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ARTICLE

Qualitative Comparison between the Brazilian Labeling Program for Buildings and the Portuguese Energy Certification System for Buildings: Proposals for Improving Brazilian Regulations

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ABSTRACT

Buildings represent a significant share of the world's energy consumption, and the sector has drawn the attention of governments, which have adopted policies to reduce energy expenditure. The Certifications of Energy Efficiency in Buildings stand out as one possible solution to achieve this goal, employed in several countries worldwide. The European Union presents advanced energy assessment programs for buildings, being a reference and model for several other regulations in the world. The Energy Certification System for Buildings (SCE) of Portugal is considered a success case, reflected in the significant number of energy certificates issued. The Brazilian Labeling Program for Building (PBE Edifica), first launched in 2009, does not find a broad application today in the Brazilian scenario. This work shows a synthesis of the European Energy Performance of Buildings Directive (EPBD) and the Brazilian and Portuguese regulations' history. A qualitative comparison is made between the SCE and the PBE Edifica to verify a European and a developing country's regulations with a certain degree of cultural and climatic similarities. Through this comparison, proposals are made for improvements to Brazilian certification, seeking to improve its energy planning and energy policy concerning its building stock. The suggestions for improvement presented may also be appropriate for other developing countries that have started and have not yet successfully implemented their energy certification programs in buildings.

KEYWORDS

Energy efficiency; energy policy; building labeling; energy certification; improvement proposals

1 Introduction

Residential and service buildings account for 34% of total world energy consumption and almost half of the total electricity consumption [1]. In the European Union (EU), they account for 40% of energy consumption and 36% of CO_2 emissions [2]. In 2019, Brazil consumed 545.6 TWh of electricity, with buildings accounting for 52% of this consumption, the residential sector accounting for 26.1%, the commercial buildings accounting for 17.4%, and the public sector accounting for 8.5% [3].

With the worldwide increase in electricity consumption, which is essential for our daily lives, there is a need to expand electricity generation and supply. Two solutions that can be considered ideal and possible are generating more energy in an efficient and environmentally correct way or reducing consumption while preserving natural resources [4].

Efficient buildings, lifestyle changes, and population consumption patterns can reduce climate changes in the short and medium-term [5]. Most buildings increase their operating costs by disregarding the criteria of bioclimatic architecture, from building design to end-use, materials, equipment, and construction technologies, focusing on energy efficiency [6].

According to [7], energy efficiency in architecture can be understood as an inherent attribute of the building, representing its potential to provide thermal, visual, and acoustic comfort to users with low energy consumption. Therefore, one building is more energy-efficient than another when it provides the same environmental conditions with lower energy consumption.

A 30% reduction in electricity consumption is estimated in buildings that upgrade energy efficiency concepts and up to 50% for new buildings that consider energy-efficient alternatives from the design phase [8]. It is essential to highlight that the pursuit of energy efficiency in buildings is not related to energy restriction but instead to the best way to use it, obtaining adequate thermal and environmental comfort levels.

According to [9], "The concept of Energy Efficiency cannot be understood as a static methodology, but as an evolutionary process where there is no milestone to be achieved, but a constant search for increasingly energy-efficient processes and products." This definition perfectly fits building energy efficiency certifications since updating the regulations should always accompany previously established implementations.

With the current scenario of global building energy consumption and, above all, the advantages of implementing policies aimed at energy efficiency, several countries have applied and developed certification procedures for buildings [10]. Of the world's energy assessment programs for buildings, the Portuguese program one of the most widely propagated and used certifications; it shows relevant features such as suggestions for improvements to improve the building energy performance and access to information and services related to accreditation [11].

This paper aims to do a brief synthesis of the EPBD and the history of Portuguese and Brazilian regulations on buildings' energy performance, make a comparison between the current regulations in Portugal and Brazil, and offer some proposals to improve the Brazilian Labeling Program for Buildings based on the successful practical implementation of the Portuguese Energy Certification System for Buildings.

To achieve the proposed objectives, buildings' regulatory structures and energy policies in the European Union, focusing on Portugal and Brazil was thoroughly investigated. The energy certification process for buildings was compared with the inputs and output parameters, and the differences were exposed. Finally, Brazilian regulatory policy proposals were made based on Portuguese regulation, taking care of structural differences, and pointing out each fundamental aspect to be questioned and revised in Brazilian ordinances.

The comparison between the labeling programs of both countries is focused on the programs' structural and regulatory bases, aiming at changing the political-structural application of energy certification. The study of technical issues, such as comparisons of methods and individual certification results, would lead to another type of research, out of the scope of this work.

2 Energy Efficiency Certifications in the European Union

Over the last three decades, industrialized and developing countries have promoted policies to encourage reduced energy consumption in buildings. Most of these policies can be grouped into three

categories, economic incentives (through taxes and energy prices), information programs (energy awareness campaigns and energy audits), or regulatory requirements (codes or certifications) [12].

The Council of the European Union established, in March 2007, an action plan to contribute to the three objectives of the Energy Policy for Europe (EPE) to be achieved by 2020, which are: a reduction of at least 20% of emissions of greenhouse gases, compared to 1990; the need to increase energy efficiency in the EU to achieve the goal of saving 20% of EU energy consumption, compared to projections for 2020, according to Commission estimates; 20% renewable energy target concerning total energy consumption in the EU [13].

As pointed before, buildings in the EU account for 40% of energy consumption and 36% of CO_2 emissions, thus having great potential for energy efficiency measures. Reducing energy consumption in European buildings by 30% would decrease total energy consumption in Europe by 11%, more than half of one of the 20-20-20 targets [2].

In 2002, Directive 2002/91/EC [14] on building energy performance was launched to improve energy efficiency in the building sector by requiring that the methodologies be implemented in the EU using codes and regulatory measures. The document required all member states to adopt their regulatory requirements by early 2006.

Experts and politicians have assessed that the EU's goal of reducing energy use in buildings by 30% by 2020 could not be met through the 2002 Directive. To achieve this goal, the share of existing buildings was more significant than that of new buildings. Directive 2002/91/EC established that only existing buildings with more than 1000 m^2 would meet the latest regulatory requirements, representing only 29% of the European building stock. Then, stricter objectives were needed to reach this goal [2,14].

In 2008, it was proposed by the European Commission and approved by the European Parliament, a revision of Directive 2002/91/EC with substantial changes and a recast of commitment. In 2010, Directive 2010/31/EU [15] was issued, which extended the 2002 Directive scope, abolishing the limitation of requiring renovations only for large buildings. Member States were to implement the new Directive within two years.

The recast requires buildings built after 2020 to meet the Nearly Zero Energy Building (nZEB) concept. That means a building with very high energy performance and the very low amount of energy required should be covered by energy from renewable sources produced on-site or nearby. Public buildings must meet this requirement after 2018 [15].

In November 2016, the European Commission published a package of measures to maintain the EU's competitiveness [16] as the transition to clean energy changes global energy markets. The Commission wants the EU to lead the transition to clean energy and not only adapt to this energy source. In this way, the EU has committed itself to reduce CO_2 emissions by at least 40% by 2030, simultaneously modernizing the economy and generating employment and prosperity for all European citizens. The proposed package has three main objectives: to prioritize energy efficiency, take global leadership in renewable energy, and establish a level playing field for consumers.

The Directive 2018/844 [17] amends the Directive 2010/31/EU. The EU establishes ambitious commitments to further reduce greenhouse gas emissions by at least 40% by 2030 compared with 1990 to increase the proportion of renewable energy consumed. The EU is committed to developing a sustainable, competitive, secure, and decarbonized energy system by 2050. Considering that almost 50% of the EU's final energy consumption is used for heating and cooling, of which 80% is used in buildings, the achievement of the Union's energy and climate goals is linked to the Union's efforts to renovate and decarbonize its building stock.

3 Portuguese Energy Certification System for Buildings

To comply with the requirements of Directive 2002/91/EC [14], Portugal approved the National System for Energy Certification and Indoor Air Quality in Buildings, by Decree-Law No. 78/2006 [18]; the Regulation of Energy Systems for Climatization in Buildings, through Decree-Law No. 79/2006 [19]; and the Regulation of Characteristics of Thermal Behaviour of Buildings, with Decree-Law No. 80/2006 [20].

Applying the provisions of these Decree-Laws, Portugal promoted energy efficiency in buildings. It acquired relevant experience that translated into energy certification system effectiveness and the diagnosis of evaluative aspects, verifying in practice the possibility of improving the certification system [21].

By Directive 2010/31/EU [15], the European Parliament reformulated the regulation established by Directive 2002/91/EC, clarifying specific points and introducing new provisions that reinforce the promotion of energy performance in buildings, aiming at the targets and challenges agreed to by the Member States for the year 2020 [21].

On 13 November 2013, Portugal published Decree-Law No. 118/2013 [21], which ensured not only the amendment to comply with Directive 2010/31/EU, but also the revision of previous legislation, with Decree-Law No. 78/2006, No. 79/2006 and No. 80/2006, including in a single document the Energy Certification System of Buildings (SCE), the Housing Performance Energy Regulation (REH), and the Energy Performance Regulation of Commercial Buildings and Services (RECS).

A clear distinction was made between the REH scope, with guidelines for residential buildings, and the RECS, determining requirements for trade and service buildings. Residential buildings are evaluated by the thermal behavior and efficiency of technical systems such as air conditioning, water heating, lighting, and renewable energy use. For commercial and service buildings, requirements are added concerning installing, operation, and maintaining technical systems [21].

In the SCE updating, international guidelines and practices were incorporated based on technological innovations in energy efficiency and thermal comfort. The performance of different professionals and entities are detailed, aiming at more significant and better integration of all agents in the context of rigor and requirement [21].

4 Brazilian Labeling Program for Buildings

In 1984 the National Institute of Metrology, Quality, and Technology (INMETRO) started a discussion with Brazilian society on creating conformity assessment programs focused on energy performance. It was the first step to reach what is now known as the Brazilian Labeling Program (*Programa Brasileiro de Etiquetagem*—PBE) [8].

Brazil suffered an energy crisis at the beginning of the 21st century due to the scarcity of rainfall, which hindered the hydroelectric plants' full operation and did not count on enough alternative sources for energy generation [22]. In response, the Brazilian government published Law No. 10,295 [23] on 17 October 2001, known as the Energy Efficiency Law, which is regulated by Decree No. 4,059 [24] on 19 December 2001. These documents provided legal reinforcement for the energy evaluation programs linked to the PBE, which were in different implementation phases, some with compulsory labeling and others seeking to become obligatory.

In 2003, the National Program for the Conservation of Electric Energy (Procel) developed a subprogram specifically directed to buildings, *Procel Edifica*. In 2005, Procel was appointed responsible for the Buildings Technical Secretary to discuss technical issues involving energy efficiency indicators. The following year, INMETRO created the Technical Commission that defined the criteria for obtaining the National Energy Conservation Label (ENCE) for buildings [8]. Currently, ENCE has five levels of energy classification, A (more efficient), B, C, D, and E (less efficient) [25].

The PBE Edifica regulations are the Technical Requirements for the Energy Efficiency Level of Commercial Buildings, Services and Public Buildings (RTQ-C) [26], the Technical Qualities of the Quality of Energy Efficiency Level of Residential Buildings (RTQ-R) [27], and the Requirements for Conformity Assessment of the Energy Efficiency Level of Buildings (RAC) [25].

Labeling buildings allows consumers to know the property's energy efficiency level, becoming an important decision-making tool in purchasing or renting a property, in addition to promoting the search for more efficient buildings and reducing electricity consumption. It is a fundamental instrument for the Brazilian government to analyze buildings' energy performance and improve programs and regulations to promote energy efficiency in buildings [28].

In Normative Instruction No. 02 of 2014 of the Ministry of Planning, Budget and Management (MPOG), the rules for using ENCE in new or retrofitted federal public buildings are defined. New buildings must have a general ENCE class A, and retrofit works must be done to obtain a partial ENCE class A for the reformed item, except for specific cases of non-feasibility [29].

In addition to federal public buildings, other categories may become subject to mandatory labeling. According to the National Energy Efficiency Plan (PNEf), published in 2011, the regulations should make ENCE compulsory for other public buildings over a 10-year horizon, commercial and service buildings in 15 years, and residential buildings in 20 years [30].

Since 2012, an agreement has been created between Brazil and Portugal for labeling in buildings since the Agency for Energy of Portugal (ADENE) has a practical, recognized worldwide knowledge in implementing energy certification in buildings, which can benefit the development and growth of the Brazilian program [31].

Since 2014, Procel Edifica and the Brazilian Centre for Energy Efficiency in Buildings have planned a change in the PBE Edifica evaluation method. The new version of the regulations was scheduled to be launched in mid-2018 (but not started yet and with no exact forecast for launch), and will have as its main change the presentation of the building's primary energy consumption, as happens in Portugal and several European Union countries [32].

5 Comparison between PBE Edifica and SCE

5.1 Eligibility of Comparative Choice

The choice of Portugal as a comparison for Brazil's building labeling program was based on the following factors:

- Several countries have used the European Directives 2002/91/EC and 2010/31/EU as a reference to create or update their energy efficiency certifications for buildings, showing how Europe established itself as an authority on the subject [2];
- In the study published by Concerted Action EPDB [33], the following points were highlighted concerning energy certificates: the role of the State in promoting energy certification, display of energy certificates, and making the energy certificate more user-friendly to the general public. Portugal presents solutions and is cited as an example;
- Portugal is the leader in the absolute number of certificates issued in the EU, and among the largest in relative numbers, according to the database of the EU Building Stock Observatory [34];
- Among European countries, Portugal has greater climate comparability to Brazil concerning the others, in addition to the historical-cultural proximity that can determine behaviors.

Although both countries have similarities, such as those highlighted above, there are significant quantitative differences, such as the territorial and population dimension. While Brazil has 8,516,000 km² and an estimated 210 million inhabitants [35], Portugal has 92,212 km² and an estimated 10.3 million inhabitants [36].

The comparison follows the supply chain of issuing certificates, include as input parameters of the policy instrument for the emission of buildings energy labeling: Scope of regulation, building requirements, nature of regulation, certifiers, certificate content, and supportive measures. It is exhibited as output parameters, the number of buildings certified, and the number of professionals qualified.

5.2 Input Parameters

In both countries, the scope of regulation is aimed at new and existing buildings; however, with some crucial differences. Although Brazilian certification makes no distinction between new and existing buildings, Portuguese law has different regulatory requirements, and existing building certification is an essential tool for identifying and promoting energy improvement measures [21].

The PBE Edifica does not establish minimum indices or reference energy classes for the building requirements, except for federal public buildings, which must have a level A certificate [29]. In contrast, the calculation of the energy classes in the SCE is made by the relationship between the building's consumption evaluated by a reference consumption, minimum percentage indices, and reference energy classes [21].

The nature of regulation presents a fundamental difference in this comparison. PBE Edifica, since its launch in 2009, has been volunteering for almost all buildings. The only exception is federal public buildings, which from 2012, have been required to present ENCE level A for new buildings and renovations [29]. In Portugal, labeling is mandatory for all buildings covered by the SCE: New buildings, existing buildings subject to intervention, large commercial and service buildings, public buildings, and existing buildings for sale and rent contracts [21].

Another determining point in the parallel drawn between both regulations is the role of the certifier. For the issuance of energy certificates in Brazil, it is necessary to resort to an Accredited Inspection Body (*Organismo de Inspeção Acreditado*—OIA), a legal entity composed of engineering and architecture professionals [25]. In Portugal, the expedition is carried out by a Qualified Expert (PQ), an engineer approved by ADENE [37].

PBE Edifica energy certificate has only one-page information on prerequisite compliance and partial and general ratings evaluation of the assessed items [25]; Fig. 1 shows an ENCE example. In contrast, the SCE energy certificate has the first page with the evaluation of the systems performance indicators with percentage comparison with the reference values of each; energy class evaluated with the minimum reglementary exigencies and comparative percentages to the reference condition; and information on renewable energy and CO_2 emissions, as shown in Fig. 2. It presents additional pages with concise data for the end consumer and proposals for improvements identified by the PQ and technical details of the systems evaluated in the building [38].

PBE Edifica has only specific incentives through credit lines for micro, small, and medium enterprises for the tourism sector [39]. In Portugal, there are incentives at national and municipal levels for buildings with higher energy ratings or implementation of improvement measures identified by the PQ in the Energy Certificate [40].

5.3 Output Parameters

Tab. 1 presents the total number of certificates issued by the PBE Edifica [41] and SCE [42], from the beginning of certification to the present day. PBE Edifica started labeling in 2009, and SCE started building certification in 2006. The number of Brazilian housing buildings certificates considers the three different kinds that can be found by the regulation: Autonomous housing units (5,460), multifamily buildings (615), and areas of collective use (20), while the SCE number consider just individual units for the certification. It can be observed in the higher number of residential buildings certificated compared with commercial, service, and public buildings in both countries.

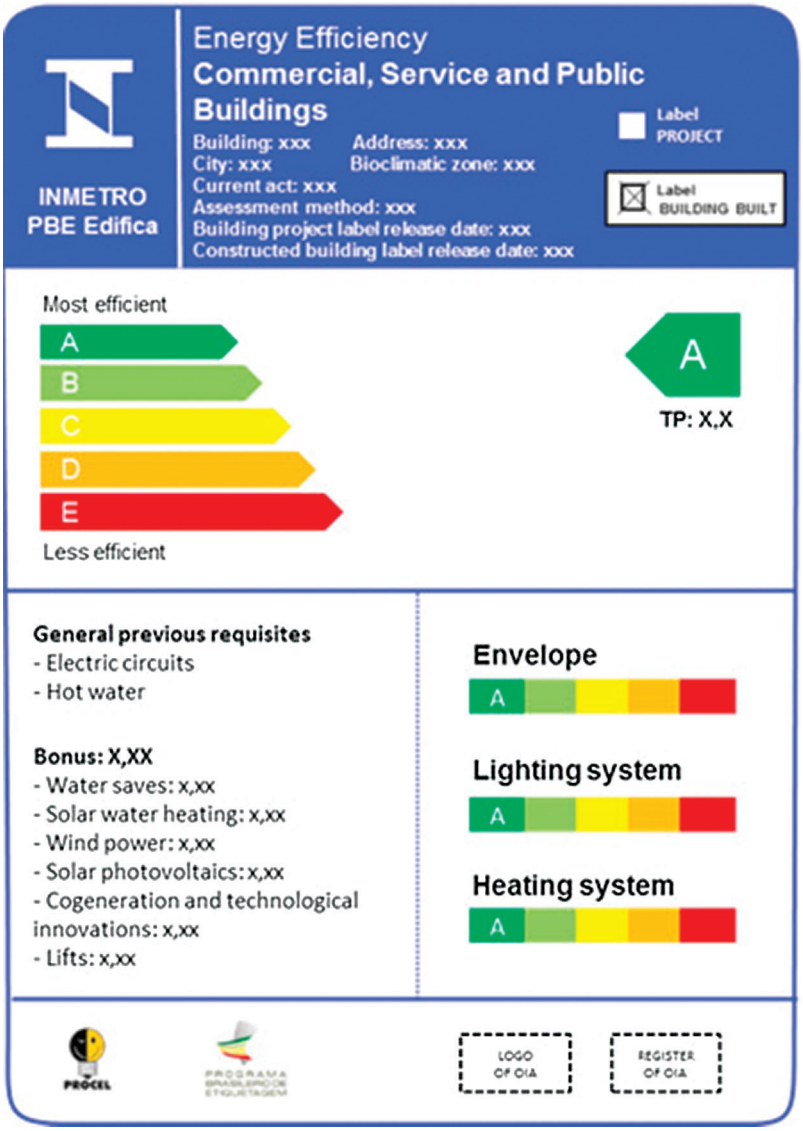

Figure 1: Example of the Brazilian National Energy Conservation Label for Buildings [43]

Comparing the absolute number of certificates issued by Portugal and Brazil, it is found that the number of Portuguese labels is about 205 times higher than the Brazilian ones. For the issuance of energy certificates, there are currently only 3 OIA accredited for certification in Brazil [44], while in Portugal, the SCE has 1,615 PQ qualified for accreditation [45].

6 Proposed Improvements for PBE Edifica

6.1 Modifying the Process for Issuing the Certification

An OIA is a public or private legal entity recognized by INMETRO, which must have at least one civil engineer or architect. Furthermore, if it is accredited for specific evaluation and inspection of lighting and HVAC systems, an electrical and mechanical engineer is needed, respectively. Therefore, to obtain general ENCE, the OIA must have at least three different professionals with higher education registered in the class council.

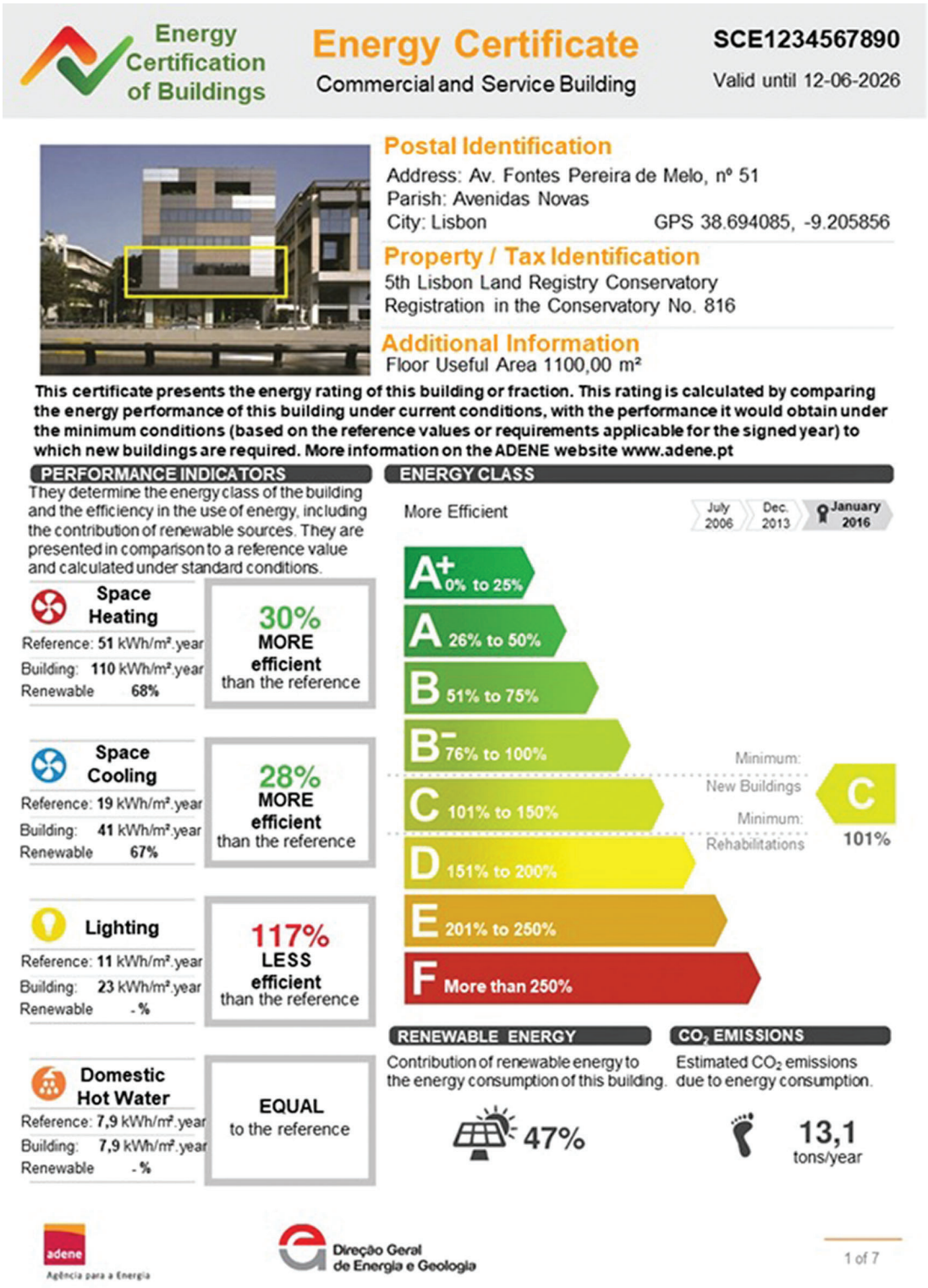

Figure 2: Example of the first page of the Portuguese Energy Certificate for Buildings (translated to English by the authors). Adapted from [38]

Table 1: Number of Labels Issued by PBE Edifica and SCE [41,42]

Building typology	PBE Edifica	SCE
Housing buildings	6,095	1,150,319
Commercial, service, and public buildings	250	155,953
Total	6,345	1,306,272

In Portugal, obtaining the Energy Certificate is performed by qualified experts who, to carry out the activity, must have graduated in engineering or architecture and have at least five years of professional experience and a training course with subsequent approval in an examination applied by ADENE. The experts are called PQ-I and PQ-II and are responsible for the certification of residential and commercial buildings, respectively. The professionals qualified for registration as PQ-I are architects, civil engineers, mechanical engineers, electrical engineers, and energy engineers. Meanwhile, mechanical, electrical, or energy engineers are required for registration as PQ-II [37].

As PBE Edifica requires specific formation professionals to evaluate and inspect particular systems, it can be considered more careful and detailed in its ENCE issuing method. This fact seems to be, in reality, an obstacle to the increase in the number of entities and professionals qualified for labeling. The designation PQ-I and PQ-II, as regulated in Portugal, could be considered by PBE Edifica, which would continue to have professionals with specific formation to evaluate and inspect systems such as lighting and air conditioning. With this solution, ENCE issuance can be facilitated without reducing the requirements of vocational training.

Another point that could change would be the reduction of bureaucracy concerning those responsible for labeling buildings. The compulsory constitution of a legal entity under public or private law could be released to liberal professionals with registration in the class council and passing a specific exam. The exchange of OIAs by PQs will make it possible to increase the number of persons responsible for issuing ENCE without compromising the quality and specificity of the process. Besides, the bureaucratic steps to obtain ENCE will be reduced.

6.2 Assessment and Distinction of New and Existing Buildings

The success of the SCE is mainly due to the evaluation and differentiation between new and existing buildings, as can be seen in the data for the last six years of certification presented in Fig. 3. In the SCE, existing buildings are differentiated by those that are renovated and those that do not undergo renovation but must be labeled to comply with legal requirements for sale or rent.

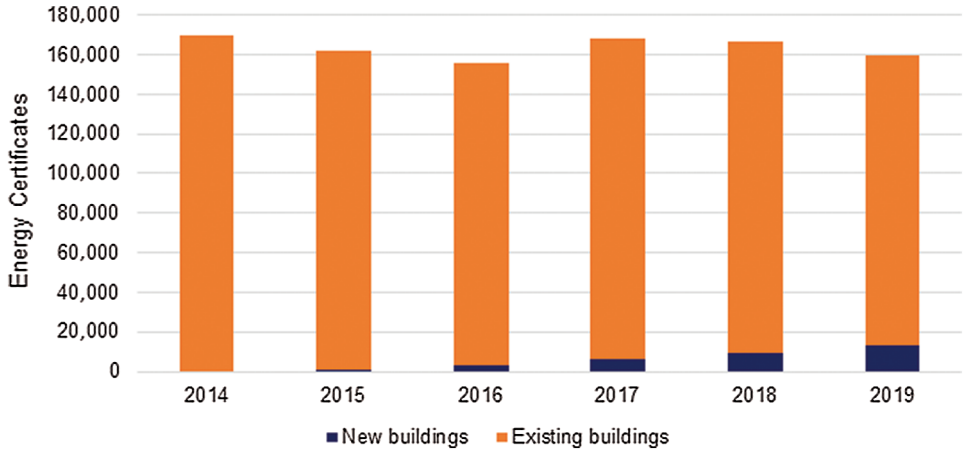

Figure 3: Portuguese Energy Certificates issued per year and by document type. Adapted from [42]

The PBE Edifica should distinguish between new and existing buildings subject to renovation. This measure would help increase the number of ENCEs issued and inform the consumer about the building's energy characteristics. However, for assessment and differentiation, the requirements must be applied to each type of building.

6.3 Setting Energy Threshold Values and Reference Classes

In the SCE, energy threshold values and reference classes are set with revised indexes every five years due to the introduction of new technologies and concepts in the energy and construction sectors. New, existing, and retrofitted buildings must comply with reference values related to percentages.

PBE Edifica, so far, does not present energy threshold values and reference classes. However, the project to update the building energy evaluation method already foresees changes, defining reference values [32]. Nevertheless, the document only defines the reference energy class for new buildings, not considering existing buildings subject to renovation. However, the differentiation between new and existing buildings would establish other, lower energy classes, like in the SCE.

6.4 Establishing Compulsory Labeling

The PBE Edifica, since its inception, is a voluntary labeling program, except for federal public buildings, which, since 2014, should present ENCE level A [29]. Other labeling programs linked to the PBE are already widespread and accepted by Brazilian consumers, such as labels on vehicles, refrigerators, air conditioners, and stoves. These programs are compulsory, and part of the success of energy labeling is due to this condition.

Fig. 4 shows the results related to the mandatory use of the PBE Edifica label through the research carried out by the CERTI foundation [46] with teachers, students, consultants, and professionals to identify the most significant challenges and opportunities regarding the labeling of buildings in Brazil.

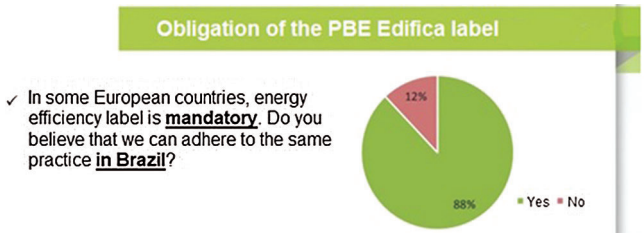

Figure 4: Results of the poll about the possibility of mandatory PBE Edifica labeling. Adapted from [46]

In 2011, the PNEf stated that labeling should be compulsory for other public buildings by 2021, commercial and service buildings by 2026, and residential buildings by 2031 [30]. The document presents an analysis of the future scenario aiming at mandatory labeling, but deadlines binding are not legally defined. Considering that these dates are still met, it would even take time for the program to earn the obligation of energy labeling. To establish mandatory labeling, a change in legislation is essential, with shorter projections than that established in PNEf.

6.5 Creating Incentives for Labeling

In addition to the compulsory requirement, tax incentives should also be evaluated by governments. These incentives would ensure adherence to the labeling program by the consumers, who would also benefit in the short run in addition to having a return on energy savings in the medium and long term. In the opinion of teachers, students, consultants, and professionals in the construction sector, obtained through the research carried out by the CERTI Foundation [46], it is challenging to increase the number

of buildings labeled in Brazil due to the lack of incentives. Other correlated aspects, such as more affordable prices for certification and financing, are cited, as shown in Fig. 5.

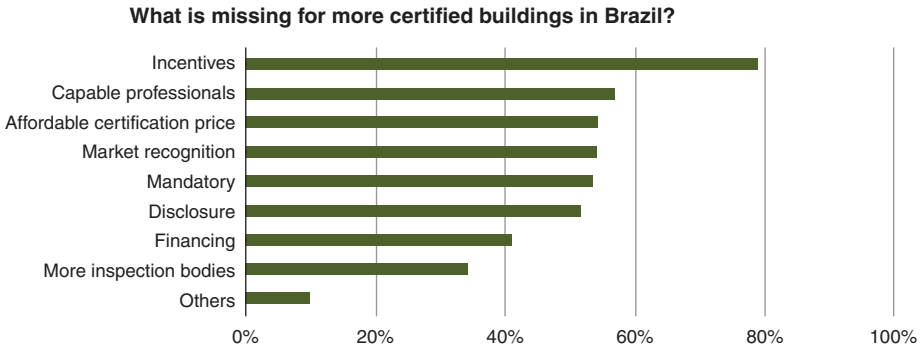

Figure 5: Possible reasons that hinder the labeling of buildings in Brazil. Adapted from [46]

As in Portugal's case, the Brazilian government could reduce or exempt the Urban Territorial Property Tax for existing buildings with ENCE, compensating the amount invested in the emission and not generating additional costs to the consumer, who would also know the energy consumption of the building. It could also contemplate subsidies for buildings with higher energy classifications, making new construction and retrofits aimed at a more efficient energy class.

6.6 Creating a Higher Energy Class

PBE Edifica requires several modifications to establish itself in the market and reach its essential purpose before including buildings with superior performance. However, creating a class for buildings with higher energy performance than the one established (Label class A) can aim at differentiated buildings in the real estate market.

PBE Edifica could reconcile introducing the nZEB concept with the creation of a higher energy class in its labeling program. This kind of measure could benefit the research and development of a precursor concept in the global construction sector related to energy consumption. Also, to benefit the real estate market that would offer customers a building with superior energy performance as attested by a national label and incorporate the search for government incentives directed to high-performance buildings, fostering the effort to obtain energy classification.

The SCE has the class A+ in its certificate; the PBE Edifica can similarly create and name a new energy class on its label, without modifying its structure with the current class divisions ranging from A up to E. In this new superior energy class, nZEB criteria can be implemented with an extensive energy supply reduction and an energy supply through renewable sources. Initial reflections on implementing the nZEB concept in the Brazilian context indicate great potential [47].

6.7 Availability of Information in the Label

The product of PBE Edifica is the ENCE, which presents the building energy performance in one page that shows the classification of the evaluated systems, the general classification, the fulfillment of the prerequisites, and the bonuses [25].

Besides presenting the energy consumption of the analyzed systems and the general classification, the Energy Certificate of the SCE has a series of detailed information for easy consultation by the users and technicians of the SCE, such as the consumption evaluated concerning the reference value, information on the contribution of renewable energies and CO_2 emissions, proposals for improvements to buildings

carried out by the PQ, losses and heat gains by the constructive elements of the residence, alternative versions of public display of the label and additional benefits obtainable through the means proposed by the PQ [38].

The consumption assessment concerning a reference value, the renewable energies contribution, CO_2 emissions, and detailed technical information is already included in the proposal for upgrading PBE Edifica [32]. However, suggested improvements to the building, alternative versions for public ENCE display, heat losses and gains in residence buildings, and additional benefits concerning the improvement proposals are not yet considered.

One of the main focuses of SCE's Energy Certificate is the proposed improvements to the building suggested by the PQ. The five most viable proposals identified by the professional are listed, aiming to improve the building's performance and energy rating and reduce energy costs. The suggestions range from replacing the building's construction components to replacing equipment or maintaining technical systems. The description of the suggested measure, the estimated cost of the investment, the estimated annual reduction of the energy bill, and the energy class that can be achieved after the improvement is applied are presented in each proposal suggested [21].

The SCE Energy Certificate for residential buildings illustrates the building's thermal performance in winter and summer, specifying which constructive elements contribute to the energy consumption related to air conditioning. The information facilitates the consumer's interpretation and knowledge of the building, besides providing data on the elements that require more attention in possible substitutions and reforms [21].

7 Conclusion

With the qualitative comparative analysis performed between the two energy certification programs for buildings through the input parameters, it was possible to elucidate the output parameters' data and present reasoned improvement proposals. The SCE is considered a success due to the Portuguese experience in applying its regulation [11], which is reflected in the number of labels issued. While Portugal has about 1.3 million Energy Certificates issued, PBE Edifica released just more than 6 thousand ENCEs.

The improvements proposed to PBE Edifica were made based on the differences found in this policy instrument's input parameters. However, a significant part of the proposed revisions cannot be individually analyzed because they are associated and interdependent. The Portuguese regulation is consolidated due to several synergistic factors, and each of the proposals presented contributed to its condition. If considered and implemented, the recommendations may help in the evolution of Brazilian regulation.

The verified acceptance of the SCE can help in reformulating the Brazilian regulation. However, the PBE Edifica should not merely copy the Portuguese structure or immediately implant all the suggestions proposed in this work. It is necessary to evaluate each recommended item carefully. Specific proposals will only work if correlated with others, such as the compulsory labeling, that has undoubtedly been fundamental to the number of certified buildings in Portugal, which will not be possible without modifying the ENCE process.

The product of the energy certification process is the label, which must be user friendly. The information presented is crucial in the energy certificate, mainly when informing through each analyzed system and the whole building relative to the reference levels. The presentation of possible individualized improvements proposed by the certifiers for each building is a strong point in the Portuguese Energy Certificate to improve the building sector's energy efficiency, not only in new buildings but mainly in existing ones.

As the Portuguese case, labeling incentives are also crucial in expanding labelings even with mandatory energy certification. They act as a stimulus to promote energy efficiency and help consumers to implement

improvements in their buildings with the reduction or removal of taxes proportionally, in addition to serving as an incentive for more ambitious proposals, such as the implementation of the nZEB concept.

The Brazilian Center for Energy Efficiency in Buildings is working on a proposal to update the PBE Edifica evaluation method. However, the public documents only mention the technical issues related to assessing buildings, with no political-structural changes in the labeling program, as proposed in this paper. The modification in the building's energy performance assessment will not be enough to expand, strengthen, and consolidate PBE Edifica. Therefore, political-structural matters must be considered by the responsible authorities and treated with the same relevance and importance as technical issues.

Developing countries must initiate, or in some cases, improve energy policies for buildings as soon as possible. The EU, through its Energy Performance of Buildings Directives, for more than a decade, has presented goals for reducing energy consumption and gas emissions, in addition to expanding the use of renewable energy sources and promoting the energy efficiency of its building stock. This political-structural experience can serve as an example in the (re)structuring of regulatory and energy policies in developing countries, which will expand their energy consumption in the coming decades.

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References

1. Key World Energy Statistics (2018). *International energy agency.* France: IEA.
2. Liu, F., Meyer, A. S., Hogan, J. F. (2010). *Mainstreaming building energy efficiency codes in developing countries*. Washington: The World Bank. DOI 10.1596/978-0-8213-8534-0.
3. Ministry of Mines and Energy (2020). *Brazilian energy balance—final report year 2019*. Rio de Janeiro: EPE.
4. Mazzaferro, L. (2015). *Analysis of the recommendations of ASHRAE 90.1 standard envelope for commercial buildings (Masters Dissertation)*. Brazil: Federal University of Santa Catarina.
5. Fossati, M. (2008). *Methodology for assessing the sustainability of building projects: The case of offices in Florianópolis (Ph.D. Thesis)*. Federal University of Santa Catarina, Brazil.
6. Assis, E. S., Pereira, E. M. D., Souza, R. V. G., Diniz, A. S. A. (2007). Social housing and energy efficiency: A prototype for Belo Horizonte's climate. *Proceedings of the II Brazilian Congress on Energy Efficiency,* pp. 1–7. IICBEE_ART173.
7. Lamberts, R., Dutra, L., Pereira, F. O. R. (2014). *Energy efficiency in architecture*. 3rd Edition. Rio de Janeiro: Eletrobrás/PROCEL.
8. PROCEL Info (2020). *PROCEL EDIFICA—Energy efficiency in buildings*. http://www.procelinfo.com.br. Accessed in July 2020.
9. Buges, N. L. (2014). *Applicability of the building label of the Brazilian labeling program in Mato Grosso do Sul (Masters Dissertation)*. Brazil: Federal University of Mato Grosso do Sul.
10. Carlo, J. C., Lamberts, R. (2010). Parameters and methods adopted in the energy efficiency regulation for buildings —Part 1: Prescriptive method. *Ambiente Construído, 10(2),* 7–26. DOI 10.1590/S1678-86212010000200001.
11. Telles, C. P. (2016). *Proposal to simplify the RTQ-R (Masters Dissertation)*. Brazil: Federal University of Viçosa.
12. Janda, K. (2009). Worldwide status of energy standards for buildings: A 2009 update. pp. 485–491. *ECEEE 2009 Summer Study Proceedings on Energy Efficiency.*
13. Council of the European Union (2007). *Presidency conclusions of the Brussels European Council—Brussels*. https://data.consilium.europa.eu/doc/document/ST-7224-2007-REV-1/en/pdf.

14. European Parliament, Council of the European Union European Commission (2003). Directive 2002/91/EC of 16 December 2002 on the energy performance of buildings. *Official Journal of the European Communities L1,* 65–71.
15. European Parliament, Council of the European Union (2010). Directive 2010/31/EU of 19 May 2010 on the energy performance of buildings (recast). *Official Journal of the European Union, L153,* 13–35.
16. European Commission (2016). *Communication from the Commission—clean energy for all Europeans-Brussels*. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52016DC0860.
17. Parliament, European, Council of the European Union European Commission (2018). Directive 2018/844 of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. *Official Journal of the European Union, L156,* 75–91.
18. Ministry of Economy and Innovation (2006). Decree-Law no 78/2006 of 4 April 2006. *Republic Diary of Portugal, 67,* 2411–2415.
19. Ministry of Public Works, Transport and Communications (2006). Decree-Law no 79/2006 of 4 April 2006. *Republic Diary of Portugal,* vol. 67, pp. 2416–2468.
20. Ministry of Public Works, Transport and Communications (2006). Decree-Law no 80/2006 of 4 April 2006. *Republic Diary of Portugal,* vol. 67, pp. 2468–2513.
21. Ministry of Economy and Employment (2013). Decree-Law no 118/2013 of 20 August 2013. *Republic Diary of Portugal,* vol. 118, pp. 4988–5005.
22. Bottamedi, M. G. (2011). *Energy efficiency assessment of four-star hotels in Florianópolis: application of the building labeling program (Masters Dissertation)*. Brazil: Federal University of Santa Catarina.
23. Federative Republic of Brazil (2001). Law no 10295 of 17 October 2001. *Official Diary of the Union, Section 1,* 1.
24. Federative Republic of Brazil (2001). Decree no 4059 of 19 December 2001. *Official Diary of the Union, Section 1*, 5.
25. Ministry of Development, Industry and Foreign Trade (2013). *Ordinance no 50 of 1 February 2013–Conformity Assessment Requirements for Energy Efficiency in Buildings*. http://www.inmetro.gov.br/legislacao/rtac/pdf/rtac001961.pdf.
26. Ministry of Development, Industry and Foreign Trade (2010). *Ordinance no 372 of 17 September 2010—Technical Quality Regulation for the Energy Efficiency Level of Commercial, Service and Public Buildings (RTQ-C)*. http://www.inmetro.gov.br/legislacao/rtac/pdf/RTAC001599.pdf.
27. Ministry of Development, Industry and Foreign Trade (2012). *Ordinance no 18 of 16 January 2012-Technical Quality Requirements for the Energy Efficiency Level of Residential Buildings (RTQ-R)*. http://www.inmetro.gov.br/legislacao/rtac/pdf/RTAC001788.pdf.
28. Eletrobras/Procel, INMETRO, CB3E (2013). *Introduction to the brazilian building labeling program*. http://www.procelinfo.com.br/services/DocumentManagement/FileDownload.EZTSvc.asp?DocumentID=%7BCF1A3743-CECB-48EF-B2CA-E2B4D4173337%7D&ServiceInstUID=%7B46764F02-4164-4748-9A41-C8E7309F80E1%7D.
29. Ministry of Planning, Budget and Management (2014). *Normative instruction no 2 of 4 June 2014*. https://portal.tcu.gov.br/lumis/portal/file/fileDownload.jsp?fileId=8A8182A2578C7A760157902EAEA7163E.
30. Ministry of Mines and Energy (2011). *National energy efficiency plan: Basic premises and guidelines*. http://www.mme.gov.br/documents/36208/469534/Plano+Nacional+Efici%C3%AAncia+Energ%C3%A9tica+%28PDF%29.pdf/899b8676-ebfd-c179-8e43-5ef5075954c2?version=1.0.
31. PROCEL INFO (2012). *International building labeling agreement*. http://www.procelinfo.com.br/main.asp?View=%7B8D1AC2E8-F790-4B7E-8DDD-CAF4CDD2BC34%7D&Team=¶ms=itemID=%7BBE7FF463-B84D-419F-A332-E6068F558150%7D;&UIPartUID=%7BD90F22DB-05D4-4644-A8F2-FAD4803C8898%7D#.
32. Brazilian Center for Energy Efficiency in Buildings (2018). *Proposed normative instruction for the energy efficiency class of residential buildings*. http://cb3e.ufsc.br/sites/default/files/2018-09-25-INI-R - Versão02.pdf.
33. Concerted Action EPBD (2015). *2016—Implementing the energy performance of buildings directive*. Lisbon: ADENE.

34. European Commission (2019). *EU building stock observatory database—Number of EPCs*. https://ec.europa.eu/energy/en/eu-buildings-database.
35. Brazilian Institute of Geography and Statistics (2020). *Projection of the population of Brazil and the Federation Units*. https://www.ibge.gov.br/apps/populacao/projecao/.
36. Statistics Portugal (2019). *Number of resident population by place of residence, sex and age group*. https://ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&contecto=pi&indOcorrCod=0008273&selTab=tab0.
37. ADENE(2019). *ADENE academy*. https://academia.adene.pt.
38. SCE (2019). *Energy certification of buildings—types of energy certificate*. https://www.sce.pt/certificacao-energetica-de-edificios/consumidores.
39. PBD Edifica (2018). *Incentives*. http://www.pbeedifica.com.br/incentivos.
40. SCE (2018). *Investors—how to obtain benefits and access incentives with the energy certificate*. https://www.sce.pt/certificacao-energetica-de-edificios/investidores.
41. INMETRO (2020). *Energy consumption/efficiency tables—Buildings*. http://www.inmetro.gov.br/consumidor/pbe/edificacoes.asp.
42. ADENE (2020). *Statistics of the energy certification system for buildings*. https://www.sce.pt/estatisticas.
43. Lopes, A. C. P., Filho, D. O., Altoe, L., Carlo, J. C., Lima, B. B. (2016). Energy efficiency labeling program for buildings in Brazil compared to the United States' and Portugal's. *Renewable and Sustainable Energy Reviews, 66,* 207–219. DOI 10.1016/j.rser.2016.07.033.
44. INMETRO (2020). *Inspection bodies energy efficiency in buildings—OIA-EEA*. http://www.inmetro.gov.br/organismos.
45. ADENE (2020). *Search by qualified experts*. https://www.sce.pt/pesquisa-de-tecnicos.
46. CERTI (2016). *Efficiency and sustainability—Main research results*. http://www.oi3e.org.br/img/pesquisa_oi3e.pdf.
47. Resende, J., Monzón-Chavarrías, M., Corvacho, H. (2020). The applicability of nearly/net zero energy residential buildings in Brazil—A study of a low standard dwelling in three different Brazilian climate zones. *Indoor and Built Environment, OnlineFirst,* 1–21. DOI 10.1177/1420326X20961156.