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Energy efficiency optimization of new and existing office buildings in Guanajuato, Mexico

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ABSTRACT

Energy use attributed to buildings accounts for 19% of the total energy consumption in Mexico and is estimated to rapidly increase with future building development. Existing Mexican energy efficiency standards (NOM-ENER) are primarily developed through a component based approach where energy efficiency guidelines are outlined for individual pieces of equipment with no interactions between these components taken into consideration. In this paper, a holistic and integrative energy analysis approach is considered to improve energy efficiency of commercial office buildings. Specifically, interactions between various energy efficiency measures are investigated for both existing and new construction office buildings in Salamanca, Guanajuato using detailed simulation and optimization procedures. The results from the optimization analysis indicate that the most cost-effective potential for energy conservation in both new and existing offices is achieved by reducing office equipment loads and more efficient lighting technology and controls. Over 49% annual energy savings can be achieved cost-effectively for both retrofit and new construction commercial office buildings.

1. Introduction

Building energy consumption in Mexico makes up nearly 19% of the nation's total demand where 16% is from residential energy consumption while 3% is reported for commercial building energy consumption (SENER, 2010). However, various sources identify that a portion of the industrial energy consumption is actually from commercial building end use because the national utility company, Comision Federal de Electricidad (CFE) categorizes non-residential customers by voltage. Commercial buildings are categorized as low voltage, but several service-sector facilities including hospitals, hotels, schools, retail and restaurants are medium industry customers. Thus, energy consumption attributed to the commercial building sector is greatly underestimated due to lack of accurate survey of the building stock and its characteristics (Feng Lui, 2010). The results of the study presented in this paper provide some insights on the benefits of integrated energy efficiency analysis for existing and new built environment for Mexico, an emerging industrialized country where commercial building development is rapidly expanding.

The primary objective of the study presented in this paper is to utilize an integrative optimization methodology to determine the best set of energy efficiency measures for commercial buildings in one specific region in Mexico: Salamanca, Guanajuato. The integrative approach used in this study is outlined in Fig. 1. The ultimate goal of the study is to address each of the essential components to develop building energy efficiency codes: energy efficiency, market variability, available technology, construction costs, and policy enforcement (DOE Building Energy Code Program, 2010). The energy efficiency component is covered through detailed whole-building energy simulation analysis, while construction costs and market variability are incorporated through life cycle cost (LCC) analysis and associated sensitivity analyses. Available technology in Mexico is incorporated in the optimization analysis through the selection of appropriate energy efficiency measures (EEMs). Finally, the policy enforcement element is considered by selecting a prescriptive based approach for energy efficiency recommendations.

The current building energy efficiency codes and standards for commercial buildings in Mexico include prescriptive compliance and performance compliance. The prescriptive codes are primarily for equipment while the performance based approach is limited to exterior thermal insulation recommendations. The Prescriptive based approach for equipment and appliances have been very

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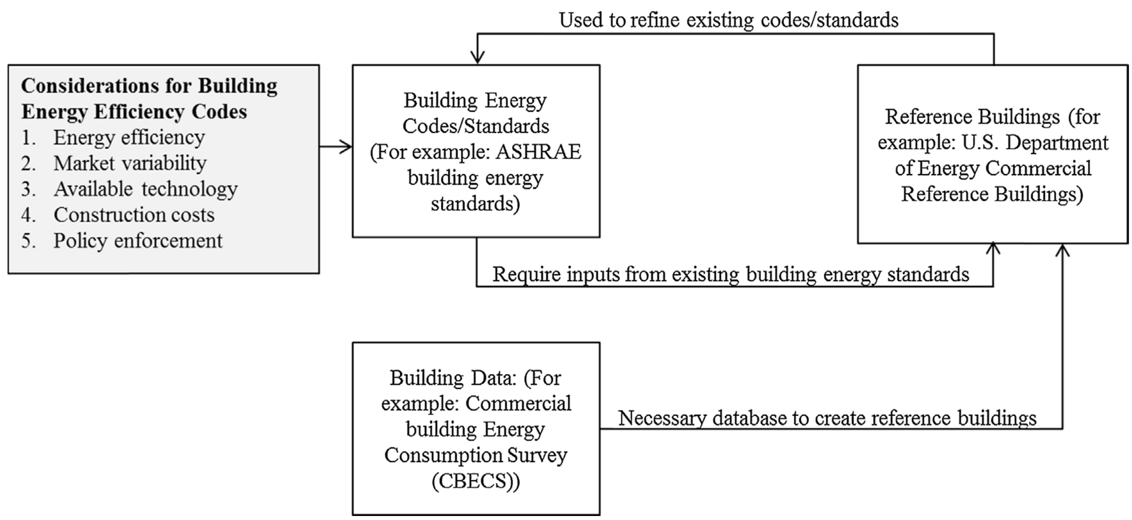

Fig. 1. Organization of primary goals of the energy analysis study.

successful (Michael McNeil, 2006). On the other hand, the performance based standards for thermal insulation in commercial buildings has not been widely adopted or enforced (Feng Lui, 2010).

The schematic diagram of Fig. 1 also illustrates how the primary objectives of study relate to the broader context of building energy efficiency codes and standards, reference buildings, and building energy data. The development of building energy standards and codes are the first step in addressing energy reduction in buildings. The next step is the development of reference buildings which are extremely useful for refining and improving upon the existing building energy codes and standards. However, comprehensive building data is necessary to determine the most representative buildings and their characteristics.

As part of the study presented in this paper, optimization analyses were performed for both existing and new office building prototypes to determine not only optimal package for energy efficiency measures but also the size of photovoltaic (PV) system to achieve net zero-energy buildings (ZEB). Recommendations from applicable Mexican Official Standards for Energy, Norma Oficiales Mexicanas (NOM-ENER), were included in the analysis to verify if they are appropriate for this region of the country (Comisión Nacional de Vivienda, 2010).

In this paper, the analysis methodology is first outlined to highlight the development of building energy models, economic analysis data, and the optimization approach. Then, selected analysis results are discussed to pinpoint the most cost-effective packages of energy efficiency measures that need to be considered for new construction as well as retrofit of office buildings in the state of Guanajuato, Mexico.

2. Methodology

This study evaluated various combinations of energy efficiency measures (EEM) and PV sizes to estimate an optimum set of recommendations for office buildings in Guanajuato, Mexico using a sequential search optimization approach. The optimization analysis was performed on for both existing and new office building prototypes. The characteristics of the existing prototypical office building were defined using specific information obtained from a detailed energy audit of select buildings. The new construction prototypical office building was characterized using various sources as well as applicable data from the existing building model.

2.1. Existing building characteristics

The evaluation of a prototypical existing office building was particularly important for this study due to the limited, up-to-date data for office buildings in Mexico. Therefore, detailed energy audit was performed for three office buildings to estimate typical operation schedules, seasonal occupancy variations, construction materials, lighting power density and office equipment power density. Based on the results of the energy audits, a two-story office building with a total floor area of 1275 m^2 (13,730 ft^2) as illustrated in Fig. 2 was selected to be representative of existing commercial buildings located in the historic downtown area of Salamanca, Guanajuato. An energy model of the office building was developed and calibrated using monthly utility data. Table 1 summarizes the basic features of the existing office building energy model.

In particular, the equipment power density (EPD) and the lighting power density (LPD) are defined using a detailed inventory of office equipment, appliances and lamp types used throughout the building. The EPD is found to be 32.94 W/m^2 (3.06 W/ft^2) while the LPD is estimated to be 25.30 W/m^2 (2.35 W/ft^2) due to the common use of T12 fluorescent lamps. The building is not heated but is cooled using packaged DX split units with a coefficient of performance (COP) of 2.35.

2.2. New construction building characteristics

The prototypical new construction office building baseline energy model differs from the retrofit construction energy model

Table 1
Existing office baseline building energy model characteristics.

Building characteristic	Value
Total floor area	1275 m^2 (13,730 ft^2)
Occupancy schedule	M–F: 8am–4pm
Lighting power density	LPD: 25.3 W/m^2 (2.35 W/ft^2)
Equipment power density	EPD: 36.9 W/m^2 (3.43 W/ft^2)
Number of employees	134 people
Wall assembly *R*-value	0.49 m^2-K/W (2.8 ft^2-h-F/Btu)
Roof assembly *R*-value	0.30 m^2-K/W (1.68 ft^2-h-F/Btu)
Window to wall ratio (WWR)	3%
Typical AC system and efficiency	DX split systems with COP = 2.35
Cooling set-points	23.9 °C (75 °F) M–F 8am–4pm floating during other hours
Ventilation flow rate	9.4 L/s (20 cfm) per person