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Low-Investment Energy Retrofit Framework for Small and Medium Office Buildings

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Abstract

Small and medium office buildings consume a significant parcel of the U.S. building stock energy consumption. Still, owners lack resources and experience to conduct detailed energy audits and retrofit analysis. We present an eight-steps framework for an energy retrofit assessment in small and medium office buildings. Through a bottom-up approach and a web-based retrofit toolkit tested on a case study in Arizona, this methodology was able to save about 50% of the total energy consumed by the case study building, depending on the adopted measures and invested capital. While the case study presented is a deep energy retrofit, the proposed framework is effective in guiding the decision-making process that precedes any energy retrofit, deep or light.

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Keywords: Retrofit, office buildings, energy, HVAC, plug loads, MELs.

1. Introduction

About 40% of the total primary energy consumed in the U.S. is consumed by buildings. Commercial buildings account for 18% of the energy consumed in the U.S. [1]. Small and medium commercial buildings (smaller than 50,000 sf) account for 95% of the total commercial buildings in U.S. They consume 47% of the commercial

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buildings' energy consumption [2]. According to the Commercial Buildings Energy Consumption Survey (CBECS), the main electricity end uses in commercial buildings are lighting (37%), Heating, Ventilation, and Air Conditioning (HVAC, 30%), and miscellaneous and electronic loads (MELs, 19%) [9]. More than 45% of the total energy consumption of small and medium commercial buildings can be saved by an energy retrofit [3]. However, these buildings' owners usually do not have enough resources or experience to perform a detailed energy audit [3].

A bottom-up methodology is a low-investment alternative for a detailed energy audit. It consists in collecting equipment power consumption data and users' activity patterns to estimate the plug loads energy use for each type of device [4]. When it comes to a retrofit analysis, there are several web-based energy retrofit toolkits. The Commercial Building Energy Saver (CBES) is one of the most comprehensive available toolkits. CBES provides quick and reliable results based on building-specific input data.

The objective of this paper is to develop a low-investment framework for selecting energy retrofit strategies to small and medium office buildings, using a combination of the bottom-up methodology and the CBES toolkit. An office building in Arizona was selected as case study to validate this framework and assess its potential savings. Although relatively simple the methodology is thorough, which increase the reliability of the results.

Miscellaneous and electronic loads (MELs)

The Miscellaneous and Electronic Loads (MELs) include the plug loads (electronic appliances' loads), elevators, cooking, and refrigeration equipment [4]. Plug loads are expected to account for 49% of total electricity use in 2030 [5]. Indeed, in a building with high efficiency systems, the MELs can represent more than 50% of the electricity use [6]. Despite their growing importance, MELs still are not fully understood by researchers. User behavior and power management rates are areas that still carry a high level of uncertainty and need to be better understood [7]. The voluntary labelling program ENERGY STAR, developed by the U.S. Environmental Protection Agency (EPA), is one of the most successful strategies to reduce plug loads. In 2006, ENERGY STAR products saved 4.8EJ of primary energy [8], which corresponds to the total annual energy spent by about one million medium office buildings.

CBES online energy retrofit toolkit

SH Lee et al. (2015) wrote a review on 18 energy retrofit toolkits [3]. Among them, the Commercial Building Energy Saver (CBES) was reported as one of the most comprehensive toolkits. CBES provides a rapid and reliable retrofit analysis. Some of the results include energy costs, retrofit investment and payback in years, a group of suggested Energy Conservation Measures (ECM) based on the user's inputs, and the Indoor Environmental Quality (IEQ) impact for each ECM. In addition, CBES includes the rich database of energy efficiency performance (DEEP), which is compiled from the results of approximately ten million Energy Plus simulations [3]. This study uses CBES for the aforementioned reasons, as well as the applicability of CBES to small and medium commercial buildings.

The case study

To serve as example for this framework, the authors apply it to a medium-size office building in Arizona. Thirty percent of the building is occupied by classrooms. Built in 1966, the building was retrofitted in 2008 and earned a USGBC LEED Silver certification. The retrofit was focused in water and material efficiency measures. The only retrofit energy measure was to install occupancy sensors for the lighting system and add renewable energy systems. Although LEED Silver certified, the case study achieved only 3 out of 17 points in the Energy and Atmosphere category.

2. Methodology

This paper presents an eight-steps low-investment methodology for identifying energy retrofit opportunities in small and medium commercial buildings. We illustrate the effectiveness of this method using a medium office