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Investigating residents' perceptions of green retrofit program in mature residential estates: The case of Singapore

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ABSTRACT

Over the past decade, green retrofit has been gaining popularity around the world, and considerable buildings have been retrofitted to improve their energy efficiency. So far, however, limited was known about the residents' perceptions of those completed green retrofit programs. Thus, this study investigated the residents' perceptions of the green retrofit programs and explored their willingness to extend the green retrofit into individual houses. To achieve these goals, a questionnaire survey was administered to 90 residents from a mature public residential estate in Singapore which just completed a pilot green retrofit program. Survey results showed that 86 percent of respondents were satisfied with the green retrofit program, and in particular, the outdoor light emitting diode lighting was found to be the most satisfied green feature. The survey results also showed that more than 50 percent of respondents were supportive of having their individual houses undergo green retrofit and were willing to bear an upfront cost up to SGD 5000 (approximately USD 3540). Also, this study found that achieving cost savings from lower utility bills in the long run was the top motivation that drives residents to retrofit their houses, and an energy monitoring system was the most preferred green feature. Additionally, this study also came up with three practical recommendations to improve upon the current green retrofit program. This study contributes to the body of knowledge by making a thorough investigation of residents' perceptions of green retrofit programs. Also, the findings from this study can help authorities upgrade their green retrofit programs to create more energy efficiency benefits for the residents.

1. Introduction

Over the past two decades, the issues of global climate change, resource depletion, and environmental degradation have been deteriorating continuously due to the various human activities, and one of the representatives is the building and construction (Hwang, Zhao, & Tan, 2015b; Wu, Xia, Pienaar, & Zhao, 2014; Zhao, Hwang, & Gao, 2016a, 2016b). Previous studies showed that the building and construction industry is a major consumer for energy and resources, which used 40–50 percent of global energy and 40 percent of global raw materials; meanwhile, this industry is also a principal waste producer, which has released 40 percent of global greenhouse gas emissions and 40 percent of global solid waste (Mao, Shen, Shen, & Tang, 2013; Yang & Zou, 2014; Yang, Zou, & Wang, 2016; Yuan, 2013). These anxiety provoking figures have put considerable pressure on policy makers who eventually decided to adopt the concept of green buildings and thus, there has been a significant growth in green building construction recently (Qin, Mo, & Jing, 2016; Zou & Couani, 2012).

As defined by the Organization for Economic Co-operation and Development (OECD, 2002), residential buildings are a particular type of built environment that is constructed to satisfy peoples' dwelling needs. As a key subsector of the building, however, residential buildings have also been criticized as a major consumer for energy and a significant contributor to waste (Attia, Evrard, & Gratia, 2012; Shen, He, Jiao, Song, & Zhang, 2016; Wan & Yik, 2004). According to Santamouris et al. (2007), residential buildings consumed about 20 percent of the energy in OECD countries. Balaras et al. (2007) stated that residential buildings accounted for 63 percent of energy consumption and 77 percent of CO_2 emission in the building sectors of European Union member countries. Consequently, determined green efforts are also devoted to the

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residential building sector. Recently, a series of initiatives that attempts to reduce the resource consumption and achieve a better energy efficiency in residential buildings have been launched by the authorities worldwide (Chau, Tse, & Chung, 2010; Liang, Peng, & Shen, 2016; Zuo & Zhao, 2014). Typical examples are *Beyond Green Guidelines for High-Performance Homes* advocated by the Sustainable Building Industry Council (National Institute of Building Sciences, 2016), and *Green Star—Multi Unit Residential* advocated by the Green Building Council, Australia (2015). It is noteworthy that these initiatives not only emphasized the development of new eco-communities but also stressed the green retrofit in existing mature residential estates.

In a typical densely populated metropolis like Singapore, a large number of residential buildings are constructed to address people's housing needs (Agarwal, Satyanarain, Sing, & Vollmer, 2016). According to the Housing and Development Board (HDB, 2016b), more than 88 percent of the existing residential buildings in Singapore were built before 2005, the first year this country launched its national green building initiative (BCA, 2014). This ratio implies that, probably, there will be considerable residential buildings facing green retrofit shortly. In fact, Singapore has swung into action already. In 2012, the Singapore government launched a green retrofit program named HDB Greenprint in several existing mature residential estates, aiming to improve their energy efficiencies and provide their residents with a healthier indoor environment (HDB, 2016a). Among those pilot estates, one named Yuhua was the first mature residential estate to undergo the green retrofit and its retrofit work already completed in November 2015; while the objectives of this study are exactly to investigate the residents' perceptions of the pilot green retrofit program, explore their willingness to expand the green retrofit program in their individual houses, and propose some practical recommendations to enhance the green retrofit program.

Although there have been considerable studies related to green retrofit, the majority of them concentrate on the environmental benefits generated from retrofitting (e.g., Berardi, 2016; Geoffrey Shen et al., 2015; Liang, Shen, & Guo, 2015; Meek, Jayasuriya, Horan, & Adams, 2014; Wilkinson et al., 2015; Wong & Lau, 2013; Zhang, Shen, Tam, & Lee, 2012). Very few have investigated the residents' perceptions of the green retrofit programs. Thus, this study can contribute to the body of knowledge of green retrofit. Additionally, this study can also benefit the practice as it summarizes the achievements and lessons learned from the pilot green retrofit program, which may improve upon the current programs and bring more sustainable benefits eventually.

2. Backgrounds

2.1. Green buildings in Singapore

Singapore is a city-state with the limited land area and natural resources (Hwang, Zhao, See, & Zhong, 2015a), which has made sustainability a necessity rather than an option to the country. Over the past five decades, Singapore has been struggling to chase sustainability in its various industries (Ministry of the Environment and Water Resources & Ministry of National Development, 2014), and the building and construction industry is one of its primary emphases. In 2005, the local government embarked on the green building movement by launching the Building and Construction Authority Green Mark scheme. Since then, this country has successively advanced three rounds of Green Building Masterplans (i.e., Masterplans of 2006, 2009, and 2014) to promote the green building development across the island (BCA, 2014). In the meantime, the Singapore government has also launched a series of incentive plans (e.g., Green Mark Incentive Scheme for New Buildings in 2006 and Green Mark Incentive Scheme for Existing Buildings in 2009) to encourage local developers, building owners and project consultants to adopt environmentally-friendly design, technologies, and practices in their building projects (BCA, 2015a, b). Stimulated by these comprehensive suite of policies and initiatives, the green building and construction industry in Singapore has achieved a rapid development, and the number of green buildings has grown exponentially, from 17 in 2005 to more than 2100 in 2014, equivalent to 25 percent of the total built-up areas in the country (BCA, 2014).

2.2. Public housing in Singapore and the relevant green retrofit efforts

Singapore is an extremely small and compact island but with a large population, making public housing a critical issue to the local society (Abeysinghe & Gu, 2016; Phang, 2015). In order to tackle this knotty problem, the Singapore government established the Housing Development Board (HDB) in 1960, an authority entrusted with the responsibility of providing quality homes and living environments for the Singapore people (Ho, Hui, & Ibrahim, 2009; Hwang, Zhao, & Ng, 2013; Lee, 2015; Low Sui, Deng, & Laura, 2012). Over the past five decades, HDB has built 1,116,485 subsidized flats across the island for the 3,408,900 Singapore citizens (Department of Statistics, 2016b; HDB, 2016b). Currently, 80.2 percent of Singapore's population chooses to live in HDB flats, with 90.8 percent of these people owning the flats they live in (Department of Statistics, 2016b). The high lodging and home ownership rates suggest that the public housing system of HDB has achieved unprecedented success in Singapore.

To achieve the target of 80 percent of buildings going green by 2030, the Singapore government has also intensified its efforts in the sector of residential buildings. Particularly, the local authorities have launched some initiatives to retrofit those existing traditional residential buildings, considering that the majority of existing residential buildings in Singapore are the traditional ones that were designed and built without sustainable considerations (HDB, 2016b). For instance, in 2011, BCA launched the BCA Green Mark for Existing Residential Buildings, aiming to help the building owners and facility operators carry out green retrofits from the perspectives of energy efficiency, water efficiency, sustainable operation and management, and community and well-being (BCA, 2011). In 2012, HDB launched the HDB Greenprint scheme and piloted it in Yuhua Estate firstly (HDB, 2016a). More details of the green retrofit program at Yuhua Estate are introduced in the following section.

2.3. The HDB greenprint @ Yuhua estate

The green retrofit of Yuhua Estate was coded as HDB Greenprint@Yuhua, and it was carried out between October 2012 and November 2015, costing about SGD 23 million (approximately USD 16.6 million) (HDB, 2016a; Yeo, 2015). The retrofit involved 38 blocks and affected 3194 households living in this community (Kelleher, 2015). Five specific green features, namely elevator energy regeneration systems, solar photo voltaic systems, outdoor light emitting diode (LED) street lighting, rainwater harvesting systems, and pneumatic waste conveyance systems, were installed under this retrofit program (HDB, 2016a; Kelleher, 2015). Among these green features, the elevator energy regeneration system is an innovative type of elevator that can save power consumption by reusing the energy recovered from the elevator's descending travels with heavy loads and ascending travels with light loads. The solar photo voltaic system is installed to convert the natural sunlight into solar power that can be used to power lift and light