

Article

Labels' Standard Deviation in Energy Performance Certificates: Portuguese Housing

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ABSTRACT

Energy Performance Certificates (EPC) went from a solely bureaucratic process to a differentiating factor capable of raising a property's value. The regulation, as conceived, is thoroughly suitable for new buildings, given their characteristics and available information. Contrary to the aging building stock, which lacks documentation and construction evidence. Surveys demonstrate pressure on qualified assessors to deliver higher EPC labels. The assessor tends to increase the grade to the detriment of a more rigorous approach aligned with the regulatory guidelines, raising the property market value, and benefitting building owners. The research oversees 30 EPCs, strictly following the regulation criteria, and concluded a global (–)8.77% average against the official EPCs, representing (–)21.93% on a 250% scale, which should not change the (letter) grade, except when close to the threshold. The following tendency shows different behavior considering the “C” threshold, when above lowers by (–)7.70% and under that level and including increases by (–)34.37% on the same scale against official EPCs: mainly, upon the uncertainty of isolation presence on opaque façade elements. The study outcome unveils a defaulted regulation mechanism introduced in 2013 (and reset in 2021), the “Simplification Rules”, which intended to surpass the lack of technical information with a prudent judgment by assessors, but became a popular shortcut on existing buildings, representing 16/30 of the random research sample.

KEYWORDS: energy performance certificates; energy efficiency certificates; energy labels deviation; housing energy labels; energy efficiency; GHG emissions, real estate

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NOMENCLATURE

EPBD—Energy Performance of Buildings Directive recast 2018/844/EU
EPC—Energy Performance Certificate
EEA—European Environmental Agency
GHG—Green House Gas
RES—Renewable Energy Sources
EPM—Energy Production Mix
MS—Member State
NZEB—Nearly Zero Energy Buildings

PEB—Plus or Positive Energy Building

SCE—(Portuguese) National Energy Certification and Indoor Air Quality of Buildings Systems

ADENE—Portuguese Agency for Energy

INTRODUCTION

EU citizens recognize the impact of climate changes (78%) and are conscious of its consequences; although demanding action to protect the planet's ecosystems, biodiversity, and resources, few (33%) accept the necessary political justifications to increase taxes related to GHG (greenhouse gas) [1]. Consumer awareness prioritizes health and well-being, food safety, and security [2].

Nowadays, EU's efficiency requirements on building codes impose half of the consumption, when compared to buildings commissioned before the use of thermal insulation and after heavy-mass construction, by the mid-2010s represented almost half of the EU-25's building stock [3], namely:

- 49% in southern countries—Portugal with 54.32% [4];
- 48% in central and eastern countries; and
- 39% in northern and western countries.

At least two-thirds of the EU's existing buildings will prevail after 2050; therefore, a more extensive renovation must comply with international commitments and goals [5]. Following the main objective, EU policies should focus on market players' confidence in the long-term, spur investment, and progressively push up renovation rates in the EU. Currently, 48% of stakeholders favor further public financial support to improve energy standards for buildings. However, when private investment is considered, only 14% of stakeholders believe in renovation strategies, and 23% oppose EPCs as mandatory for enabling transactions.

Background

In 2013, the Portuguese Ministry of Economy and Employment published the third-generation legislation, Decree-Law 118/13 of 20 August 2013 [6], extending EPCs to rentals and foreclosures (1/12/2013). In addition, the legislation oversaw the consumption of each type of envelope element and technical system (thermal, ventilation, and SHW). It assessed the correct installation, operation, maintenance, and replacement, known as the Energy Performance and Efficiency of Housing Buildings Regulations (REH).

In 2015, the minimum threshold shifted from “B-” to “B” for new buildings and from “D” to “C” for extensive renovations. These requirements became mandatory from 1 January 2016, as part of the second stage of the 2013 Decree-law. It also included the basis for nearly zero-energy buildings (NZEB), mentioning the European Commission (EC) time frames but did not set consumption limits, only defined in 2019:

postponed by the Portuguese financial crisis and high-interest rates for investors.

On 1 July 2021, the fourth generation revoked the 2013 and 2015 versions, establishing new methods and assessor practices, reframing the on-site survey procedures, and data gathering. However, no experiences or data exist about its application.

The zero-energy building's observatory (ZEBRA) monitored low-energy building market adoption across Europe, collecting data and evidence for policy review and optimization. In 2020, surveyed European real estate agents, based on 2608 interviews: only 30% considered EPC reliable and valuable in assessing the properties' energy efficiency. The majority emphasized the unnecessary costs and bureaucracy, and 38% underlined the complexity in understanding buildings' energy performance. Nevertheless, 27% recognized the influence of labels on real estate value, and 14% highlighted a 2–3 month decrease in transaction time for properties with higher EPC labels.



Chart 1. ZEBRA 2020—Deliverable D3.1: The Impact of Energy Performance Certificates on property values and nearly Zero-Energy Buildings—Report for policy-makers [7].

A study performed by Rajkiewicz et al., 2016, stated the positive effect of a higher EPC label on property valorization in sales and rentals, Chart 1 [7]. On average, the first reaches 9.8% and the latter 4.8%. Spain comes to 27% on sales and 22% on rentals, followed by Austria, with 18% and 5.4%, respectively, and Slovakia's 16% on sales. The gap between sales and rentals is associated with lower investments in newly leased properties and tenants' energy bill liability. Moreover, the landowners' reluctance to maintain or apply the EPCs proposed measures, also valid for householders, is justified by the increasing demand (pre-COVID-19) and urban developers' low offer. In the same survey, the EPCs reached 56% as

a deciding factor recognized by housing-related energy costs (electricity, NG, heat, et cetera). Nevertheless, the most crucial factor was the location, with 99% favored by urban properties; the price came second at 98%, preferred by higher values; and, in third place, space/number of rooms, at 96%, followed by others.

The EPC assessment methods lack reliability, and is not circumscribed to Europe; as more countries develop and implement building's energy performance evaluation, cited topics tend to trigger responsible awareness [8].

Literature Review

Each EU member state (MS) contributes, with data, to frame the Union energy expenditure related to the building stock. At the same time, enriching a valuable database to follow data quality, future strategies designing, and craft policies for specific goals, as driven by Nearly Zero Energy Buildings (NZEB) and Positive Energy Buildings (PEB). Where the following outstand:

- The Building Stock Observatory (BSO) gathers the MS figures. However, not all countries share data, and the European Commission, its promoter, often reports reservations about the database's quality, jeopardizing its reliability.
- The ZEBRA 2020 was an observatory of eight partners from academia, research, and private consultancy to generate data and policy evaluation to support nZEBs market across Europe, nonetheless terminated in 2016.
- The Royal Institution of Chartered Surveyors (RICS), a Horizon 2020 project, pursues the energy efficiency and residential figures published by EPCs on building renovation.
- The ExCEED database, another Horizon 2020, is a funded project to collect information on building energy performance analysis: energy efficiency, CO₂, among others.
- All underline the importance of reliability and quality of EPCs to drive the future of EU buildings' energy efficiency.

Europe is vast and presents a wide diversity in culture, landscape, and climate. So does its building stock, following architectural trends, building typologies, residential distributions, construction approaches, running costs, real estate markets, and energy production mix: especially when under renovation. These factors raise questions about the data integrity, as well as discrepancies filed by each member state [9].

A study on the EU's energy assessment systems underlines the importance of monitoring the energy performance, planning, and updating buildings, but evokes reliability and trust issues, especially when it comes to increasing building upgrade rates. Suggests engagement with BIM technology, big data techniques, and building smart-readiness indicators to improve EPC reliability, affordability, and

comprehensiveness in applicant/owner improvement activities. It also states that such interrelations enable higher energy efficiency, indoor comfort, and air quality, resulting in higher building performance monitoring, energy planning, renovation rates, energy conservation, and sustainability [10].

A study focused on the Energy Performance Building Directive recast 2018/844/EU (EPBD) highlights its building upgrading potential but recognizes the lack of EPC improvement recommendations application and suggests complementary documents centered on tailored-made construction solutions [11].

The EPBD commits each MS to mitigate possible label deviations, understand the effects of the EPC in the short term, as guiding the real estate market operations, and in the long run, as addressing building stock renovation. The following cited studies frame the mentioned issues.

In Greece [12], researchers concluded that retrofitted thermal qualities achieved higher energy performance/savings, enabling the investment reimbursement and a higher EPC label. The researchers also stated the lack of consumption accuracy due to a vacancy of empirical data; however, studies highlighted the practical implementation as a positive shift. It also affirmed that EPC needs to increase reliability and data accuracy by adding statistics on households' tendency behavior and requested awareness to results calibration by adding probabilistic sensitivity analysis to quantify unbalanced parameters [13].

In Sweden, concerning data quality, researchers concluded that 15% of published EPCs showed different thermal areas between the prior (2012) and the updated model (2018), related to assessors' issuing methods. Moreover, they concluded that, due to a systemic error in the area estimation methodology, versions presented differences in 57% of the cases, which favors the former's savings by 7 kWh/m². Besides, researchers concluded that there is a risk in statistical data accuracy (e.g., financial) to propose specific update measures. Finally, they mentioned the contribution of those points to future policies and strategies [14].

In Ireland, a study on EPCs' labels accuracy revealed that default U values, assigned to the opaque envelope of existing or renovated buildings, lead to a primary energy cut of 22%, under the current thermal regulation version, and 70% before that [15]. Another survey pointed to potential buyers' favorable trustworthiness at the cognitive involvement level, recognizing the importance of EPCs when rating buildings' energy efficiency [16]. Another study approached the labeling reliability, in the same country, due to over-calculation when drawing closer to changing the letter label. It correlated this to house-owner pressure to overvalue the property, although it did not present evidence to support that conclusion (which the authors emphasize), as leverage to approve a planned renovation financially; or merely overvalue the property to serve the owners' interests. The team resorted to software to simulate verifiable

conditions and suggested a verification (post) EPC's emission to increase the system's reliability and independence from the participant interests [17].

In the UK, a survey on consumer EPC concluded a lack of relevance. The research points to technical incorrect data assumptions on the EPCs, where 36% show at least one error and 30% more than one. The team also assessed the open UK database between 2008 to 2016 and identified at least one error in 27% of EPCs, mainly due to assessors' misinterpretation of the opaque envelope solution, which led to overvaluing the U values, pushing rates up to four points, verified in 30% of the sample. That value is further true in flats and maisonettes (20% of England and Wales dwellings), mainly due to a lack of construction quality information and on-site inspection, leading to default attributions based on the official technical guidelines. Those deviations contribute to an increase in prices favoring landlords. However, the statement does not question the EPC system's reliability since it considers a five-point fluctuation in 95% of the cases and accepts oversight under quality assurance procedures [18]. Another survey reports that consumers' cognitive perception relates contemporary aesthetics with high-energy efficiency, undermining the system's trust even with lower EPCs labels [19].

In Norway, a market study concluded that EPCs' compulsory presence in real estate transactions does not change the property value, as existing premium dwellings did not devalue against higher efficiency-rated properties. Other constructive characteristics provided in advertising brochures overlap the EPCs labels, contouring the idea of the building's energy efficiency, and emphasizing tangible aspects, such as thermal insulation, heat pumps, solar panels, photovoltaics, or highly efficient appliances. As a result, Norwegian landlords resist updating their properties, leading to low investment rates in energy efficiency [20].

In the Netherlands, a survey differs from the Norwegian study above. After EPCs became mandatory in all market operations, higher labels enabled faster house sales by 7% to 12%, depending on the property specification [21].

In Italy's Lombardy region, researchers assessed twelve parameters of the EPC's database, software-based, and found that 95% of the sample demonstrated a deviation of 3% between the declared heat demand indicator and predicted values [22].

In Switzerland, a survey on EPCs' energy performance error found that the lower classifications, on average, show less energy consumption than achieved by the simulation: $G < 40.4\%$; $F < 24.3\%$; $E < 15.4\%$; and $D < 5.22\%$. The middle range presents the opposite tendency: $C > 3.57\%$, and $B > 12.5\%$. Nevertheless, the A-labels follow a lower classification pattern, $A < 6.19\%$. The researchers related the A-label alignment with the lower grades of the reduced EPCs sample on buildings with higher performance than others [23].

The Building Performance Institute of Europe's (BPIE) survey reports findings related to EPCs' low-quality data. Some countries raise

reputational issues among consumers, undermining the system's reliability, pointing to inadequate legal frameworks and overly bureaucratic procedures [24].

EPCs, as surveyed by the [24,25] are a reliable tool to measure building energy efficiency. The BPIE frequently assesses the national systems, and throughout its short existence, it has recommended critical improvements and appraisals of its procedures to ensure data quality, in general. All to comply with the EPBD requirements and provide credible data to real estate markets, exploiting the capabilities of EPCs to track buildings' energy performance and measure renovation outcomes. More importantly, to guide future directives, including framing buildings' energy efficiency on construction elements and solutions assessment, sort, and label with improved accuracy, the BPIE:

- Establishes an independent EPC validation system (art. 18) [26];
- Ensures assessors the competencies to proceed with accreditation (art. 17) [26];
- Introduces penalties for non-compliance from EPCs weak quality data (art. 27) [26]; and,
- Enforces EPCs on sale and rental transactions and allows energy label advertising [27].

From the BPIE perspective, the assessors' training and competencies are critical factors to ensure EPCs' quality data [24]. However, national bodies are responsible for planning, training, and accredit, while guaranteeing the assessors' capacity to work in MS: 20 out of 28 run compulsory exams to validate the assessors' skills and take the best practice to support evaluation reliability. However, uniquely fourteen MS require assessor specific training, the others only for inexperienced professionals. Nevertheless, a growing number of MS are pushing for training updates and license renovations, following EC directives and recommendations, as enforced on 9 January 2013, by the EPBD, published on 19 December 2012. The "Energy performance certificates across the EU—A mapping of national approaches" mentions the Portuguese system's reliability for EPC data quality validation through a random selection system [26]. The report also states that 11 MS ran software to pre-check the data to validate its quality before submitting it to the EPCs' centralized databank. Eight members penalize assessors when detecting incongruent data by taking points from the professional license or through public CV records managed on the national bodies' web platforms. Almost all EU countries adjusted their legislation to prevent fraudulent EPC data via penalties, with twelve considering pecuniary fees. Still, the assessor's fines are minor compared to tenant and owners gains on market transactions [27].

A recent study highlights the discrepancy between actual consumption and EPC figures by following the consumers' behavior related to housing heating systems. It also introduces an optimal consumption concept to

rank the causes and mitigation strategies needed to reduce the energy performance gap. Furthermore, it points to the EPC energy consumption calculation. It suggests correcting standardized values under new calculation methods and actual data crossing and using methods to ensure monitoring and maintenance to frame the optimal consumption [28]. Mahdavi et al., 2021, ran the factors that enabled the energy performance gap and attributed the inaccuracy of building physical modeling (35%) to the significant contribution from consumers' behavior (22%), among others.

A 10-year review of 227 studies identifies, classifies, and discusses the root causes of the "building energy performance gap" from a life-cycle and a stakeholder perspective. It also points to gaps in research and underdeveloped scientific areas to mitigate the issue: (1) building energy performance, life-cycle thinking; (2) energy performance, information integrity; (3) big data collection and analytical methods; (4) stakeholders' attributions, decision criteria, and behavior; (5) stakeholder interactions; (6) modeling and simulation validation; (7) multidisciplinary approach; and (8) building system flexibility [29].

Having surpassed the 1.5 million registries by mid-2020, ADENE, the Portuguese Agency for Energy, collects and manages the EPC databank by focusing on building efficiency and GHG emissions. Since its foundation, imposed actions to prevent corrupt data gathering through updates and ruled penalties. However, it recognizes the prevailing minor deviations in the 2017 report based on 32 EPCs assessment, which announced a complete study on the issue in 2018 [30]. Still, the document was not published or shared with stakeholders. Nevertheless, public surveys bring to light doubts about EPC's label accuracy. The National Energy Certification and Indoor Air Quality System in Buildings (SCE) data reliability lack studies at a national level. A ADENE survey on EPC engagement and recognition in the same year, based on 1300 phone calls, concluded the lack of prestige (47%) or relevancy (31%), and the low rate of improvement measures applied (72%) [30]. The QualDeEPC, 2020, also stated that the SCE, although under regular evaluations, did not produce alarming results [31].

The lack of owners' interest in improving their property based on EPC's cost-effective suggestions undermines potential savings, increases in comfort and lower maintenance, as well as market appreciation [32]. In 2017, ADENE reports low implementation rate of EPCs improvement measures, especially in urban apartments. The EC lacks tools to mitigate deviations, relying on the national bodies and third parties to ensure the SCE robustness: crucial to regional frame goals, as the 2030 PEBs. Nevertheless, since 2017, the ADENE has added a branch to follow the development process, it started with 33 and planning to expand to 1300 EPCs by 2018 [30]. Besides bureaucratic procedures, it did not report any other practices or questionable behavior among the stakeholders.

Aim and Scope

The primary objective of the EPC is to categorize the actual energy consumption and to promote comfort and a healthy indoor environment in a specific climate. The label is a simplified representation of real estate energy performance by critical indicators, such as thermal requirements (air and water), ventilation, and artificial light: presenting minimum and referential rates.

The housing sector targets consumers', property owners, 'and investors' awareness of energy efficiency with a nine or ten letter label. The Portuguese EPC adds percentages aside from letters, also negative (-B) and positive symbols (A+), both crucial to real estate market offer alignment. The hypothesis lies in perceiving systemic faults in providing accurate grades and building reliable seriation; otherwise, it dispels interest from the EPC system's stakeholders.

The national bodies report the gathered statistical data to the EU's Energy Agency, essential to understanding the overall energy expenditure and improvements in the European Union. However, using incorrect EPC data, studies, analyses, scientific research, policies, and strategies could undermine the future goals on building energy and emissions cuts, risking inefficient procedures and related costs for the environment and economy.

The study intends to recalculate and validate 30 Portuguese EPCs while measuring the energy efficiency system reliability and discuss the outcomes against other research results. Plus, it seeks to frame the impact on local building stock and identify and follow the reason(s) why the deviation occurs. The method relies on reassessing and reloading the prior surveyed buildings and apartments data into the national body website (ADENE), resorting to professional software, Dentherm, to compare results with the official collected EPCs.

MATERIAL AND METHODS

The study follows the detailed legal assessment as framed in the Decree-Law 118/13 of the 20 August 2013 articles to measure the EPC deviation, which requested a blind new evaluation by a randomly selected assessor managed and qualified by ADENE, were limited to the same assessor, the study author. The study reassesses the EPC sample, resorting to approved methods and tools to gather as much information as possible to avoid the "Simplification Rules" used, as intended by the legislator. The assessment follows Diagram 1—Research graphical flow.

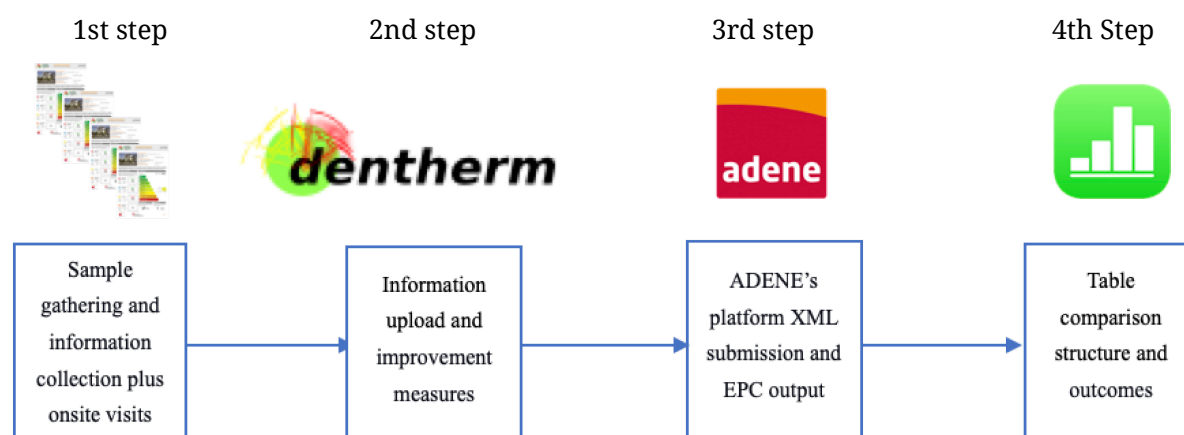


Diagram 1. Research graphical flow.

In the first step, within the scope of the Building Energy Assessment subject, students' housing EPCs were requested in addition to the necessary property documentation, and data, full access to collect on-site evidence was granted. Students did not perform any study tasks; they participated as intermediaries between the author and property owners and tenants, mainly parents. The author collected 32 EPC samples under the design methodology. However, two were impossible to validate due to data shortage: the research 30 EPCs sample match the official similar 2017's Annual Report with 33 EPCs, as presented by the reliability assessment chapter.

In the second step, the data was uploaded to a ADENE recognized software, Dentherm (DMZ) [33], which complies with its platform (XML files) to output the research EPC, as shown in Diagram 1. Densare, Lda, the software developer for the Portuguese market, provided the license and the necessary support, free of charge: the version used in 1.6.3 (updated on 8 February 2016) follows the national legislation, methodology, and EPBD. Dentherm follows the EPBD approved standards on climate, passive elements, active systems patterns, suitable renewables, and cost-effective improvement measures, more information about the software at the Dentherm—EU Directives, National Legislation and Standards (Supplementary File).

The third step had three phases. In the first, the author uploaded the building data requested only resorting to standard solutions, as enforced by the "Simplification Rules" when lacking technical documentation, when it was impossible to confirm evidence on-site to calculate parameters. In the second phase, proceed by selecting the same official EPC improvement measures to assure the balance and isolate the label deviation and surveyed information quality. The research process focuses on the information survey and not the proposed improvement measures. The third phase proceeds by exporting the XML file generated by the Dentherm uploaded to the ADENE's webpage to obtain the research-made

EPC; the layout differences resume watermarking, translating the lack of paid fees.

In fourth and last step Numbers OSX spreadsheet was used to compare the EPCs; as shown in Chart 2 and Supplementary Table S1—EPCs' deviation. The EPCs presented in Supplementary Table S1 derive from two generations (2nd and 3rd), assessed by adjusting the Dentherm software calculator base: four EPCs forms relate to the prior version, and the rest to current versions. The table opens the parameters to allow side-by-side comparison. The analysis resorts to a simple formula to calculate the deviation in perceptual points. Therefore, the Supplementary Table S1 presents different but critical characteristics, as the following groups:

- General information—"Construction year"; and , "EPC's approval date";
- Property characteristics—"Location—NUT3" [34], and "Parish council"; "Season attribution"—in three stages, according to the regulation, of winter (I1/2/3) and summer (V1/2/3); "Volume"—"Area" (m^2), and "Height (m); "Simplification Rues" use";
- The compared parameters resume to the actual annual needs of useful primary energy for heating, cooling, and water heating, "NTC", the standard needs of primary energy consumption for heating, cooling and water heating "NT (C)", ($kWh_{ep}/(m^2 \cdot year)$) "Ratio" (NTC/NT); CO₂ emissions (t.CO₂/year); and,
- Label Deviation "Process Control—Dentherm"—"Official Rate", "Research Rate" (A+ to F) and (0 to +250%).

The factors listed intend to identify specific deviations to find the most common patterns and tendencies, contributing to upcoming legislation updates. The author attested all documents against the originals' building characteristics, assuming a conservative judgment as required by the decree-laws under an on-site inspection to guarantee higher quality standards to ensure maximum accuracy.

RESULTS

The behavioral gap drew the projected tendencies from the Official against Study EPCs, and accordingly the Supplementary Table S1 "Deviation" cell, which subtracts the Official minus the Study label averages. When measuring each EPC deviation, it shows that under-rated buildings and older buildings (supported by their lack of evidence) tend to have higher deviations. The "C" label threshold highlights the deviation when the lack of data and evidence increases, favored by the contra-approach of the "Simplification Rules", as presented in Chart 2.

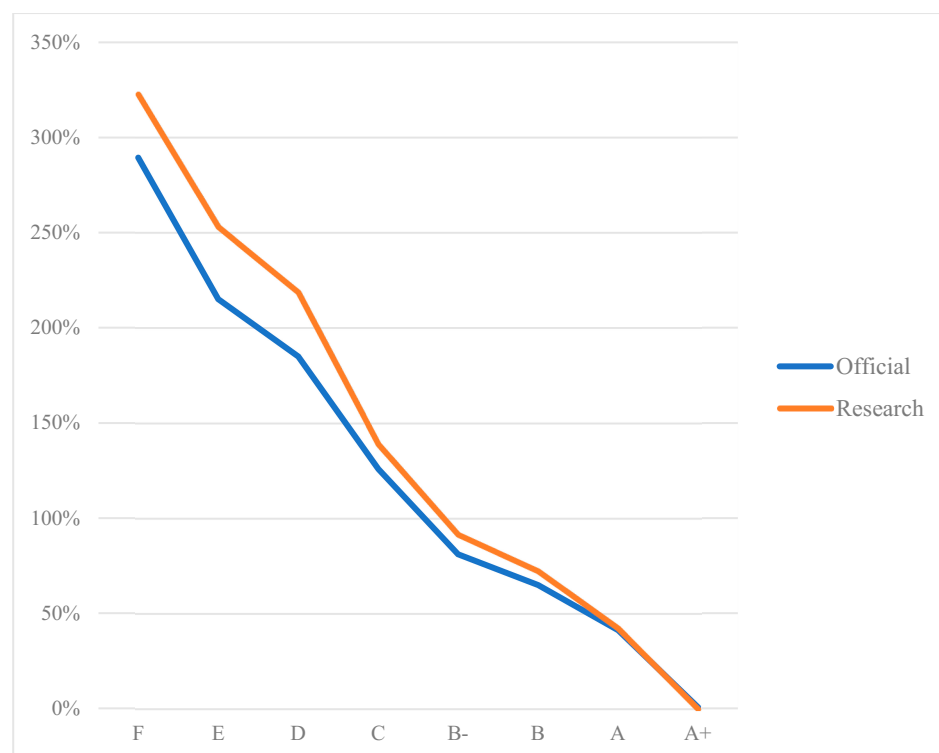


Chart 2. EPC's deviation gap derived from Supplementary Table S1.

The energy performance certifications sample suggests a global negative depreciation of $(-)$ 8.77%, which represents $(-)$ 21.93% on a 250% scale: with different behavior considering the “C” threshold, above $(-)$ 7.70%, and under $(-)$ 34.93%. The 30 reassessed EPCs support the research hypothesis, presenting a deviation as shown in Supplementary Table S1—EPCs’ deviation, Supplementary Materials, eight of those push for a higher label when near the grade threshold, favoring the applicant/owner or shareholder; as Chart 2—EPCs’ deviation gap. The higher deviation in labels under “C” results mainly from older buildings (<1990), with a share of 63.9%, in line with the ADENE’s statistics [35]. The deviation points to passive elements’ lack of evidence, especially regarding the opaque envelope, where the isolation presence positivity is assumed by the assessor and framed by the “Simplification Rules”.

Table 1 systematizes the sample’s official figures, which align with the EPCs’ labels’ national average. The construction age shows lower EPCs labels following higher “Simplification Rules”, translating the difficulty in collecting tangible documentation to clarifying performance, as shown in Supplementary Table S1.

Table 1. Official and National EPCs figures.

Labels	Average age	Sample Averages		Official Average
		“Simplification Rules” tendency	EPCs	EPCs
A+	—	—	—	2.28%
A	2010	0.00%	6.67%	11.14%
B	2005	0.00%	13.33%	9.72%
B-	2001	0.00%	3.33%	6.21%
C	1997	50.00%	16.67%	18.29%
D	1978	87.50%	26.67%	20.22%
E	1972	83.33%	23.33%	13.09%
F	1967	100%	6.67%	7.83%

DISCUSSION

Deviation Context

The deviation figure follows the paths established by some cited authors in the literature review, which highlighted the energy performance systems due to their inaccuracy [10,24,25,26,29]. The study ADENE EPCs compared against study EPCs show a (–)8.77% deviation, although this difference does not compare with the (–)35% stated by Mahdavi et al., 2021, which compares energy performance systems to meter data [35]. However, it corroborates the inaccuracy of the system’s data on EPCs in the past.

The data collected by the 2021’s Portuguese Census shows a building stock of 5.86 M residential units, where 86% does not surpass two floors. Around half built before 1990, up to 3.80 M or 65%, and part of that remains vacant, 0.53 M or 9.09%, which translates to a high-energy efficiency potential following the NZEBs updating. From those built before 1990, two-thirds are precisely the target of the study, as supported by the articles introduced by the 2021 version, to avoid spreading dubious grades to the rest of the building stock [35]. Of those, the most significant concern falls on buildings erected between 1945–1990, because the constructions before 1945, 0.62 M or 10.68%, reveal an envelope with high thermal mass outperforming the subsequent, which represent 3.18 M or 54.32%, built under a light-mass envelope and lacking physical insulation material. Most of the building stock, erected between 1945 and 1990, presents high inefficiency in existing residential buildings and a significant opportunity to renovate the Portuguese housing stock. The problem rests in the excessive and inaccurate use of the “Simplification Rules” that assumes better elements and systems performance than the reality framed by the SCE. The deviation inflates the EPC labels, misleading consumption

figures, failing to increase stakeholder conscience while weakening responsible awareness to trigger improvements to cut consumption or improve market operations [11].

The consumption related to heating, as presented in Chart 3—Average final consumption levels for heating (kWh/(m².year)) of single-family homes by construction year in Portugal [24,36], translates the higher impact on older buildings related to the uncertainty of isolation presence [15]. Also, following the Portuguese energy consumption related to air acclimatization, which represents 21.5% to heating and 0.7% to cooling, the first in 86% of houses and the second only in 10% [4] These figures show the inefficiency of passive elements and systems, considering the Portuguese's winter conditions and energy poverty to acclimate their households, ranging from 15.3 to 23.4% [24,37].

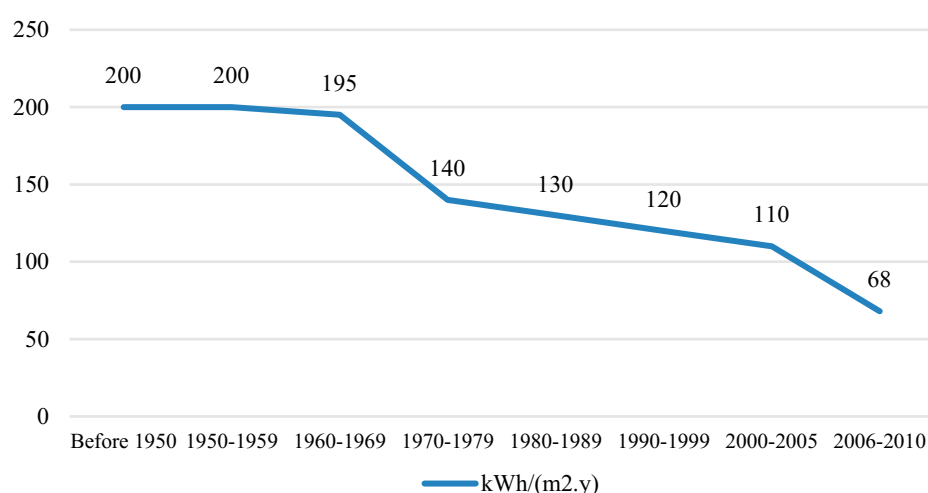


Chart 3. Average final consumption levels for heating (kWh/(m².year)) of single-family homes by year of construction in Portugal [24].

Older buildings tend to lack tangible documentation to clarify passive elements and active systems specifications, which the SCE considers, consequently requesting additional photographs and other relevant elements/data [15,24].

Following the described issues, assessors have the power to evaluate and understand building capacities. However, they must follow the ADENE's recognized documentation based on the assessor experience, due to a mechanism printed in the law known as "Simplification Rules", to precisely measure the elements and systems performance to overcome the lack of known proofs of building inner qualities [15,24,27]. Nevertheless, the same rule points to a conservative interpretation, which generically lowers the EPC's overall performance. Without a legal mechanism to detect and correct the "Simplification Rules", the assessors' evaluation tends toward the opposite, optimistic rather than guarded, resulting in less accurate data and undermining the SCE statistical accuracy, including design and financial incentive programs to target the update of older buildings [3,24].

Quality Data Implication

The EPBD emphasizes the EPC's data quality in its article 34 plus requests to its national bodies to ensure its reliability and control deviations. The Directive request an independent control system on alternative databases gathering knowledge about national and regional building stock. It also states that high-quality data is possible if MS continuously assesses the procedures enabling development under a tailored management policy. Though the clarity of the Article 34, MS fails to produce or share knowledge, which highly justifies the current research effort, as MS fail to comply with Article 34, and several studies point out arising concerns about the data gathered and shared by the EU BSO [11,18,19].

When the process lacks information, it creates the opportunity for higher performances, leveraging the property price favoring the EPC applicants in market operations [38]. It is also likely to relate to specific commercial and social circumstances, leading those to choose and hire assessors from their friends' inner circle [24,27].

The verified deviation distorts the quality of the information shared with national institutions and undermines the EU's new strategies and future policies' assertiveness to mitigate energy expenditure [39]. It also pressures the property prices against the building's real quality, supported by the EPC, as an official document, and by the robustness of the SCE. Nevertheless, the margins are narrow when emphasizing the energy efficiency in housing prices (27%), shortening the real estate market exposure, sales, or rentals (14%) [7,12,16].

Not all MS demand the presence of assessors on-site, which BPIE considers critical to understand the building's condition and guide renovation proposals; some allow EPCs based on general information; some allow EPCs based on technical drawings and documents. Nonetheless, a few MS allow owners' declaration through (e)mail at a lower cost. The EPBD does not request centralized databases at the national bodies level. However, most countries collect and share information, while nine consider it sensitive for public knowledge. The Portuguese counterpart provides general information on its website, although it restricts some data to stakeholders, only available by request.

The measured deviation undermines the option to apply the improvement measures, complying with program minimum values, and consequently losing financial incentives. From the owner's point of view, a higher EPC label relieves the pressure to update. It shortens the gap for post-labeling renovations (after applying its measures), diminishing reimbursements and performance gains [16]. It also awakens critical awareness of the practices in energy efficiency assessments related to EPCs [11,18,19].

“Simplification Rules” and Assessor Role

The sample show a 16/30 “Simplification Rules” ratio use. Pointing their high use as an easing tool and a problem that requires monitoring, measuring, and assessing through critical parameters, as crossing the assessors lack information declarations with property databases available [11]. Ensuring, at least, that the EPC has the building information available at the Municipally archive and property registration body, assuring the assessor effort to collect, produce, and provide reliable information to the SCE [13,24,27]. ADENE follows the prior issue since the 2013 version, which requires an on-site visit declaration (DRCPE) to mitigate the lack of property documentation and confirms the assessors’ visits [15,24,27,40]. The 2021 version drops the declaration (DRCPE). It strengthens the control through a set of rules to verify and evaluate the assessors’ on-site survey, official information, and archives consulted to gather reliable data.

“Simplification Rules” also help to ease the assessors’ workload, especially when considering older buildings’ information shortage; in addition, today’s certification prices decreased 50% compared to initial values (2013). In 2017, a 130 m² three-bedroom apartment, built in 2015, AC (≤ 25 kW), natural gas boiler (≤ 10 kW), represented a cost between EUR81.33 and EUR294.58, which translated an average from EUR100 to EUR150 [41], however, far below from the initial prices of 2009, estimated to be between EUR195 and EUR390 [24,42]. The latter represents a substantial depreciation of certification prices, explaining the workload shortcuts taken by SCE assessors; moreover, such practices are undetectable by the ADENE’s supervision [24,27].

Each MS assumes the EPC template that best suits the public acknowledgment, some under the fourth generation, although similar in graphics and colors, the layouts tend to focus on the national strategic goals rather than stakeholders’ interests. Few countries resist adopting the latest EPBD, which reveals different rates and stages of engagement, undermining the quality, integrity, and value of the EPC, especially in creating independent entities to validate the data quality or to issue penalties to non-complying stakeholders. The European Commission (EC) reports to its MS the lack of engaging policies and programs to push EPCs to comply with 2020 NZEBs, especially in building renovations [27].

In Portugal, the SCE assessor, associated or independent, has to visit the property to evaluate it, a situation that promotes interpersonal relationships between those and applicants, favors both parties [24,27]. Simultaneously, fulfilling the purpose of the certification process (sale or rental), all under low-cost and light workload certification, even more, assures the property’s overvaluing and speeds its transaction [14,18–24,38,43].

The practices described do not reveal friction between stakeholders and responsible bodies, regardless of the latter’s awareness [30]. The impact falls on renters and buyers in two dimensions, economic effort, and

misleading house comfort as it favors owners; the same applies to real estate operators via commissions [7,12,16].

The 2021 version includes control tools that reflect ADENE's awareness of excessive use of "Rules of Simplification" in EPCs and consequent deviations on older BS. From the research point of view, the inaction is a result of lack of staff/added workload, supplementary costs, the reassessment difficulties, and the damaging effect upon the system reliability and its database, particularly in contrast to the effort required to evolve the accuracy of EPCs and the quality of shared information. Furthermore, the research also outlines the complete absence of discussion at the EU and national body on identifying and addressing this problem. Nevertheless, the EU reveals the problem's awareness, as seen in the latest EPBD update (Directive (EU) 2018/844 of the European Parliament), whereas numbers 20, 34 and Energy performance of buildings directive (EPBD) [26] adds [28]:

- (a) in point 1, the first paragraph is replaced by the following: The competent authorities or bodies to which the competent authorities have delegated the responsibility for implementing the independent control system shall make a random selection of all the energy performance certificates issued annually and subject them to verification. The sample shall be of a sufficient size to ensure statistically significant compliance results.
- (b) the following point is added: 3. Where information is added to a database it shall be possible for national authorities to identify the originator of the addition, for monitoring and verification purposes.

A recently introduced legal mechanism justifies the research's importance. Since 2020, ADENE demands the registration of the site visit declaration (DRCPE), which generates a number to acknowledge the information reliability of the EPC [40,44].

Contribution and Knowledge

Every deviation should be in the legislators' minds, especially in designing measures to identify inconsistencies that are mandatory to avoid compromising future EPCs data; simultaneously, requiring the assessor's broader involvement [13,24,27].

The Portuguese Government delayed the NZEBs legislation to 2021 (predicted effective from 2018 in public buildings) and chose long-term, smooth, and broader support for energy efficiency and environmental protection. Also failed to prioritize short-term economic benefits and renovation incentives, only available under the European Central Bank COVID-19's monetary relief package. The research emphasizes the need for the following measures in addition to the 2021 version to ensure future EPC data accuracy [10,27]:

- The EPC database should allow external assessment to enable a more straightforward review from third parties;

- Engage stakeholders on post-consumption values to confirm what was published by the EPCs [45];
- Consider the EPC's label on public procurement of new buildings and renovations;
- Leverage the EPC's renovation proposals through fiscal credits or tax cuts;
- Introduce Wi-Fi/Bluetooth sensors for passive elements [46]; and,
- Follow the energy meter to collect data on the actives' performance.

The ADENE publishes general information on its website, mainly limited to results, and keeps the most significant portion of the data under restricted access. The EPC's system reliability could benefit from allowing third-parties access, enabling further studies, and improving overall knowledge about the true meaning of the SCE's achievements.

A solution to monitor the found deviation lies in proven technology: self-reading electric meters. This equipment provides consumption reads online to power suppliers. It is highly recommended, especially under dynamic energy assessments, as intended by the upcoming legislation, on an hourly basis. Simultaneously, it opens the opportunity to cross the EPCs values with actual electric meter (and other sources) consumptions, confirming its outcomes parallel with consumer information on actual housing comfort expenditures [47]. Such measures establish the importance of EPCs in everyday life. Besides, they also certify the energy needs, in real-time, with the site's climate (gains and losses), crossed with the current suppliers' energy production mix and related GHG footprints. Moreover, they change the "terms of traditional comfort", more focused on expenditure than needed energy, due to the country's temperate climate (short winters and light summers) and the occupants' flexibility to deal with mean discomfort.

The EPC label should be a critical and determining factor in public investments, awarding higher energy efficiency designs, and ensuring an overall sustainable strategy. The approach promotes community awareness and emphasizes the relevance of the SCE and its stakeholders.

Until recently, no significant public incentives or tax deductions were available to update the building stock's elements and systems other than state property renovations. However, due to the COVID-19 pandemic, the economy suffered a slowdown, forcing the Portuguese Government to introduce mechanisms to address the construction sector's poor cash flow. The plan draws financial support of mEUR4.5 to update the efficiency of passive elements and active systems of buildings (erected before 2006), a measure that spiked media interest. The financial support should motivate owners and stakeholders to upgrade their properties to improve comfort, reduce energy bills, and profit from real estate transactions.

Technology evolves, producing industrial devices in larger quantities than ever before: smaller, inter-connected, and less expensive than prior generations. However, while present across the economic sectors, construction tends toward conservatism when integrating new technologies, especially when building passive elements. Aside from

online energy meters, embedded sensors in envelope walls or slabs powered by euro-coin scale solar panels enable communication of the temperatures and humidity levels collected in external databases to track their behavior, performance, and degradation. When registering discrepancies between these and EPC values, a warning should trigger the authorities' awareness to prevent lifecycle (re)certification and unnecessary costs, as planned in the upcoming legislation [48].

The current Portuguese legislation, published in 2021, pushes for higher energy efficiency, such as NZEBs, and already projected Positive or Plus Energy Buildings (PEBs) for 2030, designed to generate more energy than needed, favoring low-performing buildings nearby.

The 2021 legislation also introduces changes to mitigate the research topic, though the lack of conclusive studies about the reliability of the 2013 version. Apart from a new methodology for EPC assessment, introduces regular building technical systems inspections to follow EPCs' projected efficiency and time degradation, which in theory can help to solve part of the deviation detected. Plus, a random inquire to verify and classify the assessor work-based checklist with limited deviation patterns against professional penalties. Nevertheless, the "Simplification Rules" continue to exist although in a different frame, that in theory, address the issues here raised, mainly:

- By introducing the eventual thermal resistance measurements on-site considered by the assessor without providing any technical details; and,
- By providing tables to assessors for precise identification of the opaque elements' thermal transmission coefficient following the evidence gathered on-site.

Before the publication of the 2021 version, the produced knowledge was extendedly debated by the ADENE professionals since 2019, primarily to frame the latest SCE legislation to gain consumers' trust [11,18,19]. The new legislation can shape the EPCs' reliability to enhance the real estate market's functioning. In line with the EU's Directives' intentions, this would make EPCs labels a practical differentiator element for sales and rentals while producing sharper statistical data to consubstantiate incoming policies and strategies [16].

CONCLUSION

The EU's member states develop energy assessments systems without studying prior generation deviations or measuring the data quality, highly justified when third part studies arise critical doubts about shared data by the official EU Building Stock Observatory on energy efficiency. This study measured the EPC label deviation under the Portuguese National Energy Certification and Indoor Air Quality System in Buildings (SCE); between the official made EPCs and the author's reassessment, following the same legal guidelines and body requirements.

The methodology followed four steps, official EPCs, data sharing and property access, information upload to Dentherm (DMZ) and XML export, ADENE's platform submission, and further value relation under iOS Numbers spreadsheets. The research concluded that the deviation favors the initial (official) EPCs over the author's, following the same legislation and available building information.

The outcomes indicate a negative deviation from the official, higher-margin targets, the "F" to "C" labels. On its statistical web page, the ADENE reveals that grades under "C" represent older buildings built before 1990: usually, a sample with less technical information on specifications to assure the performance assessment. As the study and the legislation suggest, this condition leads the assessors to use "Simplification Rules" based on a favorable review rather than a negative. The negative variation of 22.45% does not necessarily reveal the tendency to push for a higher letter, per 50% range, although upgrading those close to the threshold is possible. Nevertheless, it builds up an overall erroneous ranking, leveraging the older buildings (<1990) rate, primarily upon passive elements with higher impact in the opaque envelope, due to the impossibility to gather inner evidence, as isolation presence.

The study and the literature review also reveal the importance of having non-profitable third parties to validate public bodies' data, including universities' resources. It shows the importance of understanding the vicissitudes SCE assessors face when evaluating complex elements and systems without evidence of build quality and quantity, leading to excessive use of the "Simplification Rules". Over time, this tends to serve as a workload bypass, meeting the service's current low price compared to initial values. In addition, it points to the importance of implementing a mechanism to shield the influence of assessors' judgment in EPC quality data, derived from the interrelation between applicants and stakeholders: leveraging the actual energy efficiency, the market value, fastening operations, and misleading the official statistics and undermining future decisions.

Although the outcomes arise from a specific context, they represent the cutting edge of the European Union and other countries' energy and CO₂ emissions strategies, which assumed one of the first roles towards fulfilling the Paris accord higher goals. Furthermore, the knowledge built by the EU derives from different climates, cultures, and communities/states: tangible to be reproduced on third regions. From the international perspective, the EU gathers knowledge for others to follow the best practices to ensure higher reliability of their EPC systems, plus engaging the real-estate players and consumers to fulfill the policymakers and experts' strategies and policies. The contributions of this research represent a step forward to the international awareness to build higher quality energy performance systems that address today's energy efficiency and solve the local and global climate disruptions.

The author is aware of the possible limitations of the sample size (30 EPC), though it follows the 2017 official assessment with a similar sample (33). Lisbon's gathered most of the sample with 77%; nonetheless, it produced identical results to the official and revealed the tendency to EPC deviation in building stock erected between 1945 and 1990. Characterized by the lack of thermal mass and proper isolation and framed by the nonexistent technical documentation about elements and systems and built under a high proliferation of low-cost and fast build to face the post-war rapid population growth.

Even in Europe's fourth generation, policymakers and experts still fail to deliver more reliable systems that contribute to increased trust and effectiveness for both real estate agents and consumers. Able to raise awareness on the importance of energy consumption and CO₂ emissions as critical decision points on real estate transactions. All over the world, researchers and institutions continuously verify the systems' reliability and measuring methodologies, primarily to increase accuracy and trust among consumers.

The next step is to understand the changes in the assessor practices related to the 2021 version introduced tools, pressure ADENE to monitor the effects of excessive use of "Simplification Rules" excessive use. At the same time, the author will continue to follow and identify any potential deviation in the coming years, under the same method or using an improved model, considering the variables, such as susceptible building periods and how it affects the market overvaluing and transaction speeding. The author also intends to extend the spectrum of passive elements and active systems' analysis to produce the deviation details.

SUPPLEMENTARY MATERIALS

Supplementary Table S1—EPCs' deviation

Dentherm—EU Directives, National Legislation and Standards

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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