METHODOLOGY FOR THE ANALYSIS OF ENERGY AND WATER PERFORMANCE IN SOCIAL HOUSING: THE CASE OF MALAGA

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ABSTRACT

This study presents the methodology followed in the European R+D project ENERGYTIC “Technology, Information and Communication Services for Engaging Social Housing Residents in Energy and Water Efficiency”. This project focused on improving energy and water consumption using ICT solutions that provide a user-friendly system for monitoring and adapting energy and water consumption. Audits, user surveys, and onsite inspections were developed to characterize 700 social housing units involved in the project. Water and energy consumption patterns were obtained through monitored data and data provided by ENDESA and EMASA (water and electricity utility companies) for the city of Malaga.

The main conclusions highlight limited potential for improving consumption, especially energy use, and emphasize the situation of energy poverty in this housing stock.

INTRODUCTION

This paper is based on an ICT PSP 2010 project within the program of the European Commission for Competitiveness and Innovation Energy called ENERGYTIC "Technology, Information and Communication Services for Engaging Social Housing Residents in Energy and Water Efficiency" (ref. 270.947), developed by two consortiums, one in France and the other in Spain. This project has already inspired two international papers[1,2].

Much of the current residential building stock in Spain is obsolete in terms of energy efficiency and is in need of renovation and updating to meet current requirements for comfort and to reduce high energy consumption. European and national regulations tend to include measures to encourage retrofitting of existing buildings given the great potential for saving and improving energy efficiency in these, with governments providing economic incentive measures to promote this type of action, following the strategies of Horizon 2020 [3]. In this new situation it is essential to adopt suitable measures for energy retrofitting using tools that aid decision-making, quantify improvements and provide objective assessments of the intervention.

Retrofitting is used to increase the energy performance of buildings, as has been observed in several European countries [4,5,6] where there is great potential for improvement in the energy efficiency of buildings while maintaining a good and healthy indoor environment [7]. There have been many studies on the optimization of the thickness of insulation for different compositions of enclosures [8], along with their repercussion on climatization systems [9,10] for both façades and roofs. Regardless of the climate zone, most energy retrofitting actions focus on improving the thermal insulation of the thermal envelope. The impact of a green roof on building energy performance [11] has also been studied, as has transmittance through openings [12,13]. Equally, the airtightness of the envelope is particularly important for energy demand [14], while in warm climates, action on openings using solar protection [15,16] is crucial.

These studies are based mostly on the retrofitting of the envelope, with the occasional inclusion of climatization and ventilation systems, which the housing units previously lacked, without considering the users' profiles. However use behavior has a major impact on the real consumption of housing units, regardless of the energy savings forecast according to type profiles.

In this context, the project attempts to quantify the real energy consumption of actual users by monitoring the equipment installed in their housing units. The research project was carried out with a sample of 700 social housing units that were monitored with ICT solutions (Information and Communication Technologies) collecting data for water and energy consumption. An additional detailed submetering process was carried out on 6 representative housing units, obtaining the data for a full year of real time-energy consumption, the individual energy consumption of characteristic appliances, as well as indoor temperature of the homes.

Nowadays, ICT solutions provide users with direct consumption information of energy and water usage, helping to understand the opaque and static energy and water bill and providing dynamic control capacity. Therefore, ICT solutions are very useful when talking about improving the users' consumption behavior. Previous studies show that feedback solutions can lead to savings in energy consumption for the users [17,18,19,20,21]. This research demonstrates the importance and success of providing clear, immediate and specific information to the user [22] and have consistently shown that direct feedback motivates changes in behavior, resulting in energy savings of up to 20% [23].

In addition, they allow the detection of anomalous consumption behavior, reflecting energy poverty situations in these homes due to unusually low consumption or due to the existence of unsuitable comfort conditions.

Energy poverty (as defined by the International Energy Agency, IEA) is the inability of a household to meet minimal energy services to cover its basic needs, such as maintaining housing in suitable climate conditions for health.

METHODOLOGY

Case study characterization

The sample selected is made up of 700 multi-family social housing units in the city of Malaga.

Malaga, in the south of Spain, has a typical Mediterranean coast climate with mild winters between December and March, mild summers between June and September and short periods of variable temperatures between seasons in April-May and October-November. Relative average humidity ranges from 58 to 72%, with variations inversely proportional to the daytime temperature due to air heating. The predominant wind direction is south-west with low speeds (Table 1).

MONTH	T	TM	Tm	R	H
January	12.1	16.8	7.4	69	69
February	12.9	17.7	8.2	60	68
March	14.7	19.6	9.8	52	67
April	16.3	21.4	11.1	44	63
May	19.3	24.3	14.2	20	59
June	23	28.1	18	6	58
July	25,5	30.5	20.5	0	58
August	26	30.8	21.1	6	61
September	23.5	28.2	18.8	20	65
October	19.5	24.1	15	57	70
November	15.7	20.1	11.3	100	71
December	13.2	17.5	8.9	100	72
Year	18.5	23.3	13.7	534	65

Table 1: Meteorological data for Malaga

Caption:
T Monthly/annual mean temperature (°C)
TM Monthly/annual mean of daily maximum temperature (°C)
Tm Monthly/annual mean of daily minimum temperatures (°C)
R Mean monthly/annual rainfall (mm)
H Mean relative humidity (%)

In addition to compiling the approximate consumption data provided by the suppliers EMASA and ENDESA, a set of energy audits, user surveys and onsite inspections were developed to characterize the 700 social housing units involved in the project. Survey questions are designed to ascertain consumption behavior, the number of inhabitants and their age range, usage profiles, device use, etc.

Subsequently, the detailed consumption of some housing units was examined. In fact, 6 units were selected for a submetering process to represent the most common peer groups. This provides more detailed usage profiles and the time-distribution of electricity consumption, as well as the maximum and minimum energy demand. In addition the indoor temperature of the housing units was monitored.

This work analyzes the data from one of the case studies, which is representative of the buildings constructed prior to the implementation of the first Spanish energy demand regulations NBE-CT-79 (on Thermal Conditions in Buildings). This is a high-rise flat in a multifamily building, with a brick masonry cavity wall envelope (Figure 1).

Figure 1: Building typology (a) and façade (b).

As well as characterizing the housing units, the aim of this data collection campaign was to establish the conditions of the social housing stock and to identify key factors to improve its energy efficiency.

Energy and water consumption

In order to ensure a correct comparison process among the different neighbors, a peer-based clustering process was conducted using the audited data. Peers are defined as groups of housing units -expected to display homogeneous behavior- with similar energy and water consumption performances. This classification allows the homes to be compared to others with similar profiles.

The housing units are classified according to occupancy (from 1 to 5 inhabitants) and size (small < 60 m^2, medium 60-85 m^2 and large > 85 m^2). Different combinations result in different peers (small size and 1 inhabitant becomes peer 1, medium size and 1 inhabitant becomes peer 2, …).

Finally, this resulted in 15 different peers, combining 10-11 and 13-14 due to their similarity and the lack of housing units, and chosen to ensure a representative study.

Residents also take part in the study process thanks to smart meters in their homes which keep them informed on their consumption in real time.

Collaborating companies process consumption data, which users can access through an application and compare with the consumption of peers. This application runs on computers, smartphones and TVs. This process is shown in figure 2.

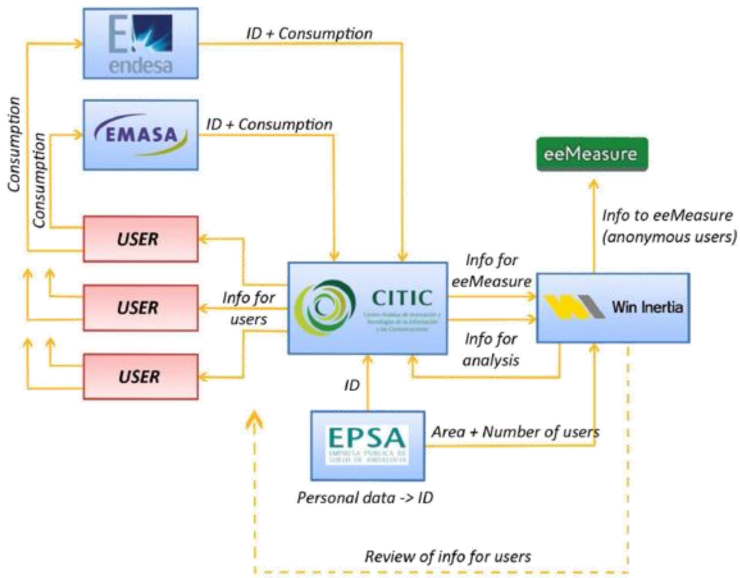

Figure 2. Information flow

The system is able to detect whether consumption falls within general performance or whether users are outliers who should take action to adjust it. The application also provides saving recommendations for users.

In conclusion, the purpose of this application is to save energy in housing units, as evidence shows that once users know their real time consumption they become more aware of poor energy habits and endeavor to modify them in order to save energy. This application can help them to achieve this and furthermore, it allows poverty energy conditions to be detected in cases where consumption is unusually lower than the average of peers.

The aim of this submetering process is to obtain further information about the different peers and to make some extrapolations over the representative housing units.

RESULTS AND ASSESSMENT

Water and energy consumption data were obtained for 700 social housing units during 2010, 2011 and 2012. The data is sorted according to the housing units' related peers, and the behavior of individual peers can be analyzed while simultaneously carrying out a comprehensive study of all housing units examined.

The submetering process focuses on the data obtained for case study 1 in 2014. This home is found in a multifamily unit built between 1970 and 1975, with a non-insulated envelope with façade transmittance of around 1.38 W/m^2K. The number of current inhabitants is 5 and it is medium sized (65-85 m^2) in relation to the housing set. Its features allow it to be characterized as a 14 peer group (5 inhabitants-medium size).

Energy consumption meters were assigned to main appliances (TV, AC, iron, kitchen socket, washer, microwave, refrigerator and notebook), in addition to the total energy meter for the home. Indoor temperature is also registered.

Real time consumption is clustered in daily and monthly consumption obtaining the average daily consumption per month. These data are compared to those provided by the electricity utility company ENDESA for the 2010-2012 period. The average consumption for all peers, the average consumption of the case study, and the average consumption of the peer where the housing unit is located are obtained.

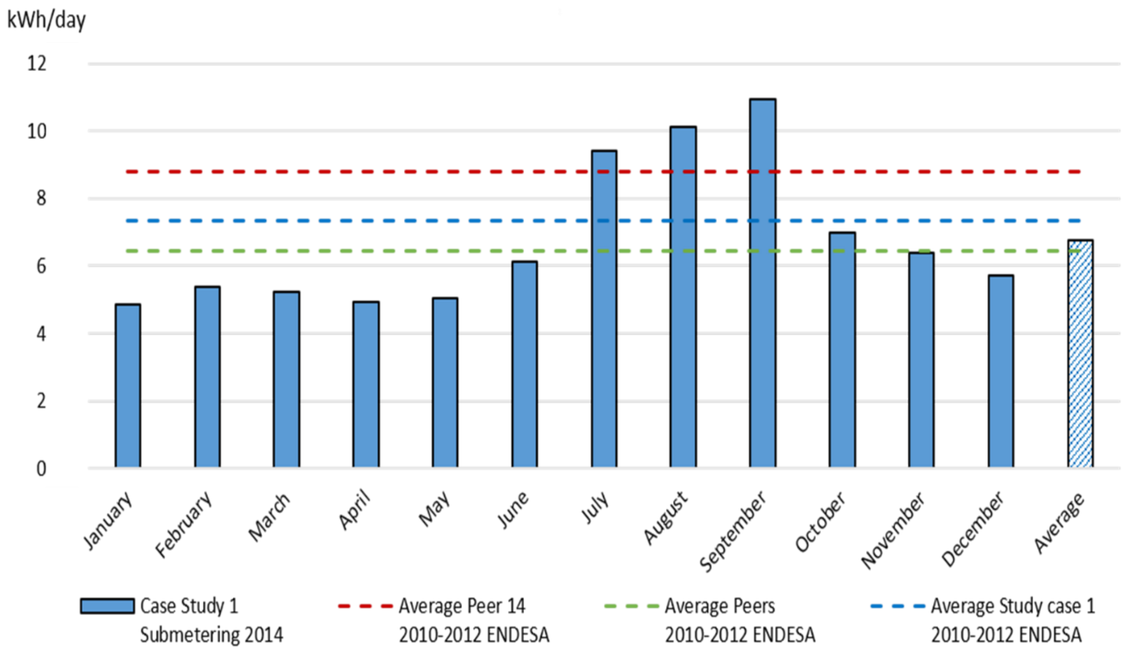

Figure 3. Case Study 1 submetering 2014. Daily energy consumption

Figure 3 shows that the highest electricity consumption is linked to the summer period when the use of AC is prevalent. The consumption for the housing unit was slightly lower for the year 2014 (submetering data) than for the 2010-2012 period, although it seems to follow the same tendency, as reflected in the energy consumption data for the peers.

As consumption is lower than for the average peer a lack of comfort conditions is expected for the housing unit in comparison with the rest of the homes.

The submetering process permits identification of the weight of the different services on the total energy consumption distribution of the home. It is worth noting the percentage of TV, fridge & AC consumption, which is higher than the rest of the set. These data are compared with those provided by the Instituto de Diversificación y Ahorro de la Energía (IDAE) in the research project SECH-SPAHOUSEC [24] (figure 4).

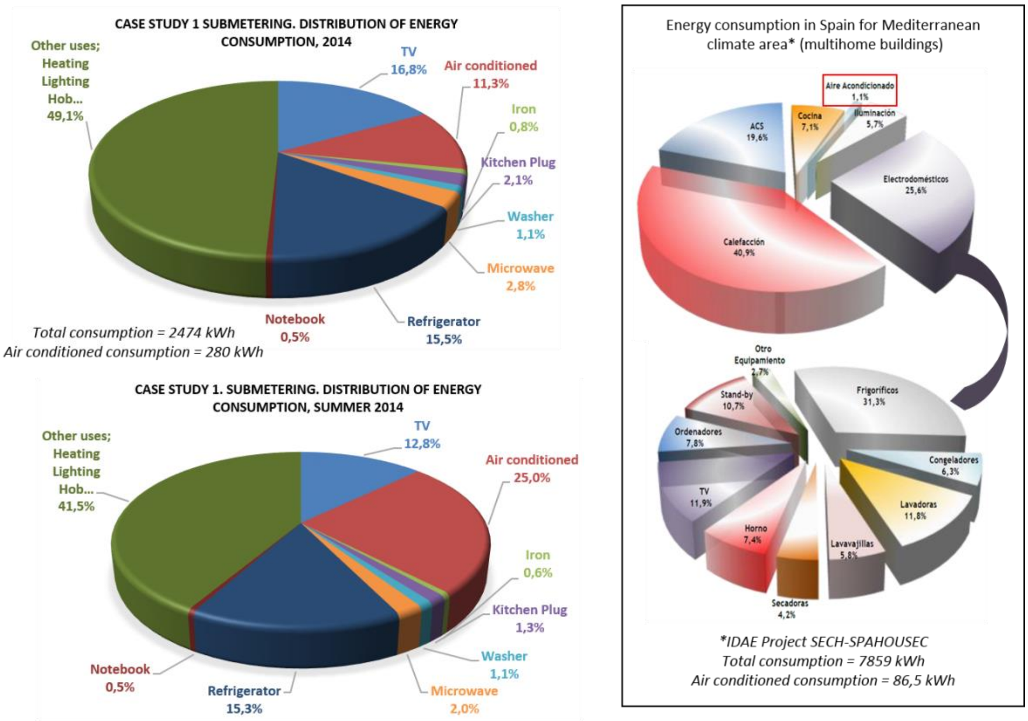

Figure 4. Comparison of consumption distribution between Case Study 1 and SECH-SPAHOUSEC Project

IDAE research (Mediterranean climate area) groups regional areas (Catalonia, Levant and Andalusia) in the same cluster. The differences existing between them are both economic and sub-climatic, and result in a general approach. Because of that, for a Mediterranean climate and this kind of housing unit SECH-SPAHOUSEC establishes a much higher energy consumption, up to 70% higher (7859 kWh instead of 2474 kWh).

On the other hand, the percentage for AC use is much lower than that obtained in the case study housing unit. SECH-SPAHOUSEC establishes a percentage of use of 1.1%, while for the case study housing unit the percentage is 11.3%. In absolute terms AC consumption is also higher in the case study housing unit (280 kWh instead of 86.5 kWh) (figure 4).

Consumption distribution throughout the year is homogeneous except in the summer period, when cooling use increases energy consumption. During this period the percentage of AC consumption is around 25% of the global percentage, occasionally peaking to 36%.

High energy consumption may also be related to old and inefficient AC systems coupled with poor building thermal insulation.

Despite the high percentage of AC consumption, the savings relating to this field are avoided due to the fact that consumption is much lower than that used as reference for the energy labeling process, developed by IDAE for housing units in the report "Escala de calificación energética para edificios existentes" ["Energy Rating Scale for Existing Buildings"][25]. The AC primary energy consumption to maintain optimum comfort conditions in housing units in this climate zone was established in this study. IDAE establishes a primary energy consumption for AC of 25.8-28 kWh/m^2 instead of the 9.14 kWh/m^2 consumed by the housing unit from the case study.

Although energy consumption for AC in these units is very high in comparison with the total consumption it is not enough to ensure comfort conditions in the housing unit since this percentage is high compared to the low total consumption. This shows that housing units do not have optimum comfort conditions, reflecting energy poverty conditions.

Comfort conditions are fulfilled if the housing unit temperature is found between the comfort threshold for summer and winter. As stated in the Spanish Technical Building Code (CTE) this threshold has a maximum temperature of 27-25˚C in summer and a minimum temperature of 17-20˚C in winter.

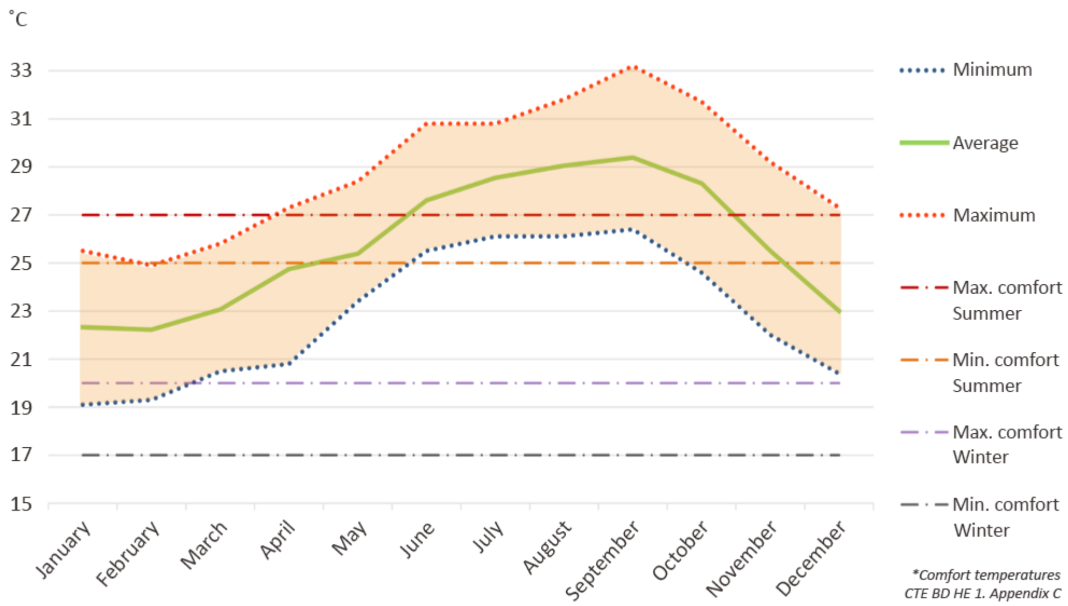

Figure 5. Case Study 1. Annual temperature submetering 2014. Comfort threshold

The submetering process shows that these housing units have difficulty in reaching indoor comfort temperatures (figure 5), especially in summer. The winter average housing unit temperature is higher than the minimum comfort threshold, so housing units maintain comfort conditions in winter. However, in summer the average temperature is higher than the maximum comfort threshold at all times, so that housing units cannot maintain comfort conditions in summer. Even at night, the minimum temperatures are higher than the minimum comfort temperatures, disturbing the rest of the inhabitants and worsening living conditions.

The lack of control of indoor temperatures in these homes, resulting in average high indoor temperatures, may be associated to the type of AC systems, usually inefficient and capable only of serving one room..

CONCLUSIONS

The SECH-SPAHOUSEC project for multi-family housing establishes electric consumption 70% higher than the average consumption obtained by monitoring this case study. This increase is also reflected when comparing AC consumption between the two. However, AC consumption in SECH-SPAHOUSEC project represents 1% of the total electric consumption, compared to 11% in this study.

The methodology used to analyze consumption in these housing units has demonstrated existing energy poverty conditions due to various causes. The inefficient envelopes and thermal installations cannot ensure thermal comfort in the homes. The buildings predate NBE-CT-79 regulations and therefore lack energy saving capacity and thermal comfort control criteria. Façade transmittance is higher than that established by current regulations for the climate zone (1.38 W/m^2K as opposed to 0.94 W/m^2K). HVAC equipment is inefficient and generally found only in individual rooms. The situation is heightened by the economic crisis which particularly affects residents of this social housing and which is worsened by the increase in electric energy prices in Spain during this period. According to Eurostat, Spain is the fourth European country in terms of high electricity prices.

All this gives rise to major variations in comfort in housing while relatively low energy consumption indicates limited potential for improvement in the reduction of consumption. This makes it advisable to apply saving measures in other fields, also benefitting comfort conditions in buildings.

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