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A systematic review of strategies for overcoming the barriers to energy-efficient technologies in buildings

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ABSTRACT

The energy used to construct, operate and eventually demolish buildings has accounted for 40% of total energy used globally and 9% of the world's greenhouse emissions. When examining major energy consumers such as Europe or the United States, the amounts of energy used for buildings is even higher. The use of energy-efficient technologies (EETs), such as low-energy windows and programmable thermostats, have had many positive results, including long-term energy reductions, a healthier living environment, the creation of jobs, and better quality housing. Unfortunately, there continue to be barriers to the use of EETs. While there are dozens of strategies for overcoming these barriers, many have gotten overlooked or lost. This paper provides a review of the literature that has focused on barriers to the use of EETs and strategies for overcoming these barriers. The method used for identifying relevant literature was a systematic search of scholarly publications addressing barriers and/or strategies for EET use. A theoretical framework is presented as a means of organizing the literature. The framework includes three broad groups of barriers: knowledge of EETs, access to EETs, and desire to use EETs. Strategies for overcoming the barriers are likewise organized and described.

1. Introduction

The energy used to construct, operate and eventually demolish buildings has accounted for 40% of total energy used globally and 9% of the world's greenhouse emissions [28,1]. When examining major energy consumers, the amounts of energy used for buildings is even higher. For example, in the European Union (EU) 42% of its energy consumption results from buildings and 35% of its greenhouse gas (GHG) emissions [20,30], and, in the United States (U.S.), at least half of the electricity used and 36% of the nation's GHG emissions are associated with buildings. The use of energy-efficient technologies (EETs), such as low-energy windows, programmable thermostats, highly efficient ventilation systems, and the like, have assisted in the reduction of energy consumption. However, unless significant changes are made, it is projected that by 2020 residential GHG emissions will increase by 21% [2].

Estimates suggest that a sustainably designed building consumes 26% less energy than a traditional building (General Service Administration, GSA, 2008). Further, it has been estimated that, in the U.S. alone, energy consumption is now roughly half of what it would have been if levels of energy efficiency had remained unchanged [50]. Where there has been an EET upgrade in buildings (e.g., new energy-efficient vinyl siding for buildings, new energy-efficient windows, cleaner energy source for heating and cooling), there has been a stimulation in construction activity and creation of jobs. This can result in better quality housing, a healthier living environment and long-term energy cost reductions [42]; Rifkin, 2011; [3,14]. Further, the reduction of a building's energy consumption can save building owners and users money by lowering energy expenses, attracting tenants, commanding higher rents and sale prices, and can improve occupant health and well-being through cleaner energy sources for heating and cooling [37,51]. The reduction in energy use can also result in a reduction in a nation's dependency on imported energy and strengthen its strategic position [81].

The amount of energy consumed by buildings depends upon the extent to which EETs are used, from the building's design, to its construction, operation, maintenance and eventual demolition and recycling (i.e., the buildings life cycle). Unfortunately, EETs are not

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always adopted by architects, builders, owners, building maintenance workers, persons occupying the buildings, etc. In such cases, potential reductions in energy use are not realized which raises important questions: What barriers are preventing the use of EETs throughout the life cycle of buildings? And, what specific strategies are currently available to overcome these barriers? The purpose of this paper is to provide an extensive review of the literature that addresses these pertinent questions. The literature is organized within a conceptual framework that focuses on the barriers and strategies for EET use.

2. Methods used for identifying literature

The focus of the literature search was on scholarly publications that examined the use of EETs, barriers to their use, and strategies for overcoming the barriers. Most of the literature data bases were found in Ebsco Host and Proquest. Databases used within Ebsco Host included: Business Source Complete, Energy and Power Source, Environment Complete, Eric, GreenFILE, Health Source: Nursing/Academic Edition, Medline, Military and Government Collection, Psychology and Behavioral Science Collection, Science and Technology Collection, and SocINDEX. Data bases provided in Proquest but not Ebsco Host included: ABI/INFORM Global; Art, Design and Architecture; British Periodicals; Dissertations and Theses at UNT; Proquest Dissertations and Theses Global; GeoRef; Political Science Database; SciTech Premium Collection; and Sociology Abstract. Other sources of publications included Google Scholar, ScienceDirect, and SAGE Journals on Line. Key phrases that were searched included: barriers to energy efficient technology use, overcoming barriers to energy efficient technologies, energy use in buildings, sustainable strategies, energy technology innovation, energy technology barriers, energy technology adoption, sustainable design practices, sustainable design barriers, sustainable technology, energy efficiency, green building, Leadership in Energy and Environment Design (LEED), emissions reduction, zero carbon technologies, building energy use, and environmental sustainability. All scholarly publications from books, peer reviewed articles, and reports from both government and non-government organizations were considered for inclusion. The publications originated from a variety of countries including Australia, Austria, Brazil, Canada, China, Germany, Ghana, India, Kenya, Netherlands, Nigeria, Scotland, Sri Lanka, Sweden, Thailand, the United Kingdom, and the United States. Due to the large number of available articles and limited space for the literature review, only those that had a primary focus on barriers to EET use and/or strategies for overcoming barriers were included.

3. A conceptual framework for the use of EETs related to buildings

Fig. 1 displays a conceptual framework for understanding the use of EETs. As important as EETs appear to be, there are at least three types of barriers to their use: knowledge, access, and intent to use EETs. Provided below is a closer examination of these major barriers followed by a catalogue of strategies that have or can be used to overcome them.

3.1. Barriers to EET use

3.1.1. Knowledge

Knowledge refers to information used by those who can incorporate EETs into a building's life cycle, including owners, architects, general managers, building operators, occupants and the like (referred collectively as potential users). Discussions on the importance of knowledge have centered on three areas (Fig. 1). First is the knowledge that EETs provide an advantage. Unless the advantages of EETs are known, potential users will have no incentive to use them [59,65,16,60]. Further, Levi and Lawn [55] have noted that organizations sometimes limit the use of EETs because they use standard accounting procedures that are unable to recognize the financial advantages. Likewise, those financing the construction of a building may not be aware of the advantages of EETs or mistakenly believe that the existing methods for building are already efficient so that new EETs are seemingly unneeded [4,52,6]. Similarly, designers, project managers, and financial underwriting institutions may not be aware of the most recent studies showing the environmental, social, and economic advantages of various EETs [7,3]. Further, building users, such as residents, may not recognize the long-term financial savings offered by using EETs such as using a programmable thermostat.

Second is the knowledge that specific EETs exist. In some cases builders and users recognize that there is a need for EETs but lack awareness of or knowledge that specific EETs exist and are available for use. For example, Nduka and Ogunsanmi [60,p. 188] have noted in their survey of 150 Nigerian professionals responsible for the construction of buildings that the barriers affecting the use of EETs included a "lack of awareness." Saraswat and Shukul [70,p. 23], surveyed 75 builders in Vadodara City, India and found that

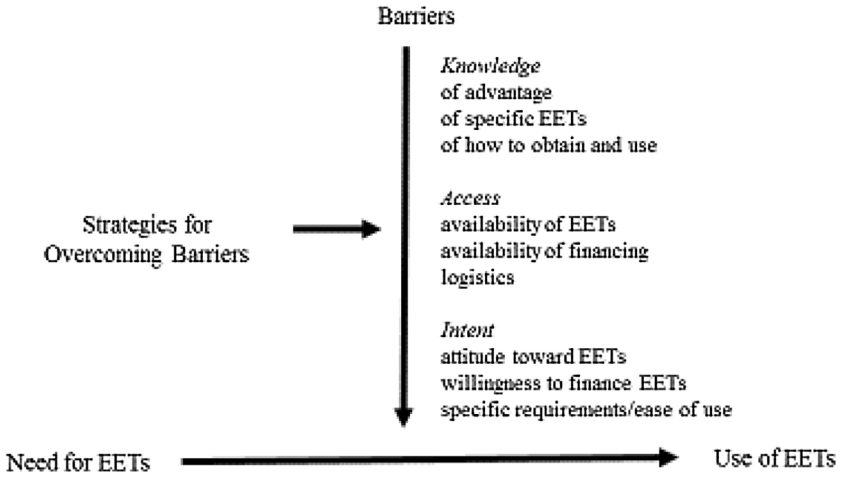

Fig. 1. Conceptual Framework Displaying Barriers to the Use of Energy Efficient Technologies (EETs) Within Buildings.

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