Sustainable Cities and Society 38 (2018) 795–805

Contents lists available at ScienceDirect

Sustainable Cities and Society

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

Assessment of electrical saving from energy efficiency programs in the residential sector in Mexicali, Mexico

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ARTICLE INFO

Keywords:
Energy savings
Efficient use of electric energy
Energy indicators
Electric energy consumption

ABSTRACT

The aim of the present work is to gather energy indicators and propose actions that achieve a significant reduction in the energy consumption of single-family house in the city of Mexicali, Mexico so that those indicators can be successfully extended and applied to other regions of the country with similar climatic conditions. To this purpose, a sampling frame of 300 Mexicali residents have been studied; by taking direct measurements and applying questionnaires to gather information on construction features, energy usage and users' income level. The average annual consumption of a home in Mexicali is 8193 kWh —73% in the summer season—. This means that 67% of users here allocate more than 6% of their income to pay their electricity bills. It was demonstrated that 39% of households have oversized air conditioning equipment, and that replacing their old low-efficiency air conditioning equipment leads to an annual savings of 32% in energy consumption. In addition, it was established that Mexicali has a 0.82 of correlation of the monthly energy consumption with all the users in the country with the same electricity rate.

1. Introduction

With the current increase in worldwide energy consumption, the main concerns center not only upon how to generate the necessary energy, but also on feasible ways to improve energy efficiency to assure there will be a sustainable energy supply to meet the required demand (Abu Bakar et al., 2015).

Several studies related to energy consumption and energy efficiency improvement have already been done. Nejat et al. (2015) performed a global review of energy consumption, CO_2 emissions and energy policies in the residential sector and found that global residential energy consumption increased 14% from 2000 to 2011, mainly in developing countries. On the other hand, Griego, Krarti, and Hernández-Guerrero (2012), investigated the interactions between various energy efficiency and thermal comfort measurements for residential buildings in Salamanca, Guanajuato and have been using detailed simulation and optimization procedures. They found that the optimization analysis suggests a combination of improved appliance efficiencies, increased values of thermal resistance in roofs and walls insulation and improvement of water heating systems efficiencies are required to achieve a minimum cost solution which results in nearly 52% annual energy savings for new homes.

To model the electricity consumption in the residential sector, Ren et al. (2016) used a mathematical model to simulate the energy consumption of households considering building envelopes, appliance characteristics, local climate and occupant behavior. To estimate the heating and cooling energy requirement for a building, Borah, Singh, and Mahapatra (2015) used a multiple linear regression technique to obtain degree-days of locations in same climatic zone for which daily temperature data is not available, with a fair accuracy.

Some other researchers (Bodart & De Herde, 2002; Ihm & Krarti, 2012; Roisin, Bodart, Deneyer, & D'Herdt, 2008; Ryckaert, Lootens, Geldof, & Hanselaer, 2010; Tsagarakis, Karyotakis, & Zografakis, 2012; Zografakis, Karyotakis, & Tsagarakis, 2012), had already worked on the assessment, implementation, design and application of energy savings and efficient use of energy in order to reduce its consumption. Additionally, Jones and Lomas (2015) established that in UK homes with floor area bigger than 100 m^2 consume more electricity than those with a floor area between 50 and 100 m^2. Other studies (Hamed Shakouri & Kazemi, 2017; Sheikhi, Rayati, & Ranjbar, 2016) propose an intelligent energy management framework that can be used to minimize both electrical peak load and electricity cost based on a reinforcement

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https://doi.org/10.1016/j.scs.2018.01.031
Received 20 July 2017; Received in revised form 16 January 2018; Accepted 16 January 2018
2210-6707/

Nomenclature

n	Sample size
N	Number of electricity users of the residential sector
p	Population proportion
(Δ-p)	Difference between the simulated and the real data
Z	Probability that a sample will fall within a certain distribution
$\theta(t)$	Dimensionless temperature
t	Hours of the day
$<m$	
$>$, A, B	Coefficients of adjustment for the function of fourier of hour temperature
$T_{\max}$	Maximum temperature in °C
$T_{\min}$	Minimum temperature in °C
T	Temperature of reference in °C
DH	Degree-hour
T_{ref}	Setpoint temperature
T_{ext}	Outdoor temperature
SEDAD	Surplus electrical demand produced by the air conditioner oversizing
EDACO	Electrical demand produced for the air conditioner oversizing
EDACR	Electrical demand produced for the required air conditioner capacity
SECV	Simulated energy consumption values
ECREB	Energy consumption reported in the electricity bill
DEC	Difference of the simulated and actual energy consumption bills
ASHRAE	American society of heating, refrigerating and air-conditioning engineers.

learning demonstrating a reduction of the residential customer energy bill and electrical peak load up to 20% and 24% respectively.

The increase in energy consumption in the residential sector of Mexico is an issue which has become more and more relevant from the political, ecological and social points of view, since this sector counts as the 88.6% of the Federal Electricity Commission (CFE) users nationwide. These customers consume 25.4% of all the electricity used in the country (Sheikhi et al., 2016). In the last decade, the sales of electric power to the national housing sector increased by 57%, while the price of electricity raised 35%, and the number of users (service demand) showed an increase of 39% (Hamed Shakouri & Kazemi, 2017), clearly revealing a significant growth for each of these parameters.

Recent studies prepared by the government of Mexico establish that there are 53 million poor people in the country, who have difficulties in accessing basic services in housing. Therefore, any study or analysis on the subject should be aimed at generating policies that achieve equity with respect to income destined for electric payments and that redistribute the gap between marginal and high-income housing. If the purpose is to reduce these indices, it is important to propose policies aimed at improving the quality of life of the most vulnerable sector.

Energy efficiency plays an important role in controlling energy usage as well as in minimizing costs and maintaining a comfortable environment inside buildings (CFE, 2014). In the case of the Mexican city of Mexicali— it is located 32.63 latitude and −115.45 longitude and it is situated at elevation 4 m above sea level, where temperatures can reach up to 50 °C (122 °F) in the summer (May to October)—the average monthly consumption of electricity exceeds three times the national average (CRE, 2014a). For this reason, government programs were created with the aim of making more accessible the implementation of measures directed toward energy saving and the efficient use of energy in the residential sector.

In 1990 the federal government of Mexico created the Trust for Thermal Insulation of Housing (FIPATERM, by its acronym in Spanish), a returnable financing fund for aiding residents with the installation of thermal insulation on home roofs in that city. Currently this is known as the Program for Integral Systematic Saving (ASI, by its acronym in Spanish), which has four existing subdivisions: thermal insulation; replacement of refrigerators; replacement of window type and central air conditioners. Users receive funding from 36 to 48 months with an annual interest rate of 12% (Parameshwaran, Kalaiselvam, Harikrishnan, & Elayaperumal, 2012).

Considering that optimal use of energy in the residential sector is an important contributor for the conservation of energy and the reduction of environmental emissions (CRE, 2014b). It is important to note that energy efficiency strategies in the city of Mexicali, have obtained favorable results as demonstrated by the fact that the consumption of electric energy per user has shown a tendency to decrease over the years (ASI, 2015a). Therefore, the city of Mexicali, Mexico is a perfect

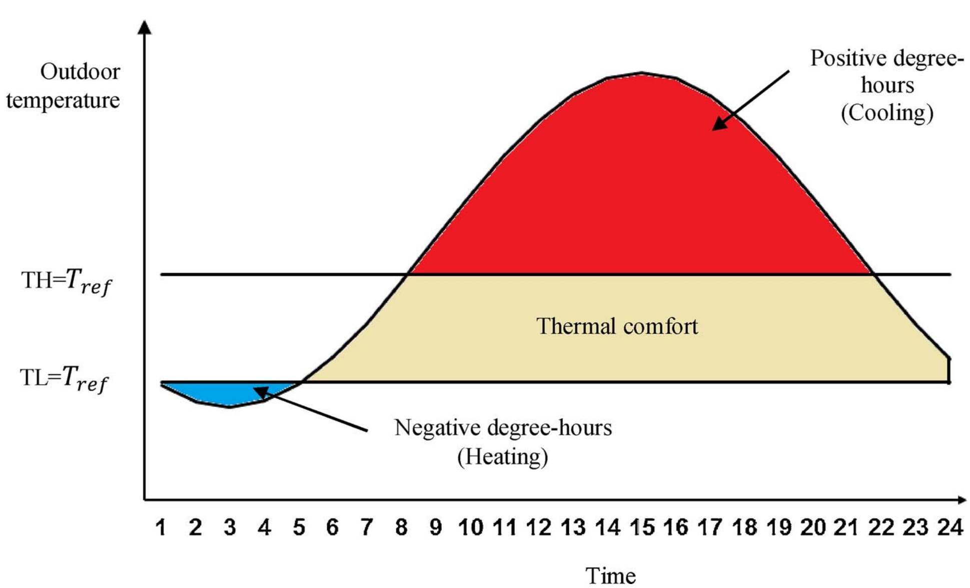

Fig. 1. Graphical display of the concept of degree-hours.