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Green retrofit of aged residential buildings in Hong Kong: A preliminary study

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ABSTRACT

Green retrofit of aged residential buildings offers an alternative solution 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 feasible 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 develop a framework for implementing suitable green retrofit technologies and green retrofit policies in Hong Kong. The particular characteristics of Hong Kong residential buildings were extracted based on the investigation of 100 public buildings. Taking the typical situations (building feature, climate environment and policy circumstance) as the selection criteria, 28 green retrofit technologies and 18 green retrofit policies were recommended. By analysing their attributes, these technologies and policies were integrated into a framework based on the three development stages of green retrofit (namely, pilot stage, promotion stage and full implementation stage). 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.

1. Introduction

Over the past two decades, sustainable development has been challenged by the issues of greenhouse gas (GHG) emissions and energy consumption [1]. One of the major contributors of greenhouse gas emissions and energy consumption is the building and construction sector [2]. Previous studies, such as Li et al. [3], showed that buildings are responsible for over 30% of global anthropogenic greenhouse gas emissions and 40% of the primary energy consumption. Meanwhile, building sector also consumes 72% of electricity, produces 67% of solid waste, depletes 13% of potable water [4]. Considering the high ratio of existing buildings to new constructions [5,6], one reasonable solution to reduce global GHG emission and energy consumption is green retrofit of existing buildings [2,7,8].

Compared to the demolition of existing buildings and rebuilding, building green retrofit to some extent is more beneficial [9]. These benefits are generalized as the triple structure (namely, environment, society, and economy) of green retrofit underpinning sustainability [10,11]. As demonstrated that green retrofit of existing buildings can improve their energy efficiency, which is essential for the promotion of environmental sustainability [12,13]. At the social level, green retrofit is deemed to preserve cultural, aesthetic, and heritage value of aged buildings [14,15,16]. In addition, retrofitted buildings are more livable and comfortable for dwellers [17]. The economic advantages of green retrofit can be found in project flexibility, low financing cost, and increased building value [11,16]. For example, Chau et al. [18] found that retrofitted buildings have 9% enhancement of their property values in comparison with un-retrofitted buildings in the same area.

By virtue of these advantages, green retrofit in existing building has been carried out in many countries. For example, the federal government of the United States has conducted the refurbishment plan to improve energy productivity by 2030 [19]. In Germany, over 900 pre-1978 built residential buildings were renovated with installing energy efficient heating and cooling systems [20]. In Switzerland, policies, such as tax incentives and financial assistance, were launched to support existing building retrofit [21,22]. Mandatory policies were adopted by Australian government to require the owners of large commercial office buildings to provide energy efficiency information to potential buyers or lessees. Similarly, there are a number of schemes to help home owners to make energy saving improvements, such as Green

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Deal, Energy Company Obligation, Feed-in Tariffs, Renewable Heat Incentive in UK (International Energy Association, IEA). In Singapore, Building Retrofit Energy Efficiency Financing (BREEF) scheme provides financing to building owners for energy retrofit. These efforts indicate the importance of green retrofit of existing buildings.

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 [9,23]. According to the Hong Kong Energy End-use Data 2016 published by EMSD, the energy consumption of residential buildings accounted for 22% of the total energy use, and there is also an increasing trend. Of these residential buildings, over 89% were built before 1998. Most buildings are not regularly maintained with low performance, accessibility, safety and security, poor indoor air quality etc. This situation indicates that the number of aged buildings in Hong Kong is increasing, and these buildings will have to be maintained or retrofitted due to poor performance. Relevant studies on improving buildings' energy efficiency have been done by local researchers [3,24,25]. 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 references 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 [3,26]. It is important to identify the 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, and establish a framework for guiding the future development of building green retrofit in Hong Kong.

2. Literature review of green retrofit

According to Tryson [27], retrofit is the "change" of elements or components of a building. Wherein, the "change" for green retrofit is limited to the "upgrade", which aims to improve a building's environmental performance. In this sense, the scope of "retrofit" covers the scope of "upgrade". The "retrofit" also refers to other terms in literature as well, such as refurbishment, rehabilitation, renovation, improvements, adaptation, repairs and renewal on existing buildings [28]. Further, green retrofit is defined by Brown et al. [29] as "the upgrading of the building fabric, systems or controls to improve the energy performance of the property". In more detail, the U.S. Green Building Council (USGBC) defines green retrofit as "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 - all done in a way that it is financially beneficial to the owner". From these definitions, it can be seen that green retrofit can improve energy performance, satisfactory service level and indoor environmental quality of existing buildings [30].

In this sense, green retrofit offers an alternative solution for greenhouse gas emissions and energy consumption issues [28]. In both developed and developing countries, extensive studies on green retrofit have been carried out from various aspects. Examples of these include studies of stakeholders' perceptions of green retrofit [31,32], evaluation [33,34], refurbishment measures (e.g., envelope renovation technologies, air conditioning system refurbishment solutions, green roofs) [35,36,37], and the policies [38,39]. Stakeholders' perceptions of green retrofit are different. For example, homeowners prefer to pay for a heat pump, whereas tenants prefer floor insulation [40]. Some owners or tenants are reluctant to retrofit because of the uncertainty in energy saving, lack of understanding of green retrofit, and long payback time [28]. In a nutshell, these studies can be summarized as "2W1H", wherein "2 W" represent "What is green retrofit" and "Why need green retrofit"; "1H" refers to "How to conduct green retrofit" [2]. The aforementioned contents have explained the definiton (what) and the necessity [41] of green retrofit. However, there is no a standard answer for the question "how to conduct green retrofit". In fact, the implementation of green retrofit is the key to achieve sustainbility.

The success of green retrofit depends on many factors, such as retrofit awareness [28] and green willingness of owners [2], retrofit cost [34], avaliable technologies [5], and policy support [42]. Among these factors, public awareness and participation in green retrofit can be improved through government policy guidance and support [43,44]. This opinion is supported by Hwang et al. [31]. They pointed out that government policies, such as retrofit guide and retrofit incentive for dwellers, are helpful for implementing retrofit work easily and effectively. By assessing China' building retrofit policies, Li and Shui [42] claimed that the government makes a significant contribution to promote green retrofit by the provision of adequate financial support, appropriate oversight and monitoring. For the issues of retrofit cost, fiscal policies such as tax deduction, loan discount, capital subsidy are successful in leveraging investment in green retrofit [12,45,46].

Moreover, the cost problem may be solved by selecting appropriate retrofit technologies [21,47]. For example, the Ground Coupled Heat Pump (GCHP) system can be used reduce the payback period in comparison with renewable energy [6]. Likewise, technology feasibility can help to reduce relevant risks of retrofitting, and increase the acceptance rate of stakeholders involved in retrofit projects [29]. It is noteworthy that available technologies are considered by Tryson [27] as the basement to improve building performance. Two reasons contribute to this argument. On one hand, the definition of retrofit stresses that the technical intervention is the main measures to improve building performance [48]; on the other hand, the innovation and adoption of advanced technologies determine the economic growth, customer satisfaction and environment effect [49]. In this sense, the availability of technology and its advancement are considered as key factors affecting green retrofit of buildings [48].

Based on above analysis, technology and policy are the two most improtant factors affecting the application of green retrofit to existing buildings. The retrofit technology and policy vary from the climate regions and the features of buildings [3,26]. For example, Ascione et al. [50] discovered the renovation technology of phase change materials wallboards is more appropriate for semi-arid climate than hot/subtropical Mediterranean climates. By applying technologies in different climate zones, Ciullaet al. [12] found pay-back time vary for the same action, increasing from colder to warmer zones. In the light of construction characteristics, Kontokosta [51] put forward that the selection of technologies and policies of green retrofit is impacted by the characteristics of buildings, such as a building's age, primary fuel type, or construction type. Additionally, the studies of green retrofit were conducted based on different building types, covering residential buildings [21,52], commercial buildings [15,53], hotel buildings [54], industrial buildings [55], laboratory buildings [30], historic buildings [56]. This implies that it is essential to identify suitable green retrofit technology and green retrofit policy based on the characteristics of buildings and their physical environment (Fig. 1).

Among the multiple building categories, residential buildings account for 29% of the total building stock built after World War II and before 1975, therefore need attentions [57]. However, few efforts have been made to retrofit those aged residential buildings [3]. Therefore, it becomes necessary to identify the suitable green retrofit technologies and develop relevant policies for residential buildings in line with particular environment (e.g., climate, characteristic of buildings).

According to Hong Kong Environment Bureau [58], many existing buildings, including old buildings, have great potentials to perform better through retro-commissioning and retrofitting. To retrofit these