Habitat International 53 (2016) 430–441

Contents lists available at ScienceDirect

Habitat International

journal homepage: www.elsevier.com/locate/habitatint

The development of an energy-efficient remodeling framework in South Korea

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ARTICLE INFO

Article history:
Received 19 June 2015
Received in revised form
8 December 2015
Accepted 11 December 2015
Available online xxx

Keywords:
Sustainability
Building
Energy-saving
Energy-efficient remodeling

ABSTRACT

Buildings are responsible for serious negative environmental impacts caused by their excessive energy and resource consumption, which all contribute to global warming due to greenhouse gas emissions. Many governments have thus implemented energy-saving strategies and technologies for both new and existing buildings since buildings have long life spans. Energy efficient building practices can minimize negative environmental impacts and improve economic growth and social prosperity, but although the use of energy efficient methods for new buildings is now widely accepted in South Korea, they are seldom implemented for the renovation of existing buildings. Here we report the development of a highly efficient Energy-efficient Remodeling Framework (ERF) to facilitate the implementation of energy-saving strategies and technologies for existing buildings. It covers every stage of the project, from the initial identification of an energy-efficient building to its eventual Operation and Maintenance (O&M), focusing specifically on appropriate energy-saving strategies and technologies for existing buildings in South Korea. The ERF includes tools for energy-efficient renovation, including 'E-Scope', 'E-Ray', 'Impact Tables A&B', and 'E-Spectrum', that have been developed to support energy-efficient remodeling processes in South Korea. The new ERF framework can help government agencies and the construction industry to accelerate the process of expanding the energy efficient remodeling market and reduce energy consumption in the existing building stock and the associated carbon emissions, simultaneously improving the nation's energy security. The ERF will provide a useful national model for creating more energy efficient buildings and guide the creation of an energy-efficient remodeling policy in the Korean context.

1. Introduction

The concept of sustainability has gained widespread acceptance over the last 25 years with growing support for efforts to achieve major goals of sustainability such as enhancing social prosperity, solving environmental problems, and supporting economic growth. In the built environment, the implementation of sustainability through green building is becoming vital because green building can increase building efficiency & performance, save energy, water, and resources, and improve the occupants' productivity and health by providing a consistently high quality indoor air quality throughout the design, construction, operation, and end-of-life processes (Ahn & Pearce, 2007; Ahn, Pearce, & Ku, 2011; Pearce, Ahn, & HanmiGlobal, 2012). In addition, green building can also minimize the construction industry's negative impacts on the natural environment, including ozone layer depletion, global warming, acidification potential, smog, solid waste accumulation, ecosystem destruction, air pollution, and natural resource depletion, all of which are of increasing importance in our daily life (Ahn, Pearce, Wang, & Wang, 2013; Kibert, 2008). One of the key benefits of green building is to reduce energy consumption and the generation of carbon emissions because the building sector consumes over 40% of the energy produced and is responsible for approximately half of all carbon emissions (EIA, 2011). It is important to expand the existing focus on new buildings to include existing buildings because more than 60% of the energy consumed by a building during its life-cycle occurs when the building is in actual occupancy and use (Ardente, Beccali, Cellura, & Mistretta, 2011; Menassa, 2011; Zavadskas, Raslanas, & Kaklauskas, 2008). The existing building stock should thus be a key target for energy

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http://dx.doi.org/10.1016/j.habitatint.2015.12.003
0197-3975/© 2015 Published by Elsevier Ltd.

efficient strategies if we are to substantially reduce the adverse impacts of buildings on the environment, human health and the economy. To improve energy efficiency during building life-cycle, it is necessary to implement energy efficient remodeling strategies and technologies with energy-efficient process. High efficiency remodeling strategies improve the insulation, reduce air leakages through the building envelope and boost heat recovery from ventilation air by, for example, installing highly efficient HVAC systems and renewable systems and replacing existing lighting fixtures with high efficiency lighting fixtures (ISO14040, 1997; Ahn & Pearce, 2013; Ardente et al. 2011; Bokalders & Block, 2010; Gustavsson & Joelsson, 2010). However, investing in energy-efficient remodeling is a highly uncertain endeavor due to the many technical challenges involved in demonstrating the achievement of the necessary energy efficiency while at the same time staying within the allocated budget. Indirect and strategic challenges such as increasing tenants'/occupants' satisfaction and the lack of a comprehensive framework for energy-efficient remodeling can also be problematic (Menassa, 2011). Several studies have suggested that the following challenges are associated with energy-efficient remodeling: a lack of information and suitable benchmarks for the actual performance of a building and its systems after the design phase (Bosch & Pearce, 2003; Gaterell & McEvoy, 2005); reluctant stakeholder participation because energy prices and taxes are not sufficiently high to create a strong incentive for remodeling (Beheiry, Chong, & Haas, 2006); and perceptions from early energy-efficient buildings that the significantly higher implementation costs outweigh the eventual economic and environmental benefits (Ahn & Pearce, 2007; Newsham, Mancini, & Birt, 2009; Pearce, 2008). However, in spite of these energy-efficient remodeling is expected to increase in the future due to its many opportunities and benefits. Thus, the expansion of energy-efficient remodeling to cover existing buildings indicates an urgent need for a comprehensive that will facilitate the energy-efficient remodeling decision making process and incorporate energy-efficient remodeling strategies and technologies that can also be applied to guide energy related remodeling policies and incentives. The Energy-efficient Remodeling Framework (ERF) proposed here could not only significantly reduce the energy required to operate buildings and thus the generation of carbon emissions, but also increase the indoor comfort level and occupants' productivity, raising the value of the building. Thus, the national standard for a 'highly efficient ERF' developed for this study is expected to provide strong support for the energy-efficient remodeling of the existing building stock in South Korea.

2. Background studies and literature review

2.1. Environmental impact of buildings

Construction is one of the biggest industries in the world, providing necessary facilities for human prosperity ranging from the homes in which we live to the highways we drive on and the power plants that provide electricity for our daily activities. However, construction activities in the building life cycle are also connected with many broader problems and issues affecting the environment, including global warming, climate change, ozone depletion, soil erosion, loss of diversity, land pollution, air pollution, and the consumption of valuable resources such as fossil fuels, minerals and gravels (Pearce et al. 2012). Perhaps most importantly, buildings consume a significant amount of energy over their lifetimes (Ahn et al. 2013; Ardente et al. 2011; Pearce et al. 2012). The building sector accounts for around 25–30% of the total energy consumption in Organization for Economic Co-operation and Development (OECD) countries, including the USA, the European Union, Japan, and South Korea (OECD, 2003). In South Korea, buildings were responsible for 22% of the total energy consumption in 2010; energy consumption in the building sector continues to increase and this trend is predicted to continue at an annual rate of 2.6% (Park, 2011). Buildings also account for 30% of the world's greenhouse gas emissions (USDOE, 2011; USGBC, 2013). In South Korea, buildings are responsible for about 25.2% of carbon emissions (MOTIE, 2009). Energy consumption and carbon emissions are mainly produced during the operation of a building due to its long life span (Pearce et al. 2012). Construction activities during the construction phase also generate many pollutants that contaminate the air and land and inevitably produce a significant amount of solid waste as a result of the production, transportation and use of materials (Pearce et al. 2012; Roodman & Lenssen, 1995). In addition, they are also related to energy consumption and greenhouse gas emission from the production and transportation of building materials.

2.2. Energy saving strategies and technologies

Although building are responsible for many environmental impacts, they also provide necessary facilities for human prosperity (Ahn & Pearce, 2007; Pearce et al. 2012). Thus, it is essential to design, construct, and operate and demolish the building in such a way as to minimize the negative environmental impact and maximize social prosperity and economic development in the area. To achieve these objectives, the concept of green design and construction offers a way for the construction industry to move toward achieving sustainability. Green design and construction is a practice that integrates design and construction processes to improve sustainable site development, boost energy efficiency, increase the use of renewable resources, conserve materials and resources, reduce waste and toxics, and improve indoor environmental quality (Pearce et al. 2012). In the building industry, green building rating systems such as Leadership in Energy and Environmental Design (LEED), BREEAM, and Green Globes have been developed and implemented to provide a baseline for green building, enabling project managers and stakeholders to benchmark green building practices, prioritize actions, and provide support for decisions, the selection of green building strategies, and the documentation of the building process (Pearce et al. 2012). Among the many green building strategies and technologies now available, those associated with energy saving and generation in a building are generally deemed the important and urgent areas that must be addressed to solve these issues in the building sector. Many different energy-saving strategies and technologies may be implemented in the building, which often makes it difficult for architects and contractors to prioritize and select the most appropriate energy saving strategies and technologies for a specific project. Lechner (Lechner, 2009) suggested the use of a three tier approach for energy-saving strategies, progressing from the first tier of basic building design approaches to the second tier of passive systems and the final tier of mechanical equipment as part of his recommended renewable approach based on active solar and Photovoltaic (PV) generation (Table 1).

A number of studies have compared energy-saving strategies and technologies and their implementation priorities and associated cost considerations (Ahn, 2010; Dubois & Blomsterberg, 2011; Pearce et al. 2012; Pérez-Lombard, Ortiz, & Pout, 2008; Vakiloroaya, Samali, Fakhar, & Pishghadam, 2014). In energy-efficient building, all stakeholders must consider not only the initial cost premiums but also the life cycle costs of energy-saving strategies and technologies because energy saving strategies can substantially reduce a building's operation and maintenance costs. Thus, many energy-saving strategies and technologies eventually lower the total cost of