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Mobile device application to calculate and simulate energy expenditure in households using CAD tools

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Abstract

The disproportionate rate of energy consumption in Spain's residential housing sector stands in the way of socioeconomic advances. Faced with rising energy demand, the country will be unable to meet European Union efficiency objectives and maintain its quality of life. This paper showcases a novel approach to identify mechanisms that can contribute to improvements in energy efficiency in Spanish households. It consists of designing a graphic environment to simulate and optimize energy expenditure by using computer-aided drawing, calculation methods and simulations on mobile devices. The use of these new graphic tools could be greatly beneficial to both end-users (consumers) and technicians carrying out energy audits.

1 Introduction

Households in Spain account for 17% of total final electricity consumption and 25% of electricity demand (SECH-SPAHOUSEC) [1]. The increase in residential housing stock, the new equipment and the poor consumption habits acquired during the country's economic boom set off a process of excessive power consumption that stands in the way of socioeconomic development [2].

The potential savings in this sector are essential for achieving the common challenges raised in Europe ahead of 2020 [3][4]. The savings potential falls into two categories. First, more stringent requirements will be introduced via building codes [5][6] and energy certificates that will apply to all of Spain's housing stock once EU Directive 2002/91/EC [7] has been approved. Secondly, greater public awareness of energy efficiency will further promote savings.

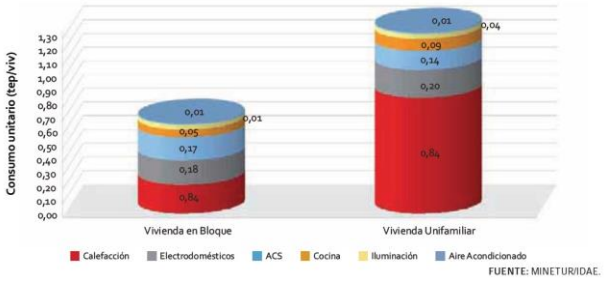

Fig. 1 Energy consumption by type of dwelling [8].

For Spain, the challenge over the next few years is to heighten environmental awareness and teach households how to be energy efficient while maintaining quality of life. The current economic crisis, along with surging consumer electricity bills, will encourage energy efficieny in households. However, certain pieces of legislation will be difficult to implement and energy efficiency recommendations for households have so far proven to be scattered and untargeted. In addition, there is a lack of software applications that can teach people how to be energy efficient.

Energy efficiency is not a tangible concept. It is a term that implies different measures that do not always have to include an investment in technology [9]. In many cases, it does not entail replacing the equipment or systems in a household with others with lower consumption. It is simply about instituting certain practices that will promote greater energy efficiency by the consumer.

The revolution in mobile telecommunications that we have experienced in recent years can provide the appropriate vehicle to combine our knowledge of energy efficiency into a platform that enables the consumer to establish implement savings strategies and reduce a household's utility bills.

2 Objectives

The objectives pursued in this research are:

1) Analyze and develop appropriate algorithms for calculating energy savings in homes.

-Determine the required input parameters depending on the existing system.

-Study the influence of system characteristics according to the data obtained: insulation, orientation, losses related to shade or shadows, terms of electricity contracts and other external factors.

-Define the areas of use for the different algorithms and the statistical margin of error.

2) Design and implement interactive software to simulate patterns of energy consumption.

-Model the characteristics of the household with vector-based graphic tools.

-Develop a comprehensive library of symbols (washing machine, refrigerator, television set, computer, lighting fixtures and heating devices, etc.) that will be displayed in their exact location in the household.

-Implement a database with the parameters that define the energy cost of each of the devices defined above.

-Integrate energy calculation algorithms in the software developed.

-Generate energy audit reports for each household.

3) Evaluate the software.

-Carry out a comparative analysis of the results obtained by using interactive tools with data from real situations.

-Outline the methods and strategies to increase energy savings in households based on the results of the data obtained.

3 Graphic interface

The first issue to address, and currently under development, is the design and implementation of an interactive graphics environment [10][11][12]. In addition, algorithms are needed to correctly calculate the specifications of the household [13][14][15][16][17][18][19][20][21]. These elements will need to take into account the advantages and disadvantages of working with touchscreeen devices such as the limited space and the need to enlarge icons.

Depending on the end user who of the interactive environment and their person's needs, two different applications will be needed: Standard and Professional. The specifications of each platform are listed in the following sections.

4 Standard Version

This version is designed for consumers who are habitual users of mobile devices and are interested in using mobile applications to monitor energy efficiency in their household.

The interactive environment in this version will allow families to become acquainted with their household energy needs, explore ways to implement energy savings and promote further ways of reducing utility bills.

The objective of this version is to encourage users to discover the elements of construction in ther household such as heating systems and air conditioning. This will allow them to visualize their home specifications in a realistic way and thus improve the results of energy audits.

The interface of this version will be user-friendly. It will consist of different modules in which data can be entered intuititvely. These modules are described below.

4.1 CAD Module

The CAD module represents a graphic interface in which the user will be able to draw the thermal characteristics of the household by choosing menu options that integrate construction elements such as façades, walls, interior partitions, doors and windows. The interface will include a grid environment consisting of editable CAD and visualization buttons that allow users to draw and edit. The buttons will allow users to define the blueprint of the household and draft complex contours.

4.2 Temperature Module

Since power consumption varies according to region, the interface will need to introduce data that specifies geographic location, the orientation of a residence and the possible shadows on walls that prevent solar gain. Through simple options, users will be able to choose their climate area and orientation, as well as predefine the parameters for cast shadows.

4.3 System Module

Household appliances have different energy consumption pattners depending on their efficiency and how often they are used. To enter data in this module, the consumer will use the CAD model already developed for the household. They will then introduce data on the blueprint by accessing the icons in the menu.

4.4 Results and Improvements Module

This module will allow users to simulate the timing for the use of different elements, displaying the average expense of household appliances. It will allow users to visualize energy consumed by each applicance. At the same time, this module will recommend measures to improve energy efficiency and provide user-generated feedback for the application.

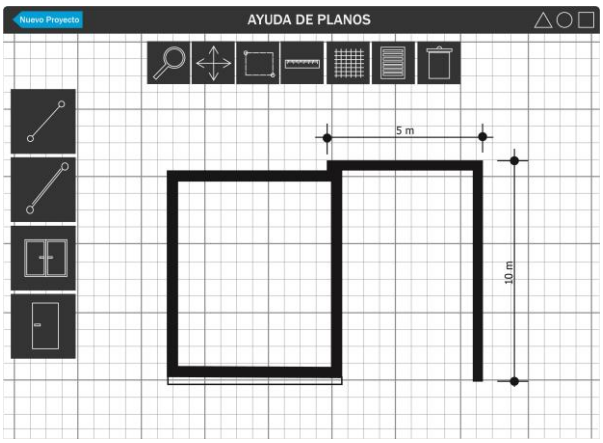

Fig. 2 CAD tool interface.

All modules listed above will be fully editable in order to adapt to different and evolving user needs.

5 Professional Version

Taking into account the needs of the market and the full implementation of energy certifications for existing homes, we are working toward the development of a more focused application that will serve the needs of qualified technicians.

To summarize, the steps to follow to carry out a household energy audit are the following:

-Preliminary audit of the household.

-Onsite gathering of data, including construction elements, geometric characteristics of the building and the equipment installed.

-Data entry in the simplified applications currently recognized by Spain's Ministry of Industry (CEX and CE3) [22].

-Issuance of an energy audit that includes specific interventions recommended to help improve the rating of a household.

The objective of this Pro Version is to create a specific work environment in which the technician collecting data directly with the mobile application can export the information to programs recognized by the Ministry of Energy. The data will then be used for certification purposes or for generating a digital report. This new methodology is an attempt to digitize the first three steps of the process and bypass deficiencies in procedures currently being used. It is intended to simplify the process, but also to save time and cost. As a result, users will be able to invest more time in learning how to introduce energy efficiency measures in their homes.

The different windows in the application follow the methodologies used in the most common programs and they are sub-divided into different work modules. Thus, a certified technician will easily be able to enter data into the different sections.

Fig. 3 View of main menu.

The energy audits are not limited to residential households, but can also be adapted for different environments in the services sector. That interface for each of the application modules can be adapted easily to the type of use assigned to a building.

Aside from the modules described in previous sections for the standard version, the following modules will be added for ease of use:

-Project management module,

-Personal data module,

-New project module.

5.1 Project Management Module

This module will manage the stored projects. Users will be able to edit, delete and export data to other programs or reports.

5.2 Personal Data Module

Data from the technician will be stored and updated here.

Fig. 4 View of project settings.

5.3 New Project Module

This module is subdivided into the following blocks of information:

-General data,

-Description of building type,

-Geometric description,

-System definition.

1) General data

This section serves to describe the building type, year of construction, climate zone and physical location. In addition, it includes administrative data, information on the legal framework, images, tests and site inspections.

2) Description of building type

This section will describe the thermal profile of the building describing each of its elements: facades, roofs, interior partitions, walls, floors, areas in contact with the ground, hollow spaces and thermal bridges. The user will be able to enter data by using predefined systems depending on the year of construction. They will be able to describe each element in order to calculate thermal transmittance.

Fig. 5 Inputs for a new project

3) Geometric description

Three options are available for the geometric description:

-Description by type of building and according to predefined libraries

-Description of the geometry of the building by the types of surface and their physical orientation.

-Description using the CAD module described in the previous section.

4) System definition

Detailed descriptions will be entered here by way of different menu options for preinstalled building equipment as well as hot water, heating systems and cooling mechanisms.

Fig. 6 Insertion device on the plane

6 Methodology

The professional version has simple algorithms to help the technician to enter data in a simple way.

It is in the Standard version where different calculation algorithms will be essential to get an answer as close as the thermal behavior of housing in study and then propose elements for improvement. This is why it will require a comprehensive behavioral modeling considering the home as an energy system which takes into account both the conditions outside the home as their own; this will have a database hosted on a remote server. Another important point to highlight is the difficulty that may come to have the user when entering data and therefore pose simplified forms that approximate the calculation within an acceptable error bound; this will involve real testing in houses.

7 Improvements

The Standard version has a number of new elements to those that can be found on the market today and include:

1-No purchase is required or installation of any measuring device in the house,

2-The study is based on the user's own home through your drawing using CAD tools,

3-Complete library of appliances

4-Total control over the data entered by user-friendly interface,

5-It takes into account external and internal influence data of housing,

6-improvement measures are adapted in relation to the input data,

7-Greater precision in the results shown.

On the Professional version, based on the energy certificates, not particularly new to be none at application for mobile devices that perform the functions described in the previous sections.

8 Conclusions

The economic crisis in Spain (2008–2013) has forced end-consumers to reduce energy consumption in their households without necessarily lowering their quality of life. However, the lack of tools offering guidance to consumers about clear criteria that can contribute to lower energy expenditure presents an opportunity to develop a user-oriented application. The application described in this study would not only calculate energy savings, but would also be able to recommend elements of home improvement. It would not require an investment in new technology. Savings awareness would be achieved by describing simple methodologies based on a mobile device application with an easy-to-use interface. The application would also introduce innovative support tools for qualified technicians carrying out energy audits. This is an additional advantage given the imminent approval of regulations in Spain whereby residential housing and the services sector will need to submit to energy efficiency certification. The study proposes both a standard software version (for end-users) and a professional version (for technicians). The platforms are based on a graphics environment generated with CAD tools that are recommended as the most targeted to solve this type of problem.

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