example, green roofs and green walls can reduce urban heat island effect and improve air quality, stormwater management, urban biodiversity [27-29]. Double glazing windows can save more energy because 10% to 25% heat transfer are through windows [30]. Building envelope retrofit measures, such as airtightness, solar shading, and insulation, can be used to reduce the energy consumption of buildings with an average saving of 33% [31]. Furthermore, renewable technologies can also be used for building green retrofit. For instance, solar-energy systems can support the domestic hot-water system, which can help reduce domestic electricity consumption [32].

The applicability and advancement of technologies are key elements for the success of building green retrofit. Based on the opinion proposed by Li et al. [17], the applicability of retrofit technologies depends on the local climatic features and building characteristics. For example, heating technologies can only be applied in the cold climate, and not suitable for tropical or sub-tropical climates, such as Hong Kong [33]. Furthermore, the adoption of GRTs is also affected by building types. For example, centralized heating, ventilation, and air-conditioning systems are mostly used in commercial buildings [34], and not common in residential buildings. Invasive retrofit interventions (e.g. building envelopes) are not recommended for heritage buildings because the architectural heritage should be preserved [35].

Hong Kong is located in a typical subtropical region so that buildings in Hong Kong are subjected to high cooling demands throughout most of the year, especially during hot summer months [9]. The number of air-conditioned residential buildings and the amount of energy use in residential buildings have increased dramatically over the past years [36]. The electricity consumption in 2019 in the domestic sector was 42937 Terajoule, responsible for about 26.6% of the total electricity consumption [37]. Therefore, green retrofit can provide an effective measure to improve the energy efficiency of existing residential buildings [23]. For example, space cooling related retrofit, such as high energy-efficient cooling system, should be highly recommended in Hong Kong, which contributes to the most electricity consumption [36]. Renewable energy technologies (e.g. solar power generation) also have high application potential for residential buildings in Hong Kong because Hong Kong has plenty of sunshine throughout the year [32].

Furthermore, the main features of public residential buildings in Hong Kong were investigated by Tan et al. [12]. Due to the high density and the limited amount of development land [9], the high rise is one of the most typical features of residential buildings in Hong Kong [32]. Lift is consequently a must for vertical transportation. However, more than 65% of the surveyed buildings are not equipped with energy-efficient lifts. Moreover, the efficiency of existing services systems and the adoption of energy-saving devices in aged residential buildings are at a low level in Hong Kong. Therefore, upgrading existing building services systems, such as lift, lighting, and domestic appliances with high energy efficiency are recommended [12]. Notably, single-layer clear glass windows with aluminium frames are commonly used in public residential buildings in Hong Kong that lead to high heat gains (in summer) and loss (in winter) [30]. Therefore, green retrofit of the building envelope (e.g. window, insulation, roof, wall) is also recommended [22].

Based on the literature review on the environmental condition (e.g., subtropical climate) and the features of aged residential buildings (e.g., the pattern of energy consumption, suitability for residential building, high-rise buildings), 28 GRTs were identified and grouped into three categories, as shown in **Table 1**. These 28 GRTs have been discussed in a previous study by Tan et al. [12]. This study will further exam the applicability of these GRTs in Hong Kong with empirical evidence.

Table 1

List of applicable green retrofit technologies (GRTs) in Hong Kong

Category		Code	Applicable GRTs in Hong Kong
Building service	Lighting (BS1)	BS1-1	Low energy lamps (T5 fluorescent)
		BS1-2	Light-emitting diode (LED) lighting
		BS1-3	Daylight/Motion sensors
	Lift (BS2)	BS2-1	Lifts with power regeneration system
		BS2-2	Modernize lifts with a VVVF (Variable Voltage Variable Frequency) control system
		BS2-3	Lifts with a permanent magnet motor
	Cooling (BS3)	BS3-1	Evaporative cooling
		BS3-2	Energy-efficient room air conditioner
	Others (BS4)	BS4-1	Time switches
		BS4-2	Energy-efficient appliances and equipment selection
		BS4-3	Installing meters for energy auditing
		BS4-4	Domestic water-saving devices
		BS4-5	Greywater reuse and rainwater harvesting
Building envelope	Roof & wall (BE1)	BE1-1	Reflective surface (cool roof/wall)
		BE1-2	Green wall/roof
	Windows (BE2)	BE2-1	Window frames with thermal break
		BE2-2	Reflective glazing
		BE2-3	Double/multiple glazing
	Shading (BE3)	BE3-1	Overhangs/Vertical fin
		BE3-2	Automatic blinds
	Insulation (BE4)	BE4-1	External wall insulation
		BE4-2	Internal wall insulation
		BE4-3	Roof insulation
	Air tightness (BE5)	BE5-1	Joint sealing
		BE5-2	Draught-proofing
Renewable energy (RE)		RE1	Solar water heating
		RE2	Building-integrated photovoltaics
		RE3	Building-integrated wind turbine

(Source: Tan et al. [12])

2.2 Green retrofit policies for building retrofit

With the increasing attention to green retrofit, many GRPs have been introduced to encourage more green retrofit projects using various GRTs [7]. The effectiveness and applicability of GRPs are important for the successful implementation of green retrofit [38]. An effective policy includes clear objectives and proper instruments [24, 39, 40]. Relevant studies have been done to review existing policy instruments for building retrofit and group them into different categories [12, 24, 41]. For example, Liao [42] grouped policy instruments into goal planning, regulatory control, financial support, tax preference. Liu et al. [43] grouped the building retrofit policies into six categories, including command and control, economic incentives, information, certification, technology, and organization and professional. Therefore, relevant policies can be grouped into several categories, such as regulations, financial incentives, technological standards and evaluation, publicity programs and education.

The applicability of GRPs needs to consider the level of economic development, industry environment, and related local government policies and regulations [12, 44, 45]. For example, relevant guidelines should be provided in those countries or regions with less green retrofit experience [46]. Existing studies also show that financial burden is one of the most significant obstacles for building green retrofit [47]. Financial supports, especially incentive schemes (e.g. subsidies, tax reduction, and low interest rate), have been proved effective to encourage more adoption of green retrofit in developed countries, such as the US, Canada [48], and some developed countries in Europe [49]. In Singapore, relevant green retrofit knowledge and information are promoted to improve public awareness and engagement of various stakeholders [50]. Besides, the local contexts and existing policies should be considered when introducing new GRPs because they will have an influence on the implementation of new policies [51, 52].

Building green retrofit in Hong Kong has its own characteristics owing to its economic development, building environment, and energy efficiency requirements. Relevant policies have been implemented for improving existing buildings' performance, such as the Buildings Energy Efficiency Funding Schemes (BEEFS) [53]. In 2012, the Mandatory Building Inspection Scheme (MBIS) and the Mandatory Window Inspection Scheme (MWIS) were implemented, which provides a good opportunity for promoting green retrofit of aged buildings in Hong Kong [15]. According to the research by Tan et al. [12], the occupants who lived in the aged residential buildings have little knowledge of green retrofit technologies. It becomes necessary for the local government to take action to enhance relevant knowledge sharing and public awareness of green retrofit. Furthermore, there is also a need to enhance professionals' knowledge and uplift workers' skills through relevant education and training programs [12].

Based on the literature review on the local context (e.g., local policies, economic level, built environment, and energy efficiency requirements), 18 GRPs were identified and grouped into six categories, as shown in **Table 2**. These GRPs have been discussed in a previous study by Tan et al. [12, 41, 43]. This study will further exam the importance of these GRPs in Hong Kong and their relationships with GRTs.

Table 2
List of recommended green retrofit policies (GRPs) for Hong Kong

Category	Code	Recommended GRPs for Hong Kong
Direction-based policies (DP)	DP1	Formulate a strategy for building green retrofit
	DP2	Develop a building green retrofit action plan
	DP3	Develop a guideline on building green retrofit
Regulation-based policies (RP)	RP1	Incorporate green retrofit element in existing mandatory schemes (e.g., MBIS, MWIS)
	RP2	Formulate codes, standards, and regulations (CSR) for building green retrofit
	RP3	Promotion programs for green retrofit

Category	Code	Recommended GRPs for Hong Kong
Evaluation-based policies (EP)	EP1	Establish a new evaluation system for green retrofit or incorporate the green retrofit element in existing evaluation systems (e.g., BEAM-Plus)
	EP2	Establish a labeling system for building green retrofit
Financial support policies (FP)	FP1	Research funds for building green retrofit
	FP2	Low-interest loans for green retrofit projects
	FP3	Tax reduction for building green retrofit companies
	FP4	Initiate subsidy scheme for green retrofit projects
Organization & professional training (OP)	OP1	Establish an institution of green retrofit or create a green retrofit branch in existing institutions
	OP2	Provide relevant professional education and training
	OP3	Encourage specialist contractors in green retrofit
Knowledge & information (KI)	KI1	Promotion programs for public awareness of green retrofit
	KI2	Provide a platform for knowledge & experience sharing (e.g., APP, website, seminar, conference)
	KI3	Encourage innovation in building green retrofit

(Source: Tan et al. [12])

With the pre-identified GRTs and GRPs, there is a need to examine the applicability and importance of these GRTs and GRPs in a particular region, such as Hong Kong, and the impacts of GRPs on the local application of GRTs for aged residential buildings. Based on previous research, an empirical investigation from professionals in the local industry is a common and effective method to validate the findings of the literature review [54, 55]. For example, a questionnaire survey was used to collect experts' views on the issues that influence green building technologies adoption in the United States [54]. Thus, it is worthwhile to survey the local professionals to examine the pre-identified GRTs and GRPs in terms of their applicability, importance and relationships, thereby promoting wider adoption of green retrofit for aged residential buildings in Hong Kong.

3. Research methodology

In this study, a questionnaire survey was used to further investigate the pre-identified 28 GRTs and 18 GRPs by Tan et al. [12], including the applicability of pre-identified GRTs, the importance of pre-identified GRPs, and the impacts of different GRPs on GRTs, with the assistance of SPSS statistics 21.0. Based on an in-depth analysis, a priority guide for green retrofit of aged residential buildings in Hong Kong was developed.

3.1. Questionnaire design

Questionnaire survey is a quantitative social research method for data collection [56] and has been widely used to gather participants' opinions on particular issues in different research areas [55, 57]. In this study, based on the pre-identified GRTs and GRPs, a questionnaire survey was designed and conducted to collect industry professionals' opinions on these GRTs and GRPs. The questionnaire contains four parts. Part one is an introduction to the research and the purpose of this survey. Part two is designed to collect demographic information of respondents, including the age, educational background, firm's type, and working experience. In part three and four, participants were invited to indicate their opinions on the applicability of the 28 GRTs and the importance of the 18 GRPs in Hong Kong, by using a five-point Likert scale. Participants were also invited to add other technologies and policies that they think applicable and important.

3.2. Data collection

The questionnaire survey was conducted from June to October 2018. The questionnaires were distributed to 500 professionals in Hong Kong by mail. The professionals were from design companies, construction companies, universities, research institutes, and other relevant organizations. The professionals were selected based on the open online data, including the Hong Kong Institute of Surveyors, the Hong Kong Institute of Architects, the Hong Kong Institute of Planners, and the

Register of General Building Contractors from the Building Department of the Hong Kong Special Administrative Region.

The research team finally received 61 responses through online, email, mail, or fax. After filtering, 59 responses were valid. Although the sample size was relatively small, statistical analyses can still be carried out because, according to the commonly accepted rule, with a sample size of 30 or above, the central limit theorem holds true [58, 59]. Besides, the sample size compares favourably with those of many previous green building-related studies [58, 60], hence, the sample size is considered acceptable in construction and building-related research [58, 60]. The collected data are reliable with Cronbach's alpha coefficient value 0.932 (higher than 0.70), indicating acceptable internal consistency [55]. The details of the respondents' demographic information are shown in **Table 3**.

Table 3
Demographic information of respondents（N=59）

Demographics	Percentage	Demographics	Percentage
Age group		**Working experience**	
20-29	16.90%	<5 years	18.60%
30-39	25.40%	5-10 years	18.60%
40-49	27.10%	11-15 years	11.90%
50-59	11.90%	16-20 years	3.40%
60+	18.60%	>20 years	47.50%
Education level		**Firm's type**	
High school or below	5.10%	Consultant	27.10%
Undergraduate	13.60%	Contractor	32.20%
Postgraduate	81.40%	Research institute	40.70%

3.3. Data analysis

With the collected data, statistical data analysis was conducted by using SPSS Statistics 21.0 software[61]. The rankings of GRTs and GRPs were determined by their mean scores [62]. Kendall's W test was used to analyze the agreement regarding the overall rankings of the GRTs and GRPs [55]. Kruskal-Wallis H test was further used to test whether there are significant differences between respondent groups' views on the 28 GRTs and 18 GRPs [55, 62].

Besides, correlation analysis was used to analyze the correlations between the GRTs and GRPs [63]. Correlation analysis mainly studies whether there is a dependency relationship between the main research objects, and discusses the correlation level of the phenomenon with the dependency relationship. However, it cannot accurately determine one research object according to another, and also cannot forecast whether two research objects with significant correlation can have significant positive or negative effects on other research objects [63]. This study aims to find out the dependency relationships between the pre-identified GRTs and GRPs by using correlation analysis. The results will provide a good reference for studying the relationships between the identified GRPs and GRTs. In this study, Spearman correlation analysis was adopted because it can eliminate the bias due to the abnormal distribution of data in this study, which are generally occurred in empirical research [64, 65].

4. Results

4.1. Results of GRTs analysis

Respondents were invited to rate the applicability of the pre-identified green retrofit technologies in Hong Kong, and add other technologies that applicable in Hong Kong. However, no other technologies were suggested by the respondents. The survey results are shown in **Table 4.** For all respondents, all the mean scores are greater than 3.00, which indicates that the applicability of all GRTs is agreed by the local professionals in Hong Kong. The top GRTs (mean score equal or greater or close to 4.00) are "Energy-efficient appliances and equipment selection" (BS4-2), "Energy-efficient room air conditioner" (BS3-2), "Low energy lamps (T5 fluorescent)" (BS1-1), "Time switches" (BS4-1), and "Light-emitting diode (LED) lighting" (BS1-2).

Table 4
Survey results on the 28 GRTs

GRTs	**All respondents (N=59)**		**(1) Consultant (N=16)**		**(2) Contractor (N= 19)**		**(3) Research institute (N=24)**		**Diff. (CS–CT)**	**Diff. (CS–RI)**	**Diff. (CT–RI)**	**Kruskal-Wall H p-value**
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank				
BS4-2	4.15	1	4.00	1	4.05	2	4.33	1	-0.05	-0.13	-0.28	0.285
BS3-2	4.03	2	3.88	3	3.84	6	4.29	2	0.04	-0.42	-0.45	0.150
BS1-1	4.02	3	4.00	1	4.16	1	3.92	6	-0.16	-0.33	0.24	0.916
BS4-1	3.98	4	3.75	8	3.89	5	4.21	3	-0.14	-0.02	-0.32	0.215
BS1-2	3.97	5	3.75	8	4.05	2	4.04	5	-0.30	-0.38	0.01	0.571
BS4-4	3.88	6	3.81	6	3.68	9	4.08	4	0.13	-0.29	-0.4	0.292
BE4-3	3.81	7	3.86	5	3.74	7	3.71	10	0.12	-0.58	0.03	0.536
BS1-3	3.78	8	3.43	16	4.05	2	3.79	9	-0.62	-0.27	0.26	0.167
BE2-3	3.64	9	3.69	10	3.53	10	3.71	10	0.16	-0.48	-0.18	0.997
RE1	3.64	9	3.81	6	3.42	12	3.71	10	0.39	-0.54	-0.29	0.584
BE1-1	3.59	11	3.88	3	3.21	21	3.71	10	0.67	0.15	-0.5	0.081
BE2-1	3.58	12	3.38	17	3.32	15	3.92	6	0.06	-0.71	-0.6	0.059
BE2-2	3.56	13	3.50	13	3.16	23	3.92	6	0.34	0.10	-0.76	0.019*
BE5-1	3.54	14	3.25	20	3.74	7	3.58	21	-0.49	-0.58	0.16	0.291
BS2-1	3.54	14	3.63	11	3.26	18	3.71	10	0.37	0.17	-0.45	0.389
BE1-2	3.53	16	3.63	11	3.32	15	3.63	18	0.31	-0.08	-0.31	0.614
BE3-1	3.47	17	3.50	13	3.26	18	3.63	18	0.24	-0.39	-0.37	0.555
BE4-1	3.47	17	3.38	17	3.32	15	3.67	17	0.06	-0.38	-0.35	0.496
BE5-2	3.46	19	3.00	27	3.11	24	3.71	10	-0.11	-0.71	-0.6	0.100
BS2-3	3.44	20	3.25	20	3.42	12	3.58	21	-0.17	-0.33	-0.16	0.563
BS2-2	3.42	21	3.44	15	3.37	14	3.46	25	0.07	0.17	-0.09	0.897
BS4-3	3.41	22	3.25	20	3.26	18	3.63	18	-0.01	0.10	-0.37	0.343
RE2	3.39	23	3.06	26	3.47	11	3.54	23	-0.41	-0.42	-0.07	0.306
BS3-1	3.32	24	3.19	24	3.21	21	3.50	24	-0.02	-0.54	-0.29	0.520
BS4-5	3.29	25	3.13	25	2.89	27	3.71	10	0.24	-0.13	-0.82	0.059
BE4-2	3.25	26	3.25	20	3.11	24	3.38	26	0.14	-0.27	-0.27	0.743
BE3-2	3.17	27	3.31	19	3.00	26	3.21	28	0.31	-0.33	-0.21	0.675
RE3	3.05	28	2.94	28	2.79	28	3.33	27	0.15	-0.02	-0.54	0.172

Note: The Kendall's W for ranking the 28 GRTs is 0.106 with a significance level of 0.000;
Diff. (CS–CT) = Difference in mean scores from consultants and contractors; Diff. (CS–RI) = Difference in mean scores from consultants and research institutes; Diff. (CT–RI) = Difference in mean scores from contractors and research institutes;
*The Kruskal-Wallis H test result is significant at the significance level of 0.05 (p-value < .05).

In **Table 4**, Kendall's W test result is 0.106 with a significance level of 0.000, which indicates respondents' high agreement on the overall ranking of the GRTs. Kruskal-Wallis H test was used to test the differences between the three respondent groups. There are no significant differences between the respondent groups, except one GRT, "Reflective glazing" (BE2-2), which is ranked 13^{th} with an overall mean score of 3.56

(see **Table 4**). Research institutes (mean score=3.92, rank=6) gave BE2-2 a higher rank than consultants (mean score=3.50, rank=13) and contractors (mean score=3.16, rank=23). Replacing clear glass with reflective glazing can reduce heat gains and thus reduce the cooling load of air-conditioning [17]. However, from a practical view, contractors may have some difficulties when implementing building envelope technologies, such as temporary scaffolding work, disruptions to occupants.

4.2. Results of GRPs analysis

The survey results of GRPs are shown in **Table 5.** There are no other policies added by the respondents. All the mean scores of the GRPs are greater than 3.50, indicating the importance of the identified GRPs. Based on the ranking, eight GRPs have a mean score above 4.00, including "Tax reduction for building green retrofit companies" (FP3), "Research funds for building green retrofit" (FP1), "Formulate codes, standards and regulations (CSR) for building green retrofit" (RP2), "Promotion programs for public awareness of green retrofit" (KI1), "Develop a guideline on building green retrofit" (DP3), "Initiate subsidy scheme for green retrofit projects" (FP4), "Formulate a strategy for building green retrofit" (DP1) and "Encourage innovation in building green retrofit"(KI3). These GRPs are considered as the most important policies to promote green retrofit practices so that local government should pay more attention to these policies.

Table 5
Survey results on the 18 GRPs

GRPs	All respondents (N=59)		(1) Consultant (N=16)		(2) Contractor (N= 19)		(3) Research institute (N=24)		Diff. (CS–CT)	Diff. (CS–RI)	Diff. (CT–RI)	Kruskal-Wall H p-value
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**				
FP3	4.19	1	4.00	3	4.11	2	4.38	2	-0.11	-0.38	-0.27	0.363
FP1	4.15	2	4.00	3	4.21	1	4.21	6	-0.21	-0.21	0.00	0.661
RP2	4.12	3	4.06	2	3.89	5	4.33	3	0.17	-0.27	-0.44	0.242
KI1	4.12	3	4.19	1	4.00	4	4.17	7	0.19	0.02	-0.17	0.692
DP3	4.10	5	3.94	5	3.84	7	4.42	1	0.10	-0.48	-0.58	0.034*
FP4	4.07	6	3.88	9	3.89	5	4.33	4	-0.01	-0.45	-0.44	0.178
DP1	4.03	7	3.81	11	4.05	3	4.17	7	-0.24	-0.36	-0.12	0.296
KI3	4.02	8	3.88	9	3.79	10	4.29	5	0.09	-0.41	-0.50	0.065
KI2	3.93	9	3.94	5	3.74	11	4.08	12	0.20	-0.14	-0.34	0.358

GRPs	All respondents (N=59)		(1) Consultant (N=16)		(2) Contractor (N= 19)		（3）Research institute (N=24)		Diff. (CS–CT)	Diff. (CS–RI)	Diff. (CT–RI)	Kruskal-Wall H p-value
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**				
DP2	3.90	10	3.88	8	3.84	7	3.96	17	0.04	-0.08	-0.12	0.900
OP2	3.90	10	3.94	5	3.74	11	4.00	15	0.20	-0.06	-0.26	0.523
RP3	3.88	12	3.75	13	3.79	9	4.04	13	-0.04	-0.29	-0.25	0.363
FP2	3.86	13	3.75	13	3.63	14	4.13	9	0.12	-0.38	-0.50	0.125
EP1	3.83	14	3.63	17	3.74	11	4.04	13	-0.11	-0.41	-0.3	0.260
OP3	3.83	14	3.69	16	3.58	15	4.13	9	0.11	-0.44	-0.55	0.046*
RP1	3.75	16	3.56	18	3.42	17	4.13	9	0.14	-0.57	-0.71	0.032*
OP1	3.75	16	3.81	11	3.37	18	4.00	15	0.44	-0.19	-0.63	0.042*
EP2	3.69	18	3.75	13	3.47	16	3.83	18	0.28	-0.08	-0.36	0.318

Note: The Kendall's W for ranking the 18 GRPs was 0.064 with a significance level of 0.000; Diff. (CS–CT) = Difference in mean scores from consultants and contractors; Diff. (CS–RI) = Difference in mean scores from consultants and research institutes; Diff. (CT–RI) = Difference in mean scores from contractors and research institutes;
*The Kruskal-Wallis H test result is significant at the significance level of 0.05 (p-value < .05).

In **Table 5**, Kendall's W test result is 0.064, at the significance level 0.000. It indicates that a significant degree of agreement exists on the overall ranking of the GRPs. As shown in **Table 5**, professionals from research institutes gave higher scores to the GRPs than consultants and contractors. Furthermore, Kruskal-Wallis H test results show that there are four GRPs with p-values less than 0.05, indicating significant differences between the three respondent groups. These four GRPs are “Develop a guideline on building green retrofit” (DP3), "Incorporate green retrofit element in existing mandatory schemes (e.g., MBIS, MWIS)" (RP1), "Establish an institution of green retrofit or create a green retrofit branch in existing institutions" (OP1) and "Encourage specialist contractors in green retrofit" (OP3). The differences mainly exist between contractors and research institutes (see **Table 5**). Researchers gave higher scores to these policies than contractors from a long-term view. Contractors’ scores reflect their practical view by considering the implementation effectiveness and difficulties of these policies, which may not be considered by the researchers. Therefore, different views from various stakeholders should be considered when developing new policies.

4.3. Results of correlation analysis

The data collected in this study is not normally distributed. Therefore, Spearman correlation analysis is suitable for the data analysis [64, 65]. Correlations between the 28 GRTs and the 18 GRPs were examined by using Spearman Correlation analysis, and the results are shown in **Table 6**. The significant correlations are highlighted.

Table 6
Results of Spearman Correlations analysis of GRTs and GRPs

Rank	Rank / GRP / GRT	7 DP 1	10 DP 2	5 DP 3	16 RP 1	3 RP 2	12 RP 3	14 EP 1	18 EP 2	2 FP 1	13 FP 2	1 FP 3	6 FP 4	17 OP 1	11 OP 2	15 OP 3	3 KI 1	9 KI 2	8 KI 3
3	BS1-1	-	-	*	-	*	**	-	-	-	-	-	**	-	*	**	**	*	**
5	BS1-2	-	-	-	-	*	*	-	*	-	-	*	*	-	*	-	-	-	*
8	BS1-3	*	-	*	-	**	*	**	-	-	-	*	*	-	**	*	*	-	-
14	BS2-1	**	-	-	-	*	-	-	-	*	-	-	-	-	-	-	-	-	*
21	BS2-2	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
20	BS2-3	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
24	BS3-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	BS3-2	-	-	*	-	-	*	-	*	-	-	-	-	-	**	*	-	-	-
4	BS4-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	BS4-2	-	-	**	-	*	-	-	*	-	-	-	-	-	-	*	-	-	-
22	BS4-3	-	-	**	-	-	*	-	-	-	-	-	-	*	*	*		*	-
6	BS4-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	BS4-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	BE1-1	-	-	-	-	-	*	*	-	-	-	-	-	*	*	-	**	*	-
16	BE1-2	*	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
12	BE2-1	*	-	**	-	*	*	-	-	-	*	-	-	-	-	*	**	-	-
13	BE2-2	-	-	**	-	**	*	-	-	-	-	-	-	-		*	-	*	-
9	BE2-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	BE3-1	-	-	-	-	*	**	-	-	-	-	-	-	-	-	-	-	-	-
27	BE3-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*		-
18	BE4-1	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
26	BE4-2	-	-	-	-	-	-	*	-	**	-	**	*	-	*	*	-	-	*
7	BE4-3	-	-	-	-	**	-	-	-	-	-	-	-	-	-	-	-	-	-
15	BE5-1	-	-	-	-	**	*	-	-	-	-	-	-	-	-	-	-	-	-
19	BE5-2	-	-	-	-	-	**	-	-	-	-	-	-	-	**	-	*	-	-
10	RE1	-	-	-	-	**	-	*	**	-	-	-	-	-	**	-	*	-	-
23	RE2	-	-	-	-	*	-	-	-	-	-	-	-	**	-	*	-	**	*
28	RE3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level.

5. Discussion

5.1 Top GRTs and GRPs

For the top GRTs, "Energy-efficient appliances and equipment selection" (BS4-2) is ranked first with a mean score of 4.15. Electrical equipment and appliances account for a significant portion of total domestic electricity consumption [66]. According to related reports, domestic appliances are responsible for an average 27.2% of total residential energy consumption in Austria [33], while this figure is 47% in Hong Kong [67], which includes cooking, refrigeration, laundry, and hot water. Up to 25% of household energy use can be saved if energy-efficient appliances are adopted, especially refrigerators and laundry [33]. Moreover, replacing existing appliances and equipment will cause only minimal disturbance to the occupants [68]. “Energy-efficient room air conditioner” (BS3-2) is ranked second with a mean score of 4.03. Located in a subtropical climate, buildings in Hong Kong have high cooling demand for air conditioning systems throughout most of the year [9]. Energy consumption of air conditioners accounts for 38% of the total residential sector energy consumption in Hong Kong [67]. Using high energy-efficiency air conditioners can help to reduce 20% to 50% energy use for air conditioning [69]. Thus, the adoption of energy-efficient air conditioners is an effective method for energy saving in Hong Kong. “Low energy lamps (T5 fluorescent)” (BS1-1) is ranked the 3rd with a mean score of 4.02. Upgrading the existing lighting system is a simple solution for building green retrofit. Only 15% of public residential buildings in Hong Kong use LEDs for lighting [12]. Energy-efficient lamps can reduce energy consumption by about 50% by using a T5 fluorescent lamp [70], and 65 to 80% by “Light-emitting diode (LED) lighting” (BS1-2) [71], which is ranked the 5th with a mean score of 3.97. “Time switches” (BS4-1) is ranked the 4th with a mean score of 3.98, which can be used to control home electronic appliances so that up to 50% of energy can be saved [72].

“Tax reduction for building green retrofit companies” (FP3) is ranked first with the highest mean score (mean = 4.19). Based on previous studies, the high refurbishment cost is a major obstacle to building retrofit [50, 73]. From the government point of view, the investment tax credit is one of the least-cost option [74]. Tax reduction on certain expenditure on building green retrofit would encourage more adoptions of building green retrofit and avoid excessive government financial burden concurrently [75].

"Research funds for building green retrofit" (FP1) is ranked as the 2nd important policy. It indicates that more research funds should be provided to support relevant research on green retrofit, thereby promoting a large scale of green retrofit adoption [40]. "Formulate codes, standards, and regulations (CSR) for building green retrofit" (RP2) is ranked third with a mean score of 4.12. Regulations, codes, and standards play important roles in promoting green retrofit as they are used to regulate the market and provide guidance for building green retrofit [76, 77]. "Promotion programs for public awareness of green retrofit" (KI1) is also ranked third. Information asymmetries, lack of awareness, and lack of knowledge and expertise are considered the obstacles for the adoption of green retrofit [78]. Public awareness of green retrofit can be improved through knowledge and experience sharing of successful projects and best practices in green retrofit [55].

Besides, the policies ranked 5th to 8th are also considered important by respondents with a mean score above 4.00. "Develop a guideline on building green retrofit" (DP3) (mean score = 4.10) and "Formulate a strategy for building green retrofit" (DP1) (mean score = 4.03) are direction-based policies. Clear strategies and guidelines for the adoption of green retrofit in the short and long term can help various stakeholders have a better understating of green retrofit and future directions [79], such as Consumer Guide to Energy Efficient Products in Austria [80], the Energy Efficiency Technology Strategy 2016 in Japan [81]. "Initiate subsidy scheme for green retrofit projects" (FP4) (mean score = 4.07) is an effective financial support for promoting green retrofit. Based on the previous research, subsidies normally involve direct cash incentives and other indirect subsidies, such as income tax incentives, sales tax incentives [82]. Furthermore, Innovation (KI3) is ranked 8th with a mean score of 4.02. Innovation is a key driver of sustainability [83]. Novel GRTs may change the traditional building retrofit practices and building performance can be improved substantially by new technologies [84].

5.2 Correlation between GRTs and GRPs

For aged residential buildings in Hong Kong, the lighting systems, lifts, roofs and windows need to be upgraded due to low energy efficiency. DP1 has significant correlations with BS1-3, BS2-1, BS2-3, BE1-2, and BE2-l, which indicates the relevant strategies should be developed to encourage upgrading existing lighting systems, lifts, roofs, and windows with new technologies. Furthermore, there is a lack of a local guideline for building green retrofit, which limits the wide application of GRTs. In **Table 6**, DP3 is significantly related to seven GRTs, including lighting (BS1-1, BS1-3), cooling (BS3-2), energy-efficient appliances (BS4-2, BS4-3), and windows technologies (BE2-1 and BE2-2). It indicates the importance and necessity of developing relevant guidelines for the local industry.

Mandatory policies, such as RP1, were not very supported by professionals, as discussed above. “Formulate codes, standards and regulations (CSR) for building green retrofit” (RP2) is significantly correlated to lighting (BS1-1, BS1-2, BS1-3), lift (BS2-1), energy-efficient appliances and equipment (BS4-2), green roof/wall (BE1-2), window (BE2-1, BE2-2), shading (BE3-1), insulation (BE4-1, BE4-3), airtightness (BE5-1), and renewable energy technologies (RE1, RE2). It indicates that it is necessary to regulate and provide guidance on the application of these GRTs. The relevant CSR should benefit various stakeholders to nurture a healthy regulatory environment [58, 85]. Likewise, “Promotion programs for green retrofit” (RP3) is significantly correlated to thirteen technologies, including lighting (BS1-1, BS1-2, BS1-3), lift (BS2-2, BS2-3), cooling (BS3-2), energy auditing (BS4-3), roof and wall (BE1-1), window (BE2-1, BE2-2), shading (BE3-1), and airtightness (BE5-1, BE5-2). Promotion program is generally a series of initiatives to achieve pre-defined goals. For instance, the Singapore government launched a green retrofit program named HDB Greenprint in existing residential estates, which has effectively launched several green initiatives such as solar panels, sensor-controlled LED lightings [86].

EP1 and EP2 are evaluation-based policies. Due to the complicated evaluation process and a number of existing green building rating tools, developing a new evaluation system may not be necessary. Incorporating green retrofit elements into existing rating tools could be a better option. The results also show that evaluation-based policies are less important at the current stage [12]. Labelling systems for energy efficiency related GRTs, such as lighting (BS1-2), cooling (BS3-2), energy-efficient appliances (BS4-2), and solar water heating (RE1), have been adopted in the industry [87, 88]. In Hong Kong, evaluation of green retrofit could be incorporated into the existing green building rating system, such as BEAM Plus. The rating tool is an effective way to attract building owners to adopt GRTs in their retrofit projects.

Financial-related policies (e.g., FP3, FP4) are significantly related to GRTs in building services categories such as BS1-1, BS1-2, BS1-3. Based on previous studies, the high cost is a major obstacle to carry out retrofit works to improve the energy efficiency of existing buildings [50, 73]. Financial support can provide financial assistance to building owners and help to alleviate building owners' financial burden so that building owners' willingness of green retrofit can be increased [22, 76]. In principle, financial support policies should function to all GRTs. However, according to Table 6, the correlations among most financial support policies and GRTs are not significant. This result may be caused by insufficient financial support and the complex application process. In some real cases, insufficient incentive policies are caused by the agency problem between the government and building owners and the ignoration of the diversity of buildings and building owners, resulting in a lack of reaction from owners [89].

In **Table 6**, OP1 is significantly correlated to BS4-3, BE1-1, and RE2. This strategic policy should be considered in the long run [41, 43]. OP2 and OP3 are professional training related policies. It indicates that there is a lack of skilled professionals and labour force for some GRTs, such as “Wall insulation” (BE4-2) and “Airtightness” (BE5). For example, Zhang et al. [22] point out that the adoption of extensive green roof systems in existing buildings is very low in Hong Kong due to the lack of relevant professionals and specialist contractors. The complex construction process and technical difficulties within the existing green technologies cannot be addressed in the short term if there are not enough professional training [90]. For instance, Hong Kong's abundant solar energy provides a good opportunity for building-integrated photovoltaics (RE2). However, the lack of skilled labour is one of the obstacles to adopting this technology [17].

The publicity related policies (e.g., KI1, KI2, KI3) can help to improve the public awareness of GRTs, especially to those with significant correlations (e.g., BS1, BS2, BS4, BE1, BE2, BE5, RE2). Building owners are more willing to use GRTs if they know more about GRTs and their benefits [24]. The publicity for high-tech products and technologies (e.g. vacuum insulation panels in building façade) can increase public awareness and increase their applications in green retrofit projects [91]. Various methods can be used to promote building green retrofit and increase public awareness, such as pilot green retrofit projects, best practices sharing, publicity through social media [12, 24].

As shown in **Table 6**, not all the correlations between GRTs and GRPs are significant. The first reason may be due to insufficient policy support which could result in low adoption of GRTs [82]. Another explanation is that some policies are for general applications and not for a particular GRT. For example, “Develop a building green retrofit action plan” (DP2) is not significantly correlated to any GRTs because it is for the future development of green retrofit, not for a particular GRT. The “Energy Saving Plan for Hong Kong’s Built Environment 2015~2025+” provides the policy objectives and key actions from economic, regulatory, educational, and social aspects based on the analysis of current energy consumption patterns [92], and does not focus on certain technologies. Besides, some GRTs such as “Time switches” (BS4-1) can be easily adopted by occupants as they are available in the market with relatively low cost and less affected by relevant GRPs. Some GRTs are affected by other factors, such as high capital cost, disruption to occupants [93, 94].

Furthermore, the applicability of the 28 GRTs (mean score above 3.00) and the importance of the 18 GRPs (mean score above 3.50) are agreed by the local professionals. The correlation analysis was used to find out the impacts of policies on various technologies. It is acknowledged that the potential problem of correlation analysis between GRTs and GRPs in this study, may relate to the sample size and the demography of respondents (e.g. their experience in Hong Kong), such a problem is presented in many empirical studies of policy and technology [82]. The results can provide a good reference for examining the relationships between GRPs and GRTs but do not guarantee the causation. The detailed correlations between GRTs and GRPs need to be examined by content analysis of related policies and technologies [43].

5.3 A priority guide of green retrofit development in Hong Kong

Based on the survey results and analysis, a priority guide for promoting green retrofit implementation in Hong Kong was developed, as shown in **Fig. 1**. According to the arguments proposed by Tam et al. [8], retrofitting budgets do not always meet the ever-increasing cost. There is a need to set priorities for different GRTs and GRPs. In this study, the priority setting is category based. After an in-depth analysis of literature, cost, implementation difficulty, the local environment, and the viewpoints of local professionals, three priority levels of GRTs and GRPs were proposed, namely Tier 1 (high priority), Tier 2 (medium priority), and Tier 3 (low priority), as shown in **Fig. 1**.

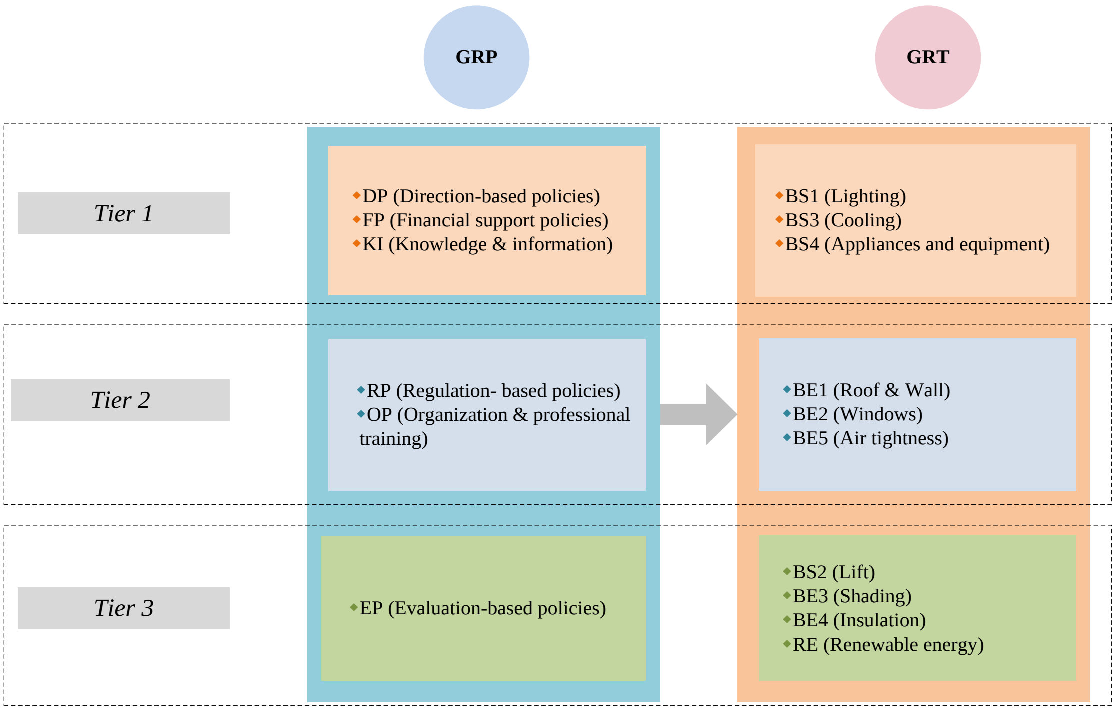

Fig. 1 Priority guide for green retrofit of aged residential buildings in Hong Kong

GRTs with high priority include BS1 (lighting), BS3 (cooling), and BS4 (other appliances and equipment). These retrofit technologies are cost-effective and easy to implement for energy saving, and also have high rankings according to the survey (see **Table 4**). Especially, "Energy-efficient appliances and equipment selection" (BS4-2) and "Energy-efficient room air conditioner" (BS3-2) are considered as effective measures to reduce building energy consumption in Hong Kong [9, 66]. Therefore, these technologies were identified as Tier 1 GRTs with high priority and can be promoted on large-scale. Moreover, BE1 (roof & wall), BE2 (windows), and BE5 (air tightness) were identified as Tier 2 GRTs with medium priority. According to the result of the survey, these technologies have lower rankings comparing with Tier 1 and have some constraints in the application (see **Table 4**). For example, "Reflective glazing" (BE2-2) has low visible light transmission properties, and the sunlight can be easily blocked by neighbouring buildings in high-density cities, such as Hong Kong [95]. Replacing existing windows can also cause disturbance to the occupants [96]. Similarly, the technologies in BE1 and BE5 also cause disturbance to the occupants, and BE1 involves relatively higher cost and technical difficulty [97].

Furthermore, BS2 (lift), BE3(shading), BE4 (insulation), and RE (renewable energy) were grouped into Tier 3, because there are more limitations or difficulties when applying these GRTs in Hong Kong. For example, BE4 (insulation) is effective for improving buildings energy efficiency because up to 60% of the energy consumption in conventional buildings is due to heat losses or heat gains through the building envelope (wall, roof, and glazing window) [98, 99]. However, insulation related technologies are not easy to implement due to technical difficulties and high disturbance to the occupants [96], which also make it difficult for large-scale application in Hong Kong. Therefore, the application of technologies in BS2 and BE4 will be on a case-by-case basis. Technologies in BE3 also involve high cost, disturbance to occupants (BE3-2 Automatic blinds), and technical problems for installation (BE3-1 Overhangs/Vertical fin). For RE (renewable energy), such as the building-integrated wind turbine (RE3) technology, it is barely used in Hong Kong because the performance of wind turbine is variable and would change via wind speed and wind direction due to the surrounding urban environments [100]. The average wind speed for the urban location is generally much lower, and the effective wind power utilization is around the windward top roof [101]. These renewable technologies would be widely adopted in the future with improved performance. The GRTs in Tier 3 also have lower rankings from the survey, which echoes the above discussion (see **Table 4**).

The pre-identified 18 GRPs were also further analyzed by considering their rankings, implementation difficulty, and impacts on GRTs, and grouped into three priority levels, as shown in **Fig. 1.** DP (direction-based policies), FP (financial support policies), and KI (knowledge & information) are in Tier 1 with high priority. Due to less experience and knowledge of building green retrofit, direction-based policies, including green retrofit strategy, action plan, and guideline, should be developed with high priority at the early stage of green retrofit development. For example, “Develop a guideline on building green retrofit” (DP3) can help various stakeholders to have a better understanding of various GRTs and their applications on aged residential buildings in Hong Kong. For the implementation of GRTs, the cost is a major concern of the building owners [68]. Financial support policies can increase building owners’ willingness for green retrofit, especially private building owners [7, 50]. According to the findings from the survey, financial support policies have high rankings, as shown in **Table 6.** However, it needs to avert the risk of increasing the financial burdens of the government [40, 102]. Additionally, public awareness, knowledge & information (KI) sharing of green retrofit are also important to help various stakeholders know more about green retrofit and their benefits, especially in those aged residential communities.

RP (regulation-based policies) and OP (organization & professional training) are in Tier 2 with medium priority. With further development of green retrofit in the local industry, there is a need to regulate the market and provide relevant professional training to ensure the healthy development of green retrofit. However, standardization is a complex process and needs time and relevant experience [103]. Therefore, RP and OP should be carried out when the market is growing, with relevant experiences and lessons learned. EP (Evaluation-based policies) is in Tier 3 with low priority. When the building green retrofit sector is mature, the evaluation-based policies should be considered to evaluate the efficiency of green retrofit projects and make improvement. There are difficulties when developing evaluation-based policies, such as complex data collection, development of assessment tools and lack of professional assessors, etc. [104], which is echoed by the professionals from the survey (see **Table 6**). Therefore, evaluation-based policies can be developed at a later stage to ensure continuous improvement in building green retrofit.

6. Conclusions

Hong Kong is facing the problem of aged residential buildings with low energy efficiency. Green retrofit provides a quick and sustainable solution for these aged buildings instead of constructing new buildings. This study examined the relative applicability and importance of pre-identified 28 GRTs and 18 GRPs for aged residential buildings in Hong Kong, and the correlations between GRTs and GRPs. Based on in-depth analysis, a priority guide for green retrofit of aged residential buildings in Hong Kong was developed, which grouped the GRTs and GRPs into three priority levels. The main findings of this study can be summarized as follows.

(1) In Hong Kong, air conditioning and lighting account for around 40% of total electricity consumption. The top GRTs identified in this study are mainly related to air conditioning and lighting, which echoes the importance of upgrading existing lighting and air conditioning systems of aged residential buildings in Hong Kong.

(2) Policies play important roles in promoting green retrofit, especially policies related to financial support, regulations, and public awareness. There is a need to review existing policies and think about how to provide effective technical and financial supports? how to regulate the market? and how to increase public awareness?

(3) Resources are always limited. A priority guide can help to allocate available resources more efficiently when developing green retrofit strategies and new policies. However, the local contexts and building features should also be considered when using the priority guide.

This study provides an in-depth examination of pre-identified 28 GRTs and 18 GRPs with empirical evidence. The findings can help various stakeholders to have a better understanding of the identified GRTs and GRPs, such as their applicability, importance, and priority levels. The findings also provide a useful reference for the local Government to develop future green retrofit policies and ensure the healthy development of green retrofit in the local industry. Furthermore, this study also provides a fundament for the development of green retrofit in other countries or regions that have similar contexts and building features with Hong Kong. However, there are also limitations to this study. For instance, this study is mainly based on a questionnaire survey from the local professionals, not including policy actors' and end-users' views. and the sample size was relatively small. Thus, future research should include more stakeholders (e.g. building owners, developers, and government) and increase the sample size. Furthermore, the application and effectiveness of different GRTs and GRPs can be further examined through real green retrofit projects.

Acknowledgement

This research was fully supported by a grant from the Environment and Conservation Fund of Hong Kong Special Administrative Region, China (Project No. ECF 55/2015). It was also partially supported by the start-up fund for new staff, School of Engineering, RMIT University, Australia, and by the National Social Science Fund of China (No. 18ZDA043).

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