The European Standards for Energy Efficiency in Buildings: an analysis of the Evolution with Reference to a Case Study

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Abstract. The improvement of the energy efficiency of building stocks represents an important contribution for the reduction of the energy consumption in the European Union (EU), along with the decrease of greenhouse gases emissions. In this aim both the public administrations and the technical experts need reliable calculation methodology to assess buildings' energy performance. In this framework, despite the recent publication of the Standard EN ISO 52016, that deeply modifies the approach to the energy building simulation by introducing a new hourly dynamic calculation model, the current normative framework (EN ISO 13790) will maintain its validity until the incorporation of the new Standard in the national Standards and Decrees (such as the Italian Standard UNI/TS 11300-1) will take place. The aim of this paper is comparing the suitability of the simulation approaches proposed by the above-cited Standards in relation to their different levels of complexity and to the levels of details of the results provided by them. On purpose, a case study in which the energy behaviour of a public building, sited in the Sicilian city of Trapani in the South of Italy, will be analysed and the results of the simulations conducted according to the aforementioned Standards will be compared considering the outcomes of the EnergyPlus software as reference values.

Keywords: Building Energy Efficiency, European Standards, Building Simulation.

INTRODUCTION

According to the JRC Energy Report 2018 [1], the energy consumption in the building sector accounts for the 25.7% share of the total energy use in the EU-28, while the IEA Global Status Report 2018 [2] states for the same sector a 36% share of the final energy use (corresponding to a 39% of energy-related CO_2 emissions). Therefore, the improvement of the energy efficiency of building stocks represents an important contribution for the reduction of the high dependency from energy supplied by countries outside European Union (EU), along with the decrease of greenhouse gases emissions. The diminution of such dependence constitutes also a strong element of safety for the EU-28. In this aim both the public administration and the technical experts need reliable calculation methodologies able to assess the level at which the energy efficiency is achieved in the building sector, also in sight of awarding buildings with high performance environmental labels [3].

Loonen et al. [4] and Pieter de Wilde [5] have made general observations about the opportunities, strengths and challenges relative to the use of building performance simulation and analysis to support future innovation processes.

In addition, simulations have also been conducted and analysed to compare different retrofit solutions to identify energy action priorities [6, 7] and to assess the price impacts of energy efficiency ratings on the building market [8].

The above-cited considerations led EU Member States to draw up a common energy policy in order to set up a suitable calculation methodology to assess buildings' energy performance [9, 10]. Despite the recent publication of the Standard EN ISO 52016 [11], that deeply modifies the approach to the energy building simulation by exclusively referring to the dynamic time-dependent regime (allowing for a more accurate evaluation of the energy performance [12, 13]), and that calls for the need of a more cognisant category of experts, the current normative framework (EN ISO 13790 [14]) will maintain its validity until the needed incorporation of the new Standard in the national Standards and Decrees (such as the Italian Standard UNI/TS 11300-1 [15]).

In this framework, many problems have arisen concerning the definition of energy ratings (based on operational or asset ratings) and the accuracy of the calculation methodology (simplified or detailed). In fact, as shown by various studies in recent literature, designers and researchers need suitable tools able to facilitate energy analysis in buildings, while still obtaining reliable results [16, 17, 18].

Simulation toolkit based on the EN ISO 13790 have been developed in several research case studies, by using simple methods such as Excel-based calculation tools [19, 20], or more sophisticated ones, namely MATLAB-based calculation codes [21, 22, 23]. In addition, when considering strategies for consumption reduction, tools like EnergyPlus [23, 24, 25] and TRNSYS [22] (using a transient method to simulate the building energy behaviour), have been used to validate the energy performances' results obtained by the application of the above-mentioned Standard, considering buildings under various climate conditions, and with multiple energy conservation measures being applied to them. In addition, algorithms to select the best combination of retrofit solutions for a building, taking also into account the costs, have been investigated [26]. As for the Standard EN ISO 52016, since we are actually in a transition phase, its application for research purposes has only recently begun to be taken into consideration. To date in [27] a calibration of the procedure described in the EN ISO 52016 was carried out by means of the results provided by the dynamic software TRNSYS adopting a black-box approach, referring to buildings located in the Mediterranean area.

In the present work the differences between the new Standard EN ISO 52016 and the EN ISO 13790 will be analysed by means of a case study in which the energy behaviour of a public building, sited in the Sicilian city of Trapani in the South of Italy, will be simulated. In particular, the results of the simulations conducted according to the aforementioned Standards will be compared, considering the outcomes of the EnergyPlus software as reference values. The final aim of the paper is comparing the suitability of the above-cited approaches in relation to their different levels of complexity and to the levels of details of the results provided by them, in order to provide professionals (designers and researchers) with considerations regarding whether it is convenient to keep using the EN ISO 13790 or start utilizing the EN ISO 52016 during the transition phase.

COMPARISON BETWEEN THE EN ISO 13790 AND THE EN ISO 52016 STANDARDS

The hourly calculation method proposed by the EN ISO 52016 [28] is a revised, and more advanced, method than the simplified hourly one given in EN ISO 13790 [14]. The main difference is that the building elements are not aggregated to a few lumped parameters, but kept separate in the model, as shown in Figure 1.

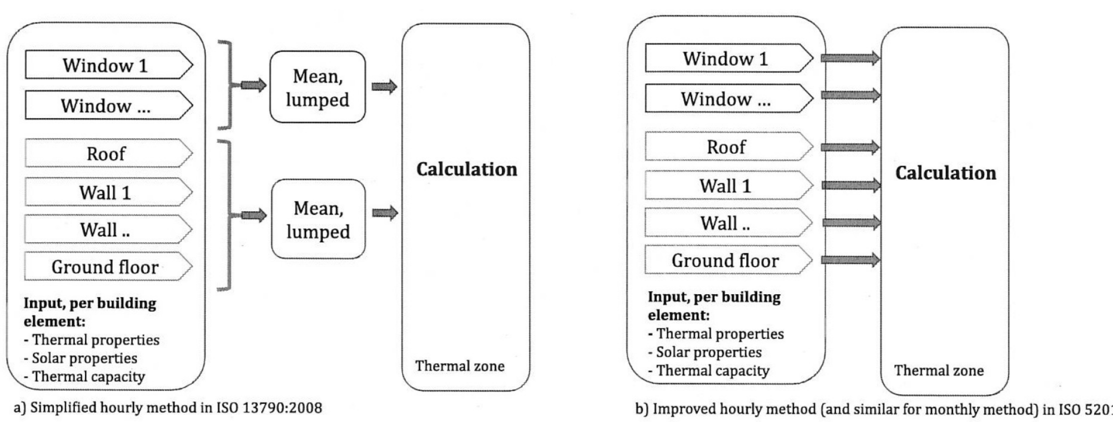
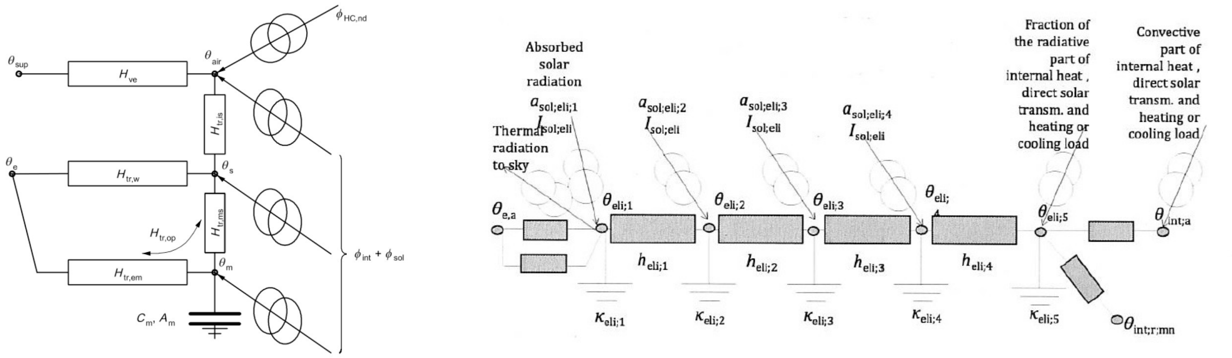


FIGURE 1. Simplified method in EN ISO 13790 (a) compared to improved hourly method in EN ISO 52016 (b) [28].

Specifically, the EN ISO 52016 uses a more complex and an extensive RC network thermal model for each building element separately, that is considering five nodes per building element and a capacitance for each building element inside a thermal zone – instead of using a 5R1C model, as in the EN ISO 13790 – to perform the hourly calculation relative to the energy loads and needs for heating and cooling and the hourly indoor temperature (air, mean radiant and operative). Figure 2 shows a comparison between the two models.



(a) (b)

FIGURE 2. Comparison between the 5R1C model of the EN ISO 13790 (a) [14] and the improved RC network thermal model of EN ISO 52016 (b) [28].

As a consequence, this leads to a number of advantages, in particular that the properties of each building element remain individually known, instead of being aggregated to only two thermal resistances, which makes the model more transparent and more widely usable compared to ISO 13790. Some advantages (which make the method better suited to deal with passive solar energy and other techniques, as requested by the EPB Directive [10] on the energy use and the thermal performance of buildings and building elements) and drawbacks of the method proposed by the EN ISO 52016 are given in Table 1.

TABLE 1. Advantages and drawbacks of the EN ISO 52016 model, with respect to the EN ISO 13790 model [28].

Advantages of the EN ISO 52016 model	**Drawbacks of the EN ISO 52016 model**
There is no worry about how to combine e.g. the heat flow through the roof and through the ground floor, with their very different environment conditions (ground temperature and ground inertia, solar radiation on the roof).	The model requires higher inputs of building properties and dimension which may not be available all the time.
The thermal mass of the building or building zone can be specified per building element and there is no need for an arbitrary lumping into one (mean) overall thermal capacity for the building or building zone.	Due to the much higher number of nodes a robust numerical solution method (software) is required when considering a whole building - the solving of the matrix needs to be done by programming (the rest of the calculation can still be done in a spreadsheet).
The mean indoor surface temperature (mean radiant temperature) can be clearly identified and kept distinct from the indoor air temperature.	

Furthermore, the EN ISO 52016 also contains a specific hourly method to calculate the moisture and latent energy loads, and needs, for humidification and dehumidification and the hourly indoor air moisture content (i.e. humidity), making it possible to predict the dynamic behaviour of a building in a way more similar to the one provided by the sophisticated software products, like EnergyPlus.

In addition, the possibility of taking into account in a more detailed way the hourly/daily variations in weather conditions, their dynamic interactions with technical buildings systems, control aspects and boundary conditions (where relevant for the calculation), represents a further advantage, with respect to the EN ISO 13790, allowing to use the model as a simulation tool to put in act both design and control strategies relative to the building's technical systems.

It must be underlined that, despite the fact that the EN ISO 52016 hourly calculation method constitutes a more powerful instrument than its predecessor EN ISO 13790, it still requires the same input data from the user, so that a limited access to input data is no reason to choose a simpler calculation tool.

MATERIALS AND METHODS

Not a lot of research work has been done on the hourly dynamic calculation model provided by the EN ISO 52016 [28], being it a recently published Standard and considering the fact that its use is not mandatory yet. Thus, the aim of the case study presented in this work is to test the accuracy of the aforementioned model by comparing it with the, still in force, 5R1C model of the EN SO 13790 [14], considering the outcomes of the EnergyPlus software as reference values. Specifically, the numerical simulation models of the two Standards, EN ISO 13790 and EN ISO 52016, have been implemented in the MATLAB environment.

To this purpose, the differences between the two Standards will be analysed by means of a case study in which the energy performance of a public building will be simulated. The building in question is the city Hall of the Sicilian city of Trapani in the South of Italy, whose general characteristics are reported in Figure 3. Given its position, the city of Trapani is characterized by a Mediterranean climate profile, typical of Italian coastal and Southern areas.

Position: Trapani (TP)

Latitude: 38°01’01”

Longitude: 12°30’48 ”

Altitude: 14 m a.s.l.

Climate zone: B

Degree days: 810

Building typology: Office

Construction year: 1904

FIGURE 3. General characteristics and south-east elevation view (on the left) of Trapani city Hall building.

The city Hall building has a covered area of about 2000 m^2 and consists of four storeys above the ground, resulting in a total volume of about 6700 m^3. The interior plan layout of the typical floor is structured around a central light-well court. The building is completely isolated on all four sides and presents the typical construction characteristics of the era in which it was built, therefore without any attention to energy saving solutions. In particular, the main structure consists of load-bearing masonry walls, made up of natural limestone ashlars and wooden floors, while the windows are of the single-glass type with wooden frames and shutters without solar shadings.

The input boundary conditions for all three simulation approaches were made as close to each other as possible. In particular, set-point temperatures of the building for the heating and cooling of 20°C and 27°C, respectively for winter and summer seasons, were assumed. As for the main thermo-physical properties of the building’s opaque and glazed elements, these are reported in Table 2, and have been mainly obtained using the UNI/TR 11552 [29].

TABLE 2. Thermo-physical properties of the elements of the considered building.

Building element	Typology	Thickness (m)	Thermal Transmittance (W/m^2°K)
Masonry wall - 1st and 2nd floor	Opaque	0.54	0.90
Masonry wall - 3rd and 4th floor	Opaque	0.34	1.341
Roof slab	Opaque	0.06	1.18
Floor slab	Opaque	0.455	1.622
Windows (single glass)	Glazed	0.005	5.835

Regarding, instead, the functioning of the building in terms of internal heat gains related to thermal comfort [30, 31], occupancy, lighting, equipment, ventilation and infiltration, it was decided to adopt values (and relative schedules) based on those reported in the studies conducted by Corgnati et al. [32, 33] and Fabrizio et al. [34] on medium-sized office buildings. The adopted values are reported in the following Table 3.

TABLE 3. Internal heat gains' adopted values and relative schedules for the considered building [32, 33].

Internal heat gain element (unit)	Adopted value	Element schedule	
People (Person/m^2)	0.06	9:00-17:00 Monday to Friday	
	0	17:00-9:00 Monday to Friday	0:00-24:00 Saturday and Sunday
Lighting (W/m^2)	13	9:00-17:00 Monday to Friday	
	0.065	17:00-9:00 Monday to Friday	0:00-24:00 Saturday and Sunday
Equipment (W/m^2)	10	9:00-17:00 Monday to Friday	
	0	17:00-9:00 Monday to Friday	0:00-24:00 Saturday and Sunday
Ventilation (l/person)	11	9:00-17:00 Monday to Friday	
	0	17:00-9:00 Monday to Friday	0:00-24:00 Saturday and Sunday
Infiltration (m^3/s)	0.1	always	

As concerns the weather climatic conditions, those considered to perform the simulations are the ones relative to the Trapani-Birgi meteorological station, indicated in the EnergyPlus database [35].

Regarding the HVAC system it was decided to consider for both the EN ISO 13790 model and the EN ISO 52016 model an ideal one capable of maintaining the internal temperatures within the set point temperatures range. For consistency, an ideal HVAC system ("IdealLoadsAirSystem") was also considered in the EnergyPlus simulation.

RESULTS AND DISCUSSION

In the following, the outcomes of the different simulation approaches defined in the previous section will be shown and analysed, in order to make a comparison.

Specifically, the main results of interest for the presented case study are represented by the monthly heating and cooling energy needs, which have been summarized graphically in the following Figure 4 and Figure 5.

Looking at Figure 4, showing a comparison amongst the heating energy needs results obtained from the three calculation models, it is evident how all three models present a similar monthly trend.

As regards instead the comparison relative to the cooling energy needs, reported in Figure 5, results show that the gap between the EN ISO 13790 model and the EnergyPlus reference values is much more limited respect to the one relative to the EN ISO 52016 model results. This latter gave, in fact, a substantial overestimation of the cooling needs. This could be due to different reasons, the first one concerning the way in which this model calculate the internal solar gains, and in particular the allocation between the two components radiative and convective. Such aspect is indeed particularly relevant for the climate context considered. A second aspect which could contribute to such discrepancy in the results is related to the way the HVAC system comes into operation when the temperatures returned by the calculation models fall out of the optimal range. In particular; in the case of the EN ISO 13790 model the set point temperatures are compared with the air temperatures returned by the model, while in the EN ISO 52016 model this comparison is made with the operative temperatures. After all, the current sensors that enable the HVAC on-off regulation are all driven by the air temperature and not by the operative one.

Comparing, instead, Figure 4 with Figure 5 it can be seen how the heating needs result very low (reaching zero) during summer, thanks to the high radiation and external air temperature and, accordingly, quite higher cooling energy needs occur. Similar considerations can be drawn for the winter needs.

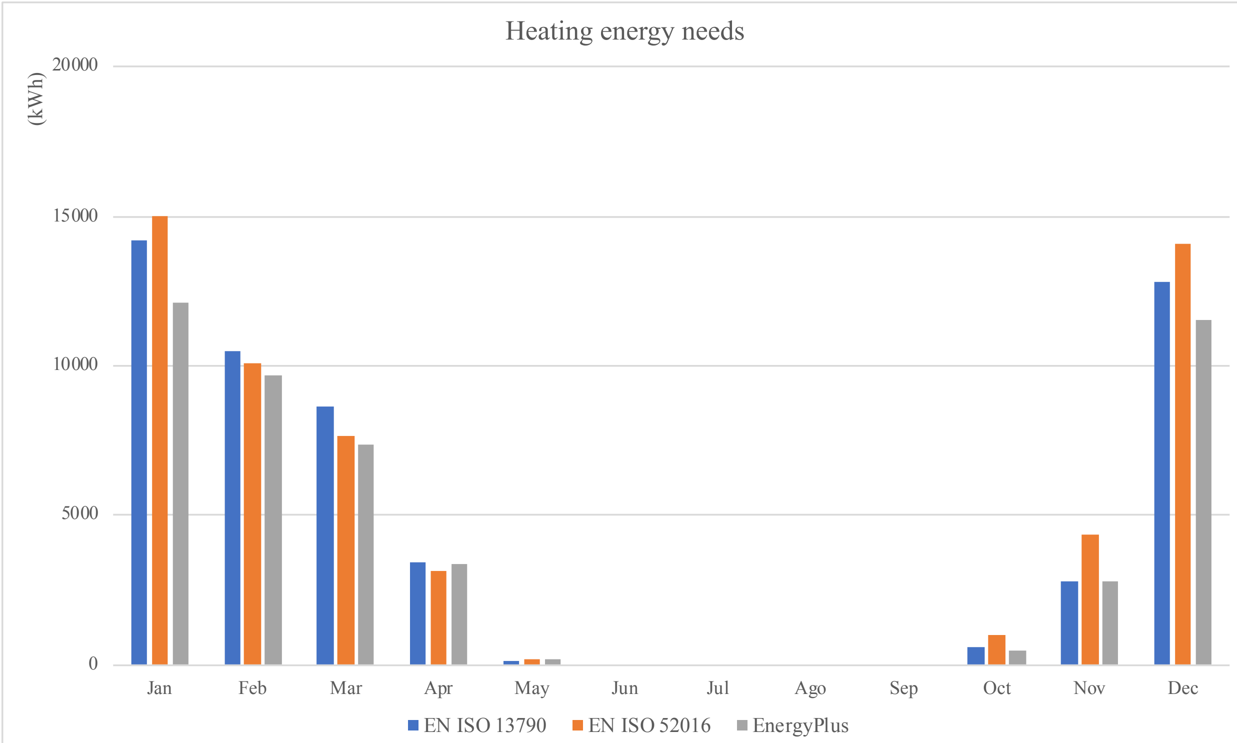


FIGURE 4. Comparison amongst the heating energy needs results obtained from the three calculation models.

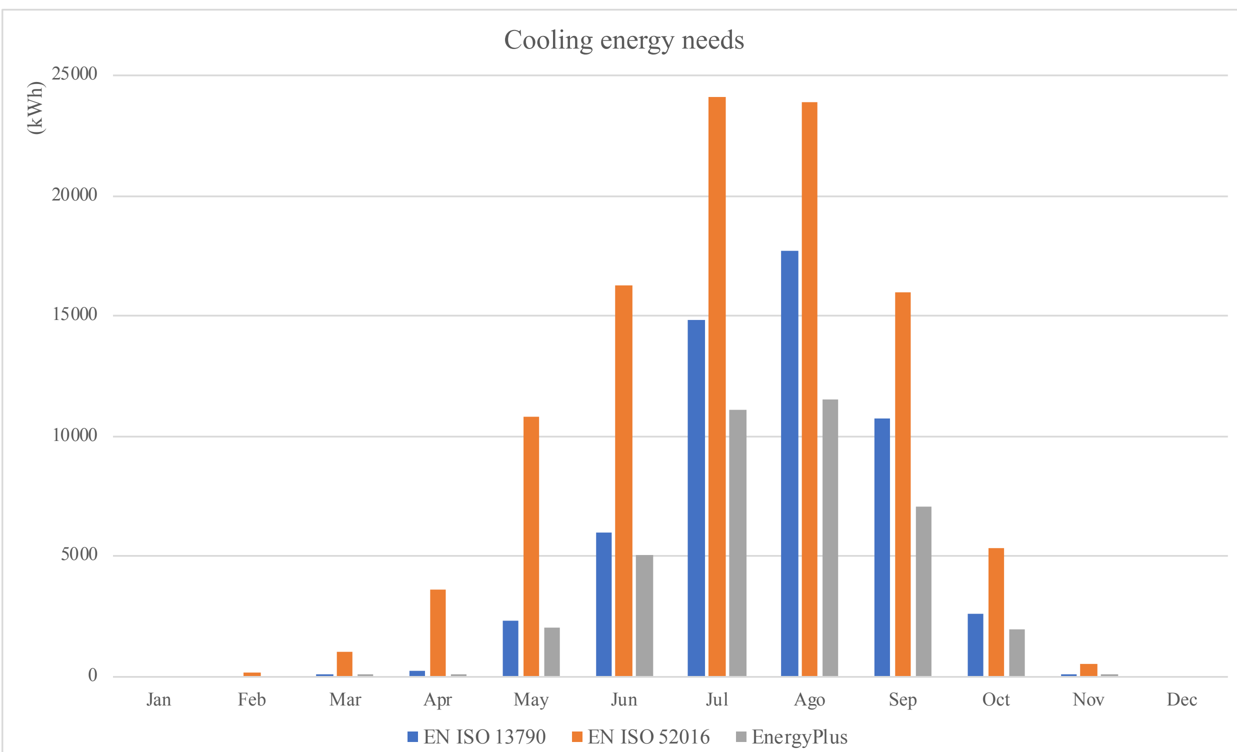


FIGURE 5. Comparison amongst the cooling energy needs results obtained from the three calculation models.

The above-mentioned differences, which could have been expected, between the two Standards are ascribable to the intrinsic definition of the two models proposed by them. The inputs for the EN ISO 13790 5R1C model are less compared to the EN ISO 52016 extensive RC network model as the elements are lumped to a few parameters, which increases the uncertainty in the dynamic simulation of the building. In fact, the improved calculation method introduced by the EN ISO 52016 allows to model a more advanced dynamic behaviour considering the contributions from each nodes of the building elements. Thus, the EN ISO 52016 model should derive more accurate results and could give a dynamic behaviour considerably different from the previous Standard.

In addition, a difference in the results relative to the energy needs could also be due to the utilized calculation methods. Specifically, EnergyPlus dynamic model calculates the exact value of the energy needs required at each time step, while both the EN ISO 13790 model and the EN ISO 52016 model are based on an approach that increases a discrete value of the heating and cooling needs until the set-point is reached.

CONCLUSIONS

The comparison between the EnergyPlus reference values and the results obtained from the models relative to the two considered Standards, object of the presented case study, suggest that for the considered context both the EN ISO 13790 model and the EN ISO 52016 model seem to be consistent with the EnergyPlus reference values in relation to the heating energy needs. While, concerning the cooling energy needs the EN ISO 52016 model makes a significant overestimate.

The presented case study represents a first investigation in the field, as a future development it can be deepened by extending the simulation models to multiple thermal zones, taking into account different usage and boundary conditions for separate parts of the investigated building, and by also including detailed HVAC system as well. Moreover, as a further step, it would also be useful to discuss the simulation results in terms of final energy utilization; in fact, considering that the energy market is being projected towards an electrification also at European level, it could be advisable to investigate the economic aspects.

Therefore, buildings' energy performance analysis can be used as a decision-making support tool in the development of innovative materials for energy efficiency in the building sector; moreover, it also represents an enabler for the proper design, construction and operation of buildings, especially when the expectations of a wide range of stakeholders need to be meet. In this aim both the public administration and the technical experts need reliable calculation methodology (easier to use compared to complex dynamic simulations) to assess buildings' energy performance with sufficient accuracy.

In conclusion, the cooperation between public administration, technical experts and researchers working on simple but yet reliable energy performance calculation methodologies, is essential in order to improve the energy efficiency of the building sector. Such aspect is, indeed, of paramount importance for the reduction of the high dependency from energy supplied by countries outside European Union (a strong element of safety for the EU-28), along with the decrease of greenhouse gases emissions.

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