Energy Certification of Existing Residential Buildings: Adaptations to the Energy Transition

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Abstract.
In Portugal, the energy certification of existing buildings is mandatory since 2009 in the sales or lease contract. This obligation, imposed by the first legislation of the SCE (Energy Certification System) was based on the Energy Performance of Buildings Directive from 2002. Since then, the SCE legislation has been undergoing constant changes. The last change concerns Decree-Law No. 101-D / 2020, with practical application from July 1, 2021.
More than a decade later and considering that the validity period of the energy certificate for residential buildings is ten years, the objective of this work is to present a reflection on the evolution of concepts and methodologies for calculating energy performance. The procedures for issuing the energy certificate, the content, and the graphic image, will also be analyzed. For this purpose, a single-family building, built in the 1990s and certified in November 2010, is used as an example.

Keywords: Energy certification, Residential, Existing buildings, Portugal

1 Energy Certification of Existing Buildings

1.1 Evolution of national legislation on Energy Certification of Buildings

In Portugal, the first regulation on energy performance of buildings appeared in 1990 (RCCTE, Decree-Law nº 40/90). Although undemanding, it introduced the frequent practice and the growing interest in introducing thermal insulation in buildings [1].

To address the problems associated with the excessive consumption of fossil energy in buildings, the European Commission approved the directive on the energy performance of buildings, Directive 2002/91/EC (EPBD-2002). With it, came the following novelties: -Minimum requirements for the energy performance of major renovations; -Review of legislation at least every five years; -Recourse to renewable energy; - Adequate qualification of technicians for certification and installation of systems; - Energy Certification of Buildings [2]. Its transposition into national law was carried out by: -Decree-Law nº 78/2006, SCE (National System for Energy Certification and Indoor Air Quality in Buildings); -Decree-Law nº 79/2006, RSECE (Regulation of Energy

Systems for Air Conditioning in Buildings); - and Decree-Law nº 80/2006, RCCTE (Regulation of the Thermal Behavior Characteristics of Buildings), which revoked the Decree-Law nº 40/90 [3,4,5].

In 2010, EPBD-2002 was revoked by Directive 2010/31/EC (EPBD recast-2010). This new version included a set of new challenges, such as buildings with almost zero energy consumption from 2020 onwards [6]. Its transposition into national law took place through Decree-Law nº 118/2013, revoking the aforementioned legislative instruments [7]. This diploma brought together in a single document the Energy Certification System for Buildings (SCE), the Energy Performance Regulation for Residential Buildings (REH), and the Energy Performance Regulation for Commercial and Service Buildings (RECS). In 2016 there was a relevant change regarding the values of the thermal behaviour and efficiency requirements of technical systems. This change considered the cost-optimal studies carried out in Portugal, in accordance with the directive's recommendations.

Intending to further reduce greenhouse gas emissions, and with an even greater focus on rehabilitation and the use of renewable energies, the European Union approved directive 2018/844, of 30 May 2018, which amends the EPBD recast- 2010. This directive was transposed into Decree-Law no.101-D/2020 [8,9].

Figure 1 summarizes the evolution of legislation referred above.

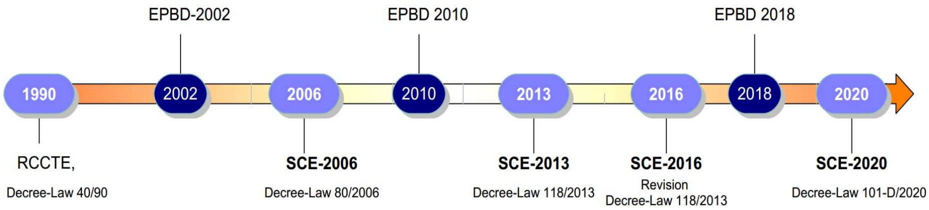

Fig. 1. Evolution of national legislation on Energy Certification of Buildings

1.2 The Energy Certification of existing buildings

The Energy Certificate (CE) allows future building users to obtain information on energy consumption and improvement measures. The CE classifies a residential building based on its integrated performance, which includes heating, cooling, and preparation of domestic hot water (DHW). The energy rating scale of buildings until 2013 was composed by 9 classes, A+, A, B, B-, C, D, E, F and G (class A+ corresponding to the best performance and G to the worst). After 2013 the G class disappeared.

The national energy certification of buildings took place in stages. First (in 2006) it became mandatory for new buildings, and in January 2009, it was extended to existing buildings [10]. As opposed to a new building, an existing building is understood to mean any building whose application date for construction license prior to the entry into force of the SCE legislation. In these cases, the building owner must be responsible for obtaining the CE to hand it over to the future owner or tenant, in the act of sale or lease. He will have to contract a Qualified Expert (PQ) to carry out the CE and providing him the necessary documentation for a good characterization of constructive and technical solutions of the building. In addition, the PQ must make a visit to the building.

Logically, there are no minimum requirements regarding the envelope, technical systems, and energy needs for existing buildings, as the assessment is made considering the characteristics of the building at the time of certification, assuming any of the classes mentioned above. The energy performance assessment of this type of building can be done using a simplified calculation method since it is not possible to determine all the solutions accurately [11,12,13]. However, the PQ should only use the simplification rules that it deems strictly necessary. These simplifications are related to the following items: -Dimensions; - Thermal bridges; - Loss reduction coefficient of non-useful spaces; - Mechanical ventilation; - Solar factor of the glazed span; - Thermal transmission coefficient; - Inertia class; - Solar energy; - Efficiency of systems; - Shading factors.

PQs must study the opportunities for improving the energy performance of building and registering them in the CE. These improving measures are very important, as they aim to guide owners to intervening in the building to increase thermal comfort and energy savings.

In the last years, Energy Certification was an important issue treated by several international studies [14-19]. Some of them, demonstrate flaws, such as the superficiality with which some subjects are treated, like the indoor air quality and health [17], and the comparison with the real energy consumption [18]. Also, the constant changes in legislation cause different values of energy needs calculation, which causes inconsistencies in the changes and discredits the system [19]. In any case, relative to EU countries, the implementation of the Energy Certification System was similar, although the need to adapt the methodologies to the climate zone.

As already mentioned, in Portugal, since 2009 certification of existing buildings has been mandatory, but only when selling or renting. As legislation has been continuously amended, there are similar buildings on the market built in the same year but certified in different years, subject to different calculation methodologies. Furthermore, the validity of CE Residential Buildings is ten years. Many buildings needs or will soon needs a new certificate for sale, lease or interventions included in financing programs. Previous and current CEs will be compared. It is important to take stock of the situation and reflect on the main changes.

2 Methodology

This study aims to analyze and reflect on the evolution of national legislation on the energy certification system applied to existing residential buildings. To this end, a case study of a typical single-family house certified by the SCE-2006 Methodology is used. Then Certification is simulated using SCE-2013, SCE-2016 and SCE-2020 Methodologies. As it is an existing building, some simplifications allowed by legislation were used. In the end, calculation methodologies and results are compared.

3 Case study

3.1 Description of climate data and building solutions

General description

This case study is based on an existing single-family house built-in 1990. It consists of a ground floor, comprising two living rooms, one kitchen, one toilet, one pantry, one hallway and one stair, which communicates with the 1st floor comprising four bedrooms, one toilet and one corridor (all conditioned spaces). The ground floor is in contact with the land, and the 1st-floor ceiling is with an unconditioned attic. Laterally, the walls are in contact with another building. The main facade is oriented to the East. Most significant shading is caused by neighbouring buildings.

Fig. 2. Location and facade of the building.

Climatic data and Location

The building is in Bragança city, in an urban area, at an altitude of 699m, inserted in the Climatic Zone I3-V2.

Climate data have been updated over the years. Table 1 shows the main climatic data referring to the different methodologies.

Table 1. Climatic parameters.

Climate Data, Bragança, 699m	**SCE-2006**	**SCE-2013/2016/2020**
Climate Zone (I, Winter e V, Summer)	I3-V2	I3-V2
Degree-days, GD (ºC.dias)	2850	2042
Heating season duration (months)	8	7,3
Cooling season duration (months)	4	4
Average summer outdoor temperature (ºC)	19	21,4
GSul (kWh/m2. month) - Average solar energy incident on a south-facing vertical surface	90	125

Table 2 shows the average solar energy incident on a surface accumulated during the cooling season (June to September).

Table 2. Intensity of solar radiation for the cooling season.

	Solar Radiation Intensity for the Cooling Season, kWh/m2								
	N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**	**Horizontal**
SCE-2006	200	320	450	470	420	470	450	320	790
SCE-2013/2016/2020	220	345	480	485	425	485	480	345	790

Dimensional and thermal characterization

The exact dimensional survey of the building was conducted, which allowed the following information: Useful area (m2) = 148m2; Average right foot = 2.6m; Exterior walls = 108m2; Interior walls = 66m2; Glazed spans = 17m2.

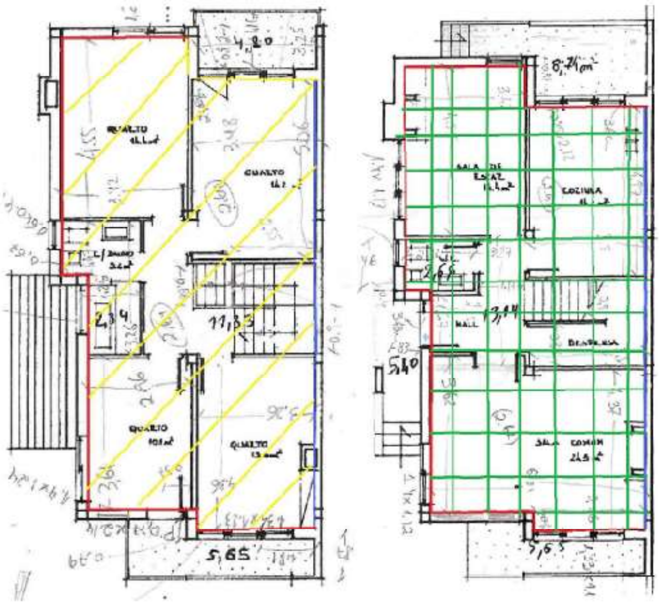

Fig. 3. Building plans.

The unconditioned spaces identified were: - Buffer zone; - Coverage attic; - Adjacent building. The methodology for determining the loss reduction coefficient for unconditioned spaces has been changed since SCE-2006.

For being a building built in 1990 (before the first thermal regulation), the absence of any thermal insulation in walls and floors was considered. The values of thermal transmission coefficient considered for the building envelope were: - Exterior walls, 34cm, =0.99 (W/m2.°C); - Internal walls, 34cm, U= 0.91 (W/m2.ºC) and: - Interior roof, 20cm U= 2.25 (W/m2.ºC).

It was impossible to identify if pillars and beams were isolated, so they were increased by 35% of the losses associated with the current envelope.

All situations of linear thermal bridges were identified and measured, and the simplifications provided for in the legislation were adopted. The methodology for this type of loss has changed from SCE-2006 to SCE-2013, with the latter increasing losses through these elements.

The material of windows/openings frames are in aluminium, without thermal break, 4mm single colourless glass, with the following values of thermal transmission coefficient: - U= 3.9 W/m2.ºC, for windows with rotating system and external blinds; - U= 4.1 W/m2.ºC, for windows with sliding system and external blinds; - U= 6 W/m2.ºC, for windows with a fixed system, without blinds, and - U= 6.2 W/m2.ºC, for windows with swivel system, without blinds.

The ventilation was natural without any systems. The methodology for calculating ventilation significantly changed with SCE – 2013/2016/2020 (air changes per hour, RPH =0.99 h-1) compared with the SCE-2006 Methodology (RPH: 0.73 h-1). A spreadsheet developed by LNEC (National Civil Engineering Laboratory) was used.

Since it was impossible to know all the construction solutions, the average thermal inertia was considered using simplifications.

Energy Systems

As there weren´t heating and cooling systems, default systems and efficiencies were considered (electrical resistance for heating and air conditioning for cooling). The existing system in the house for DHW was a natural gas boiler with natural ventilation and power of 17.4KW. The water pipeline was considered without isolation. Solar collectors or other renewable energy systems were not considered.

3.2 Analysis and comparison of energy performance results and energy Certificate

The most relevant comparisons between the different methodologies are presented in this chapter. It should be noted that the SCE-2013 Methodology has changed significantly compared to the SCE-2006 Methodology. After that, the SCE-2016 and SCE-2020 Methodologies almost didn't change.

In winter (Heating Station), according to Fig.4, Total Energy Losses was reduced after the SCE-2013 Methodology. That is because the number of GD (Degree-days) (which reduced the losses by transmission and ventilation) and the air changes per hour, Rph parameter, (which reduced the losses by ventilation) were changed. Regarding Useful Heat Gains value, from the SCE-2013 onwards, there has been increasing. Internal Heat Gains decreased as the season months went from 8 to 7.3. But, although this value has decreased, the Solar Gains significantly increased because the radiation incident on glazing to the south (Gsul) went from 90 kWh/m2.month to 125 kWh/m2.month.

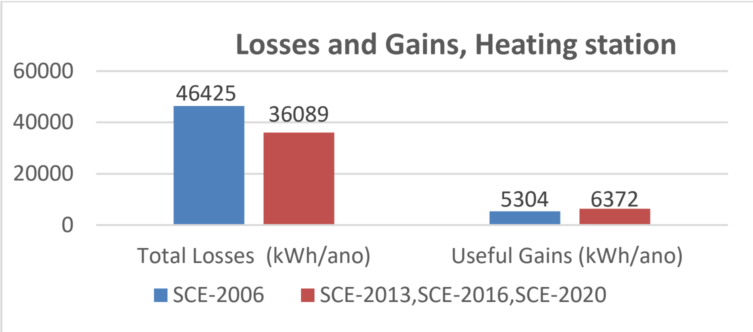

Fig. 4. Losses and Gains, Heating Station.

Regarding the summer (Cooling Station), analyzing Fig.5, the Total Heat Losses are more significant from the SCE-2013 onwards. Although the Rph parameter has decreased and the average outdoor summer temperature has gone from 19ºC to 21.4ºC, the losses caused by the elements in contact with the ground and by the interior envelope are accounted for are relevant in this example. The Solar Gains by the opaque envelope also increased significantly due not only to the increase in the values of the Intensity of solar radiation but essentially due to the accounting of the interior coverage.

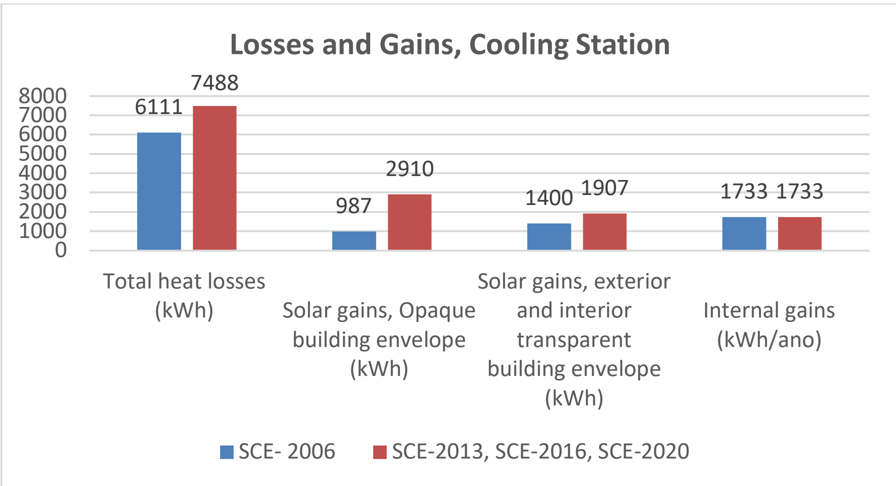

Fig. 5. Losses and Gains, Cooling station.

In summary, table 3 shows the values of: - Nominal Useful Energy required for Heating (Nic) and Nominal Useful Energy required for Heating of Reference (Ni); - Nominal Useful Energy required for Cooling (Nvc) and Nominal Useful Energy required for Cooling of Reference (Nv).

Table 3. Energy Needs for Heating and Cooling.

	SCE- 2006	SCE-2013	SCE-2016	SCE-2020
Nic (kWh/m2.year)	277,85	200,74	200,74	200,74
Ni (kWh/m2.year)	125,60	101,98	82,12	90,06
Nic/Ni	**2,21**	**1,97**	**2,44**	**2,23**
Nvc (kWh/m2.year)	4,29	10,24	10,24	10,24
Nc (kWh/m2.year)	18	10,6	10,6	10,6
Nvc/Nv	**0,24**	**0,97**	**0,97**	**0,97**

From the SCE-2013 onwards, a decrease in the value of Nic has been observed. This is because the solar gains of the Building are much higher than the Reference Building. The ratio between Nvc and Nv is close to unity from the SCE-2013 onwards.

Concerning the Nominal Useful Energy required for Heating Domestic Hot Water (Qa/Ap), as we can see in table 4, since SCE-2013, there has been a decrease in its value because the required temperature has gone from 60ºC to 50ºC.

Table 4. Energy Need for Heating Domestic Hot Water.

	SCE- 2006	SCE-2013	SCE-2016	SCE-2020
Qa/Ap (kWh/m2.ano)	30,98	24,09	24,09	24,09

Table 5 presents the energy classes referring to the different methodologies. The energy class is obtained from the ratio between Nominal Primary Energy Needs and its Reference value (Ntc/Nt). Although the SCE-2013, 2016 and 2020 methodologies are similar, there are differences in values and reference formulas adjusted over the years and which cause different energy classes. The difference between the SCE-2006 and SCE-2013 methodologies is not reflected in the Energy Class. Despite the differences in various parameters and calculation indices, as detailed above, the overall balance between thermal losses and gains is reflected in the same class, in this specific building.

The table also shows the value of CO2 emissions. We can observe an increase in its value from the SCE-2013 onwards, due to the different calculation methodologies of this parameter.

Table 5. Classes and CO2 Emissions.

	SCE- 2006	SCE-2013	SCE-2016	SCE-2020
Ntc/Nt	1,9	2,0	2,4	2,2
ENERGY CLASS	D	D	E	E
CO2 (t/year)	2,6	12,5	12,5	12,5

Regarding the CE, the SCE-2013 brought some changes in terms of its structure and information, with the objective of facilitating its interpretation, which resulted in a clear separation of information intended for the consumer and the professional. For the consumer, the changes are essentially related to the simplification of information and the incorporation of performance benchmarks, with a more appealing layout.

4 Conclusion

The SCE-2006 Methodology has undergone substantial changes compared to the SCE-2013/2016/2020 Methodologies. In addition to the methodological aspects, there are relevant differences regarding climate data, demonstrating an increase in temperatures tabulated from SCE-2013 onwards.

For the climate zone in question (I3-V2), to which Bragança belongs, these differences have an impact mainly on the level of heating energy needs (Nic), with the SCE-2013 obtaining a much lower value. However, this is not the reason why this station is no longer a concern in terms of verifying energy requirements, as the reference value (Ni) also has lower values.

About summer station, from SCE-2013 onwards, significantly higher values of useful energy requirements for cooling are recorded. The Nvc/Nv ratio tends to approach unity.

Relating to DHW, the required temperature has gone from 60ºC (SCE-2006) to 50ºC (from SCE-2013), which makes the energy requirements have lower values after SCE-2013.

The comparison with the reference building (which only came into existence after the 2013-SCE) is advantageous, as it allows for a better focus on opportunities for improving the real building. The introduction of reference values in the CE information is also practical to compare with the values of the real building.

In summary, as of SCE-2013, in total primary energy, the weight of energy needs for heating and cooling has increased, and the weight of energy for hot water production has decreased. This change is positive and more adapted to the natural energy consumption of buildings in the climatic zone analyzed in this study. Furthermore, the fact that the winter comfort temperature has been reduced from 20ºC to 18ºC (changing GD value) allows a better comparison with reality use and a better understanding about the improvement measures constant in the CEs.

Improvement measures play an essential role to guide owners in interventions. CEs are important information vehicles for these interventions. In addition, the information contained in the CE is used so that buyers or tenants can compare homes. Over the last ten years of mandatory certification of existing buildings, there have been constant changes in the methodologies applied, which have resulted in different values of energy indices, including different energy classes, which makes it difficult for owners to perceive the different certificates and their comparison for buying or renting a house. Although the CEs contain information regarding the applied methodologies, it is essential to clarify the owners and users about these differences. In addition, the constant changes in legislation do the work of those involved, especially the PQs, more time consuming due to the constant need for updating.

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