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Impact of building automation control systems and technical building management systems on the energy performance class of residential buildings: An Italian case study

M.G. Ippolito, E. Riva Sanseverino, G. Zizzo*

DEIM – Department of Energy, Information Technology and Mathematical Models, Università di Palermo, viale delle Scienze, Palermo, Italy

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ABSTRACT

The paper focuses on the evaluation of the impact on residential buildings of building automation control (BAC) and technical building management (TBM) systems. This work shows how the control, monitoring and automation functions considered by the European Standard EN 15232 can considerably influence the energy performance of a single-family test house and, consequently, its energy performance class. The study puts into evidence that the benefit that can be drawn from the installation of BAC and TBM systems depends on the type of technical appliances in the household and on the starting energy performance class.

Finally, the economic impact due to the introduction of BACS or TBM function is evaluated for different starting energy classes of the household under consideration.

1. Introduction

Buildings energy performance depends not only on thermal but also on electrical factors like:

- the presence of electrical or thermal energy generation from Renewable Energy Sources (RES) and Combined Heat and Power (CHP) systems;
- the presence of Building Automation Control Systems (BACS) an Technical Building Management (TBM) systems.

For promoting the energy performance in buildings, EU Member States have followed different ways. In particular, in the last decades various support policies have been put into effect for promoting locale RES-based generators [1–7].

Moreover, according to the European Performance in Building Directive (EPBD) 2010/31/EU [8], all EU Member States have defined methodologies for the calculation of the energy performance of buildings on the basis of a general framework.

An analysis of the progress toward implementation in European Countries of the EPBD can be found in [9].

It is important to underline, how the current edition of the EPBD, differently from the old version (Directive 2002/91/EC [10]), gives greater importance to automation, control and monitoring systems. In particular, the new EPBD encourages the use of active control systems and intelligent metering systems for energy saving purposes whenever a building is constructed or undergoes major renovation in line with Directive 2009/72/EC [11].

Moreover, the 'climate and energy package' enacted by the European Union (EU) in June 2009 sets a series of demanding climate and energy targets to be met by 2020, known as the "20-20-20". A recently issued directive of this group is the 2012/27/EU [12] on energy efficiency, that establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20% headline target on energy efficiency and to prepare for further energy efficiency improvements beyond that date. It explicitly refers to automation as a tool to attain the cited objectives through the implementation of demand response (DR) policies, and the wide spread application of smart meters is considered a cost-saving measure for energy gains and savings.

Indeed, a potential for energy savings resides in the use, control and interaction of appliances and domestic devices, in order to reach their full efficiency during normal operation, also thanks to the recourse to specific software systems that orchestrate all energy facilities in the house [13].

Following this direction, in 2007, the European Standard EN 15232 [14] was issued to devise terminology, rules and methods for the estimation of the impact of BAC and TBM systems on energy performance and energy use in buildings.

The standard EN 15232, today in its second edition, gives a list of BACS and TBM functions that can affect the energy performance of buildings (omitting however other important functions able to

* Corresponding author. Tel.: +39 09123860205; fax: +39 091488452.
E-mail addresses: gaetano.zizzo@unipa.it, ing.gaetanozizzo@gmail.com (G. Zizzo).

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improve domestic or electrical safety [15]), and introduces four different efficiency classes for buildings according to BACS and TBM systems installation:

- Class A: High energy performance BACS and TBM systems;
- Class B: Advanced BACS and TBM systems;
- Class C: Standard BACS;
- Class D: Non-energy efficient BACS.

The BACS efficiency classes refer only to the installed BACS and TBM systems and not to the building as a whole, and they are not correlated to the energy classes defined by the European Standard EN 15217 [16].

In particular Class A and B both have centralized control systems, having recourse also to SCADA [17,18], but differs only for their performance.

Given the importance of this topic, in this paper a study is presented on the impact of BACS and TBM systems on the energy performance class of a typical Italian medium scale single-family house. Purpose of the paper is not to perform a critical analysis of the EN 15232, but only to illustrate how much the promotion of BACS and TBM systems can affect the energy class of a building. The paper also investigates the economic impact of automation and control systems and the number of years required to cover the initial investment.

The energy performance class of the house under study is calculated using the Italian standards UNI TS 11300-1 [19] and UNI TS 11300-2 [20].

The electric energy consumption of the house is calculated, using a statistical approach, thanks to a simulation tool developed by the authors within the National Research Project SIRRCE [21] funded by the Italian Ministry for the Economical Development.

For the estimation of the impact of BACS and TBM systems on the energy performance of the buildings, the BAC factors method proposed by EN 15232 is used.

Finally, an economic analysis comparing the purchase and installation costs of BACS and TBM systems and the economic savings due to the reduction of the energy consumption of the house is performed.

2. Energy performance class of a residential building: the Italian case

For evaluating the energy performance of a building, the standards elaborated by CEN and efficiently summarized in the "Umbrella Document" CEN/TR 15615 [22] are commonly used. An example on how to apply this standards can be found in [23].

In Italy the energy performance class of a residential building is calculated taking into account only the primary energy consumption for heating and for hot water production and neglecting the energy consumption for cooling or lighting.

For calculating these consumptions, the Italian standards UNI TS 11300, based on technical standard EN ISO 13790 [24], are used.

An explanation on how to apply these standards is not simple and is not in the aim of this paper. However, an application of standards UNI TS 11300 to some case studies can be found in [25–27].

The above-mentioned standards give methods for the calculation of the Energy Performance Index (EPI) for heating and hot water production. By comparing the calculated value of the EPI with a limit value (EPI_L), established by Italian Decree Dlgs. 311/06 [28] the energy performance class of the building is found according to Table 1.

Table 1
Table for the calculation of the energy performance class of a residential building according to the DLgs 311/06.

EPI (kWh/m^2)	Energy performance class
$EPI < 0.25 \cdot EPIL + 9$	A+
$0.25 \cdot EPIL + 9 \le EPI < 0.50 \cdot EPIL + 9$	A
$0.50 \cdot EPIL + 9 \le EPI < 0.75 \cdot EPIL + 12$	B
$0.75 \cdot EPIL + 12 \le EPI < 1.00 \cdot EPIL + 18$	C
$1.00 \cdot EPIL + 18 \le EPI < 1.25 \cdot EPIL + 21$	D
$1.25 \cdot EPIL + 21 \le EPI < 1.75 \cdot EPIL + 24$	E
$1.75 \cdot EPIL + 24 \le EPI < 2.50 \cdot EPIL + 30$	F
$EPI \ge 2.50 \cdot EPIL + 30$	G

Table 2
BAC efficiency factors for thermal and electric energy for residential buildings (EN 15232).

Single family houses, apartment block and other residential buildings	A	B	C	D
Thermal energy BAC efficiency factor $f_{BAC,hc}$	0.81	0.88	1.00	1.10
Electric energy BAC efficiency factor $f_{BAC,e}$	0.92	0.93	1.00	1.08

3. BAC efficiency class for a BACS or TBM in a residential building

The BAC efficiency classes are defined by the European Standard EN 15232. The standard proposes two different methods for the calculation of the effects of the building automation and management functions on the energy performance of a building:

In this paper, only the method named "BAC factor method" is taken into consideration.

According to this method, the influence of BACS and TBM on the energy performance of a buildings is quantified using two energy efficiency factors, called respectively *BAC factor for thermal energy* (heating and cooling systems), $f_{BAC,hc}$ and *BAC factor for electrical energy*, $f_{BAC,e}$. The values of these factors for residential buildings are reported in Table 2.

These factors are calculated by comparing the yearly energy consumption of a given technical plant (ventilation, lighting, etc.) of a reference building (class C) with the consumption of the same plant calculated in the same working conditions (occupation time, load profile, weather, solar irradiation, etc.) after the application of a BAC system in each of the four different classes.

In Fig. 1 a chart flow details the BAC factors method for the calculation of the reduction of the energy consumed by a building when the BAC efficiency class is improved from a starting class 1 to a better class 2.

4. Calculation of the electric energy consumption

In recent years, various methods have been defined for simulating the daily power consumption of residential loads. Many of these methods have in common a probabilistic approach that allows the construction of the daily power profile starting from the knowledge of social, economical and demographic factors [29–35].

Several probability functions cover the close relationship existing between the demand of residential customers and the psychological and behavioral factors that are typical of the inhabitants of the household; the models make use of such functions through a Monte Carlo extraction process.

It is important to underline that also the automation level of a building [36] and the presence of central or local displays for providing information on energy usage [37] can affect the occupants behavior.

In this paper, the daily power profile of the test house is found according to the bottom-up approach defined in [33,34] and implemented in the tool *SirSym-Home* developed by the DEIM of the