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Intelligent decision support system for home energy retrofit adoption

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Abstract

Despite the well-established benefits of home energy retrofits (HER), its adoption has faced huge challenges. Though homeowners typically depend on energy practitioners for HER advice, previous work by the researchers has identified the inadequateness of such information as a barrier. Using an earlier developed information model, an energy retrofit intelligent decision support system (ERIDSS), that integrates expert knowledge with quantitative information to provide homeowners with accurate information for decision-making, was developed. This paper identifies the key components of the proposed ERIDSS, develops rules for relevant energy retrofit expert knowledge to be employed in the knowledge-based system of the proposed ERIDSS, develops the ERIDSS for decision-making for home energy retrofits, and demonstrates the application of the ERIDSS using a pilot system on two test homes. The quantitative information was obtained from published sources and the U.S. Department of Energy's cost database, and the expert knowledge was obtained through the application of the modified Delphi technique and job shadowing of energy auditors and retrofit contractors. The research contributes to improving the adoption of energy retrofits by homeowners, assisting industry practitioners with the corroboration of knowledge/information they provide to homeowners in order to reduce homeowner bias, providing a good understanding of available implicit domain knowledge through the development of six knowledge-based modules, and the development of a system and approach that may be replicated in other domains.

Keywords: Intelligent decision support system; Home energy retrofits; Expert knowledge; Quantitative information

1. Introduction

The importance of energy efficiency (EE), defined as reducing the amount of energy needed to perform a task by incorporating more effective systems (IEA, 2011; LBNL, 2012; Limerick & Geller, 2007), has been well established in literature. For instance, EE is viewed as a critical step in achieving sustainability in buildings by helping to control rising energy costs, reducing environmental footprints, and increasing the value and competitiveness of buildings (Johnson Controls, 2012, 2013). In addition, EE is the most abundant, cheapest, and fastest approach to significantly reducing greenhouse gas emissions (LBNL, 2013). As a result, increasing investments in EE in buildings is seen as one of the most constructive and cost-effective ways of addressing challenges with sustainability due to the economic, social, and environmental benefits

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that can be accrued (Johnson Controls, 2012; USEPA, 2006).

A growing area of application of EE to buildings is the focus on existing homes, which dominate the current housing stock. Since majority of existing homes is largely energy inefficient, retrofitting them to improve their EE increases the likelihood of achieving the benefits of EE including the potential for tremendous economic, health, social, and environmental gains (Syal et al., 2014; USEPA 2010). Despite the fairly well established benefits and opportunities of energy retrofitting of existing homes, its adoption and wide scale application has faced obstacles. One estimate of market penetration for home energy retrofit (HER) programs puts it at less than 2% (Neme et al., 2012). The lack of information to homeowners in a format not easily understood and used was identified as barriers to energy retrofit adoption resulting in low uptake (Syal et al., 2014). The research team embarked on a series of steps to investigate and solve the barrier issue. Previous works by the researchers that address different aspects of the identified problem include:

1. Information framework for intelligent decision support system for HERs (Syal et al., 2014 – published).
2. Expert knowledge elicitation for decision-making in HERs (Duah et al., 2014 – published).
3. Role of Expert knowledge in HERs (Duah et al., 2015 – under review).
4. Intelligent decision support system framework for HERs in existing homes (Duah, 2014 – published doctoral dissertation).

This paper presents the culmination of the above noted building blocks by presenting an energy retrofit intelligent decision support system (ERIDSS).

1.1. Information Barrier to Home Energy Retrofit (HER) adoption

Challenges with the adoption of HER despite the well-established benefits continue to be a concern for the drive toward achieving building sustainability. For instance, out of the approximately 150 energy efficiency-related loan programs in the U.S. in 2007, less than 0.1% of their probable customers were reached (Fuller et al., 2010; Ho and Hays, 2010; USC-OTA 1993). Reviewing 85 programs that offer audits based on data from Electric Power Research Institute, Berry (1993) established a very low average annual participation rate of 3.2%. The Office of Energy Efficiency and Renewable Energy assert that less than 1% of homes have had energy retrofits exclusively to save energy (Lee, 2010).

Generally, homeowners seek information from various sources such as word of mouth, retail and lumberyard employees, cost databases, retrofit contractors, energy auditors, utility companies etc. Earlier work by the researchers put these information sources into two broad categories of information: quantitative information and expert knowledge (Syal et al., 2014). Quantitative information, typically found in published sources, includes information related to the domain and commonly agreed upon by domain experts. Expert knowledge, however, denotes information considered as knowledge of good practice, good judgment, and credible reasoning in the domain (Palmquist, 2001; Turban, 2005; Warszawski 1985). Even though majority of homeowners typically depend on energy experts, such as energy auditors and trade contractors, for assistance with decision-making when they want to retrofit their homes, Syal et al. (2014) noted that the information provided by such professionals can lack comprehensiveness, accuracy, and consistency. This research seeks to understand the information barriers to the adoption of HER and to develop a system that can assist with overcoming the information barriers.

1.2. Intelligent decision support systems (IDSS)

A decision support system (DSS) is defined as an interactive computer-based information system intended to help users make decisions by retrieving, summarizing, and analyzing decision-relevant data (Arnott, 2004; Druzdzel and Flynn, 2002; Power, 1998). Three major components of a DSS are: database management system, modelbase management system, and dialog generation and management system. In order to provide intelligence to the three components of a DSS, an optional fourth component, the knowledge-based management system (KMS) (such as an expert system), can be included (Turban et al., 2005). A DSS with KMS is referred to as knowledge-based DSS or intelligent DSS (IDSS) (Vohra and Das, 2011).

Expert systems (ES) basically capture and organize the task-specific knowledge derived from the experts (expertise) into a computer program. Users are able to provide specific advice to solve a problem by recalling stored expert knowledge. In order to provide a specific conclusion, inferences are used to provide a logic similar to how a human expert would (Liao, 2005; Warszawski, 1985; Turban et al., 2005; Syal et al., 2013). The IDSS envisioned for this research had a KMS that incorporated the model based features into an ES (Basen and Dutta, 1984 cited by Turban and Watkins, 1986; Özbayrak and Bell, 2003; Shannon, 1985 cited by Turban and Watkins, 1986).

2. Research goal and methodology

Comprehensive and easy-to-use information is essential to decision-making for HER. The comprehensiveness of this information requires an integrated approach to harnessing the two identified information sources: expert knowledge in conjunction with vast amount of quantitative information. The goal of this research was to develop an IDSS that could integrate these information types in order to provide energy retrofit information to users with the aim of improving HER adoption rates.

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