# Review of Green Retrofit Technologies and Policies for Aged Residential Buildings in Hong Kong

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## ABSTRACT

Green retrofit of aged residential buildings contributes to reduce global energy consumption and greenhouse gas emissions. The promotion of green retrofit and the performance of retrofitted buildings depend on applicable technologies and policies. A wide range of retrofit technologies and retrofit policies have been applied throughout the world. However, little attention has been paid to identify suitable retrofit technologies and retrofit policies for particular regions, for example Hong Kong. In this study, both of technologies and policies of refurbishment were reviewed and examined with aiming to implement suitable green retrofit technologies and policies in Hong Kong. In referring to the particular characteristics of Hong Kong residential buildings, 28 green retrofit technologies and 18 green retrofit policies were recommended. The findings in this study are useful for local government setting up green retrofit strategies for Hong Kong and also provide good references for other countries and regions.

## INTRODUCTION

Building sector is widely considered as the major contributor of the greenhouse gas emission and energy consumption (Jagarajan et al. 2017). The research by Li et al. (2017) proposed that buildings are responsible for over 30% of global anthropogenic greenhouse gas (GHG) emission and 40% of the primary energy consumption. Considering the high ratio of existing buildings to new constructions (Durmus-Pedini and Ashuri 2010; Zhou et al. 2016), one reasonable solution to reduce global GHG emission and energy consumption is green retrofit of existing buildings (Onat et al. 2014).

Compared to the demolition of existing buildings and rebuilding, building green retrofit to some extent is more beneficial (Langston et al. 2008). For example, Ma et al. (2012)

demonstrated that retrofitting buildings can improve their energy efficiency, which is essential for the promotion of environmental sustainability. Wilkinson et al. (2009) further concluded that green retrofit is deemed to preserve cultural, aesthetic, and heritage value of aged buildings. The economic advantages of green retrofit can be found in project flexibility, low financing cost, and increased building value (Wilkinson 2012).

Technology and policy are the two most important factors affecting the application of green retrofit to existing buildings. The research by Tryson (2016) opined that available technologies are considered as the basement to improve building performance. The innovation and adoption of advanced technologies determine the economic growth, customers' satisfaction and environment effect (GhaffarianHoseini et al. 2013). In addition, Hwang et al. (2017) pointed out that government policies, such as retrofit guide and retrofit incentive for dwellers, are helpful for implementing retrofit work easily and effectively.

In a typical developed and densely populated metropolis like Hong Kong, the proportion of aged buildings, especially the residential buildings, to the total number of buildings is large and continues to increase, whereas the rate of retrofit is low (Chiang et al. 2015; Langston et al. 2008). In 2012, two mandatory schemes, Mandatory Building Inspection Scheme (MBIS) and Mandatory Window Inspection Scheme (MWIS), were implemented in Hong Kong. This provides a good opportunity to promote green retrofit of aged buildings in Hong Kong.

The existing experience of building retrofit accumulated throughout the world can be used as reference for decision-makers when implementing green retrofit of existing buildings. However, the distinctive climatic features, architectural characteristics, and construction standards may lead to such experience unsuitable or unfeasible for application in Hong Kong (Lam 2000; Li et al. 2017). It is important to identify those technologies and policies, which are in line with the local situation. Therefore, this study aims to identify appropriate green retrofit technologies and policies for aged residential buildings in Hong Kong.

## REVIEW OF GREEN RETROFIT TECHNOLOGY AND POLICY

**Review of green retrofit technology:** Retrofit technologies are energy conservation measures used to promote building energy efficiency and sustainability (Ma et al. 2012). To identify the retrofit technologies adopted in green retrofit, a systematic review was conducted based on related literatures. Finally, 117 technical methods for building retrofit were collected. With reference to Li et al. (2017), these technologies are grouped into three categories, building service, building envelope and renewable energy, and further grouped into sub-categories. The detailed classification and their distribution are shown in Figure 1.

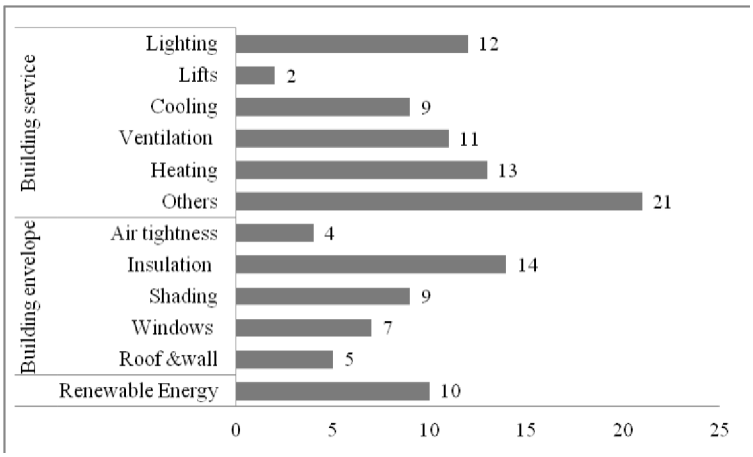


**Figure 1. Distribution of existing retrofit technologies under different categories.**

**Review of green retrofit policy:** Policies are essential for promoting green retrofit. There are great potentials for energy saving and carbon reduction by implementing efficient energy policies (Lester 2013). To understand the status quo of refurbishment policies, more than 500 policies in over 29 countries and regions were collected. The collected green retrofit policies were grouped into six categories: direction-based policies, regulation-based policies, evaluationbased policies, financial support policies, organization & professional training policies and knowledge & information policies. The distribution of collected policies is shown in Figure 2.

**Figure 2. Distribution of existing retrofit policies under different categories.**

## APPLICABLE GREEN RETROFIT TECHNOLOGIES AND POLICIES FOR RESIDENTIAL BUILDINGS IN HONG KONG

**Characteristics of residential buildings in Hong Kong:** In order to identify the features of residential buildings in Hong Kong, a survey was carried out to collect relevant information. An investigation form was designed for the survey, which consisted of five aspects, including basic information, structure, facilities, services and policies. Three main features of public housing in Hong Kong were identified as follows.

(1) High rise buildings: 99 percent of the surveyed buildings are over 10 storeys, wherein the buildings with 21-30 storeys account for 64%. According to the investigation, the average height of each storey is 2.6m. Reference to this data, the height of 64 percent of the survived buildings is more than 54.6m.

(2) Low adoption rate of energy-saving device: for high-rise buildings, lift is a must for transportation. However, 70 percent of the surveyed buildings are not equipped with energy-saving lifts. In addition, only 15 percent of the surveyed buildings are installed with LED; 27 percent are equipped with sensors. It is notable that the window material is ordinary, which may result in high heat gains (in summer) and loss (in winter).

(3) Big difference in energy consumption: the average annual electricity consumption of the public area is from 35470.0-582454.7 kW·h. It shows big differences in energy consumption of different estates.

**Recommended green retrofit technologies in Hong Kong:** To understand the suitability of technologies and policies identified above better, a desktop study was employed to eliminate those that are not applicable to Hong Kong's residential buildings. Based on the identified characteristics of residential buildings and the policy context in Hong Kong, the five criteria, namely, subtropical climate, pattern of energy consumption, suitability for residential buildings, high-rise buildings and high-density city, and development environment (e.g., political system, economic level and environment condition), were applied in the process of identifying the suitable green retrofit technologies and policies. 28 applicable green retrofit technologies were identified for Hong Kong, as shown in Table 1.

**Table 1. Recommended Green Retrofit Technologies for Hong Kong.**

| Category | | Recommendation | N. |
|---|---|---|---|
| Building service | Lighting (BS1) | Low energy lamps (T5 fluorescent) Light | BS1-1 |
| | | emitting diode (LED) lighting | BS1-2 |
| | | Daylight/Motion sensors | BS1-3 |
| | Lift (BS2) | Lifts with power regeneration system | BS2-1 |
| | | Modernize lifts with a VVV-F control system | BS2-2 |
| | | Lifts with permanent magnet motor | BS2-3 |
| | Cooling (BS3) | Evaporative cooling | BS3-1 |
| | | Use energy efficient room air conditioner | BS3-2 |
| | Others (BS4) | Time switches/sensors | BS4-1 |
| | | Use energy efficient appliances and equipment (e.g. appliances with green label, high efficiency pumps) | BS4-2 |
| | | Install meters for energy auditing | BS4-3 |
| | | Domestic water saving devices | BS4-4 |
| | | Grey water reuse and rainwater harvesting | BS4-5 |

| | | | |
|---|---|---|---|
| Building envelope | Roof & wall (BE1) | Reflective surface (cool roofs or walls) | BE1-1 |
| | | Green wall/roof | BE1-2 |
| | Windows (BE2) | Window frame with thermal break | BE2-1 |
| Building envelope | Windows (BE2) | Reflective coating of window glass | BE2-2 |
| | | Double/multiple glazing | BE2-3 |
| | Shading (BE3) | Overhangs/Vertical fin | BE3-1 |
| | | Automatic blinds | BE3-2 |
| | Insulation (BE4) | External wall insulation | BE4-1 |
| | | Internal wall insulation | BE4-2 |
| | | Roof insulation | BE4-3 |
| | Air tightness (BE5) | Joint sealing | BE5-1 |
| | | Draught-proofing | BE5-2 |
| Renewable energy (RE) | | Solar water heating | RE1 |
| | | Building-integrated photovoltaic (BIPV) | RE2 |
| | | Building-integrated wind turbine (BIWT) | RE3 |

**Recommended green retrofit policies for Hong Kong:** Similarly, for these green retrofit policies types, 18 green retrofit policies are recommended for green retrofit of aged residential buildings in Hong Kong, as shown in Table 2.

Direction-based policies, such as plans, strategies, service as roadmaps to provide the direction in long term (Stieß and Dunkelberg 2013). Regulation-based policies have great impact on promoting green retrofit, which include law, code, regulation and standard (Shen et al. 2016). Evaluation-based policies (e.g., label, rating, and star) play important roles in promoting the development of green buildings. Financial support policies are considered as one of alternatives for supplement to mandatory regulation policies (Weiss et al. 2012). Organization & professional training policies, such as research & development (R & D), can help to solve practical problems of green retrofit and to develop new retrofit technologies. Knowledge & information policies are alternative programs for supplement to mandatory regulation-based policies and financial support policies.

**Table 2. Recommended Green Retrofit Policies for Hong Kong.**

| Category | Recommended policies | N. |
|---|---|---|
| Direction-based policies | Formulate strategy for building green retrofit | DP1 |
| | Develop a building green retrofit action plan | DP2 |
| | Develop a guideline on building green retrofit | DP3 |

| | | |
|---|---|---|
| Regulation-based policies | Incorporate green retrofit element in existing mandatory schemes (e.g., MBIS, MWIS) | RP1 |
| | Formulate codes, standards and regulations (CSR) for building green retrofit | RP2 |
| | Promote programs for green retrofit | RP3 |
| Evaluation-based policies | Establish a new evaluation system for green retrofit or incorporate green retrofit element in existing evaluation systems (e.g., BEAM-plus) | EP1 |
| | Establish a labeling system for building green retrofit | EP2 |
| Financial support policies | Research funds for building green retrofit (e.g. technology, policy) | FP1 |
| | Low interest loans for green retrofit projects | FP2 |
| | Tax reduction for building green retrofit companies | FP3 |
| | Initiate subsidy scheme for green retrofit projects | FP4 |
| Organization & professional training | Establish an institution of green retrofit or create a green retrofit branch in existing institutions | OP1 |
| | Provide relevant professional education and training | OP2 |
| | Encourage specialist contractors in green retrofit | OP3 |
| Knowledge & information | Promote programs for public awareness of green retrofit | KI1 |
| | Provide a platform for knowledge & experience sharing (e.g., APP, website and conference) | KI2 |
| | Encourage innovation in building green retrofit | KI3 |

## CONCLUSION

With the increasing number of aged buildings, green retrofit is considered important during the urban renew process. It is necessary to identify the applicable green retrofit policies and technologies for particular regions by considering the local conditions, such as the climate, development stages, building features. However, few studies have been done identifying both of applicable green retrofit policies and technologies for particular regions, such as Hong Kong. In this study, a comprehensive literature review on retrofit policies and retrofit technologies was conducted. By considering the local conditions and features of residential buildings in Hong Kong, 28 technologies and 18 policies were recommended which are suitable for Hong Kong. These 28 technologies were grouped into three categories, namely building service, building envelope and renewable energy. Similarly, the 18 policies are grouped into six categories, including direction-based policies, regulation-based policies, evaluation-based policies, financial support policies, organization & professional training policies and knowledge & information policies.

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