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A Study for the Improvement of the Energy Performance Certificate (EPC) System in Turkey

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Abstract: This study aims to examine the current status of Turkey's energy consumption and energy performance system and draw improvements. To this aim, this study adopted a qualitative research method. A literature review was conducted regarding the problems related to the EPC system. Following this, a series of research questions were derived, and answers were sought through expert group interviews. The problems were categorized into three headings: the EPC system and calculation problems, problems in the regulation and inspection process and, finally, the perspective on the construction industry to the EPC system is examined in the case of Turkey. Deficiencies in the rating system and calculation, regulation and inspection, and perspective of the EPC system in Turkey were identified. Suggestions for the development of EPC in Turkey were made to make it comparable with the systems in EU countries. As one of the outcomes of the study, Turkey should focus on the use of renewable energy, taking into account its geographical advantage. In addition, a more detailed micro-zoning that focuses on regional differences should be carried out, and the authorities should introduce a better control mechanism for the EPC system.

Keywords: energy performance certificate (EPC); energy efficiency; building energy demand; energy performance; renewable energy; sustainable buildings

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1. Introduction

Buildings are Europe's largest energy consumer, accounting for 80% of the energy citizens consume. In the European Union (EU), 36% of energy-related greenhouse gas emissions are caused by buildings [1]. The increase in energy demand, as well as the fact that this demand is still met mainly by fossil fuels, affects the environment negatively. The Energy Performance of Buildings Directive (EPBD) in 2002 was introduced for EU member states and required each to establish their own Energy Performance Certificate (EPC) system by 2008. The EPC evaluates a building based on its thermal envelope and energy installations. According to the European Commission, EPC is a tool to direct the countries' economies by highlighting energy consumption costs [2,3]. The commission presented the "Fit for 55" package, which sets the aim of the EU's 2050 climate neutrality objective and its objective of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. The council agreed to gradually increase the annual energy savings target for final energy consumption from 2024 to 2030. Member states will ensure new annual savings of 1.49% of final energy consumption on average during this period, gradually reaching 1.9% on 31 December 2030 [4]. For example, Sweden's national target for energy efficiency in the building sector is to decrease energy use to 50% by 2050, compared with the level in the year 1995 [5]. In addition to this, member states would be required to renovate each year at least 3% of the total floor area of buildings owned by public bodies [4].

Turkey's growth depends on energy sources, and the demand increases. In 2022, 34.6% of electricity production was provided from coal, 22.2% from natural gas, 20.6% from hydraulic energy, 10.8% from wind, 4.7% from sun, 3% were from geothermal energy and

3.7% from other sources. As of the end of June 2023, the distributions of power by resources are 30.1% from hydraulic energy, 24.2% from natural gas, 20.8% from coal, 11% from wind, 9.7% from solar, 1.6% from geothermal and 2.6% in the form of other sources. Turkey has experienced impressive growth in renewable systems in the past decade (notably solar, wind and geothermal). Turkey has exceeded its target of 38.8% of power generation from renewable sources set out under the 11th Development Plan (2019–2023) [6].

Energy has an essential place in the economy of Turkey. Energy imports in Turkey and Turkey's energy consumption are increasing every year [7]. This shows that energy efficiency is paramount for Turkey [8,9]. Dependency on energy and fossil fuel imports not only causes economic problems but also causes political problems. The Ukraine–Russia war is the clearest example of this. Many countries in Europe experienced a supply crisis. The way to get rid of this dependence on fossil fuels is to turn to renewable energy sources.

According to the UN Environment Program, Turkey emitted 579.2 million tonnes of GHG in 2018. This is more than five times that of Greece, which emitted 91.9 million tonnes, and less than Germany, which emitted 873.6 million tonnes of GHG in the same year. Even though it counts for 1.17% of global emissions, Turkey aims to decrease its environmental footprint. Comparing the emission rates from 1970 to 2018, the United Kingdom (UK) is one of the few countries which dropped GHG emissions by nearly 40%. The UK has 6.97 tonnes of GHG emission per capita, and Turkey has 7.07 [10]. According to the national statistics, in 2021, CO_2 emissions in Turkey were 564.4 million tonnes, and the energy sector was the largest emitter by 71.2%, which is followed by the industrial use and manufacturing sector at 13.3%, agricultural use at 12.8%, and waste management at 2.6% (Figure 1) [11].

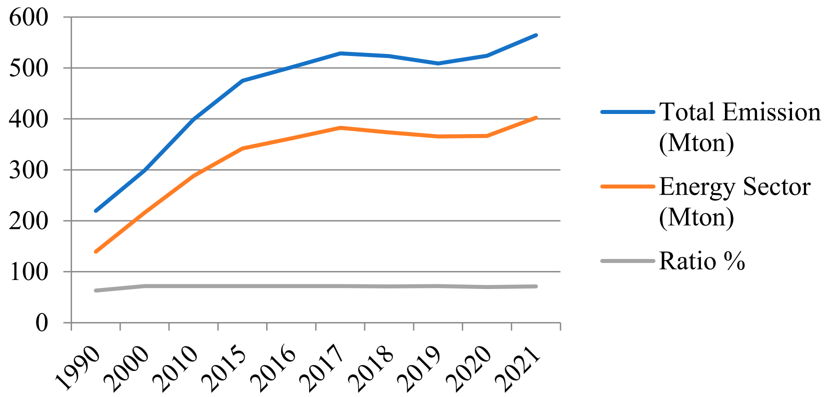

Figure 1. The GHG emissions in total and the energy sector [11].

A report [12] revealed that CO_2 emission in Turkey will be increased by 66% to 700 Mton from 2018 to 2050 and by 120% to 920 Mton from 2018 to 2070. In the Net-Zero Carbon emission scenario, 2050, a decrease of 70% to 132 Mton can be achieved. For this scenario, the most significant achievement is estimated for the buildings, with a decrease of 46% and to 27.5 Mton from 2018 to 2030 and 0% by 2050. The most significant step to achieve this is to limit/ban the use of fossil fuel (coal and oil) for heating to replace it with the use of natural gas and to encourage the use of electricity for heating. In addition, after 2035, it is suggested to use green hydrogen instead of natural gas and electricity, and after 2045, only to use green hydrogen in buildings instead of all other pollutant heating sources.

Sector distribution of the final energy consumption is as follows: industry 32%, transportation 25%, housing 20%, trade and services 12%, agriculture and livestock 4% and non-energy consumption 7% [7,13]. The energy consumed in the housing, trade and service sectors is 36 million TOE together, which is vital in showing the situation created by the buildings. One-third of the final energy consumption in Turkey originates from buildings [14]. The high amount of energy consumed in buildings requires taking precautions specific to buildings. These are to reduce the energy need, use energy efficiently, and obtain the needed energy from renewable energy sources.

A study [15] revealed that the average energy performance of the metropolitan municipalities in Turkey was 42%. The study focused on queries about the municipalities' energy performance (primarily the reduction in CO_2 emission and energy efficiency). The study of Green Municipality aims to analyze the current status of the local authorities' actions since the municipalities are the formal local authorities and, in the first place, in charge of fighting against the damages to the ecological environment and urban infrastructure caused by climate change. Antalya is a pilot city in the MatchUp Project [16], along with Dresden in Germany and Valencia in Spain. The actions hoped for by the Antalya Municipality include the use of IoT (Internet of Things) for the smart control of energy, bringing the requirement to ensure at least B class on the EPC system for residential and public buildings to be built, to install PV systems on the public buildings, to install solar heating pumps and water collector systems on the existing residential buildings, and to install charge units/stations. A recent analysis of energy consumption [15] by the Antalya Municipality reveals that the share of transportation is 51%, commercial buildings (offices, factories, etc.) are 23%, and residential buildings are 14% of the total. The amount of electricity consumption is more than double the natural gas consumption. For the residential buildings, most of the energy is powered by electricity (83%), natural gas powers as small as 14% and coal comes the last by 3%. For commercial buildings, electricity is the primary energy power of 75%, and natural gas provides 25%. For industrial buildings, natural gas is the primary energy power by 51%, electricity is the second by 45%, and coal is still in demand by 4%.

There are several laws, regulations and standards that are enacted to ensure environmentally sensitive energy efficiency, to decrease atmosphere pollutants and emission amounts and to improve the energy efficiency in buildings in parallel with the framework brought by the EU. As a trending field of research, energy efficiency and status in Turkey need a focus to understand the achievements and the possibility of achieving more in line with the EU targets. This study aims to examine the EPC, which measures the energy performance of buildings, in the case of Turkey, within the scope of increasing the energy efficiency of buildings. To this end, how the certificate is applied in Turkey, the criteria and the classification of the buildings that have received the certificate, the method of issuing and audit, the assessment in the system and how the buildings are rated have been examined in this paper. The main purpose of this study is to identify gaps and problems related to the EPC system and to produce improvement solutions. The method of the study is to re-evaluate the gaps and problems found as a result of literature-based research through interviews with authorities and practitioners in the sector from Turkey and to identify the problems and gaps through the Turkish case and suggest improvements for Turkey. For this purpose, interviews were conducted using open-ended questions to justify the problems and suggestions in Turkey.

2. Review of the Literature

Completing two decades in the EPC certification systems displayed a range of issues because the one-size-fits-all approach in the certification system evaluates diverse countries with different features, e.g., climate, population, building stock, etc. To better understand what is lacking in the system, to understand what the country-specific issues are and to draw lessons for improving the system in Turkey, a literature review was conducted.

2.1. Method of the Review

The ScienceDirect database was used to form a pool of the literature review, and the keyword "energy performance certificate" was searched at the beginning. The resulting article number was 1418. The search was advanced with different keywords to understand and yield the issues within the EPC system. A further search with the keyword "gaps" was concluded, and 158 articles were listed between 2009 and 2023. A refinement search was completed with the term "thermal gap" to reveal more related articles to define the problems of the thermal gap in the EPC system. Eventually, 35 articles were listed between 2014 and 2023. A search with the keyword "problems" was concluded, and 103 articles were listed between 2009 and 2023. A search with the keyword "impact" was concluded, and 355 articles were listed between 2007 and 2023. A search with the keyword "differences" was finally conducted, and 134 articles were listed. All articles listed in detail keyword searches were overviewed. A similar search was conducted also in other databases to enhance the content of the literature review. After reaching saturation in the review process, a frame of issues was generated and categorized into three main areas as in the following part.

2.2. Fallacy of EPC System and Gaps Indicated

The review of the literature indicated geographical and technical differences, which are highlighted as part of the issues related to the generic EPC calculation approach, overestimations and differences from actual data as part of the issues related to software used in the EPC calculations and real data in terms of the difference from actual energy billings, and the perspective of the building sector to the EPC system as part of the issues related to understanding the impact of the system and its influences in the building market.

2.2.1. Problems in the EPC System and Calculation: Geographical and Technical Differences

The generic EPC scheme is a one-size-fits-all approach, and it is seen in the examples of country-specific climate and user characteristics that affect energy consumption. For example, Vaisi et al. [17] highlight that the building stock in Iran consumes five times more natural gas than the average of the European countries since it can source it within the lands. It is a country with an arid/semi-arid climate, and some regions in the country have winters with heavy snow, whereas summer is dry and hot. As their study focused on office buildings, they concluded that natural gas consumption had a share of 85% in the total energy use, whereas only 15% came from electricity. This is different from any other European country since office buildings in the EU have an equal consumption of two, 56% of natural gas and 44% of electricity, implying a solid need to adopt an energy policy to convert the status in Iran.

Within Europe, Fuinhas et al. [18] conducted research in nineteen Portuguese districts between 2014 and 2021 because most buildings in the country were built before 1990, affecting their energy performances. The climate of Portugal is warmer than most of the European countries, and there is a particular energy shortage in its residential sector, unlike some European countries (e.g., the UK, Norway and Germany). The warmer climate affects the users' energy consumption habits, and thus, the sectors' final energy consumption per capita is lower than the European average, even less than the countries with similar climates (Spain and Italy). There are eight classes in the Portuguese EPC system, and the new residential properties must be above class B, whereas existing properties can have any class. The Portuguese EPC system calculates a class by dividing a property's primary energy demand and the corresponding limit value, which makes the reference consumption 100%. A C-class property consumes between 100% and 150% (1 and 1.5 times) of the reference consumption.

In Turkey, Kazanasmaz et al. [19] examined the energy performance of 148 residential buildings in Izmir and aimed to catch a correlation with their architectural configurations. Their study revealed that the energy consumption of residential buildings was highly dependent on their construction year since the minimum mean energy consumption was attained from the sample of buildings constructed after 2000, which can be explained by the extensive use of insulation on the buildings' facades due to the regulations. As a correlation, they found that dwellings with an external wall area per net floor area value lower than 0.604 had high energy performance, which needs further study for generalization. However, it can be a design indication for better-performing dwellings. They also pointed out the energy consumption differences between the residential properties in Greece and Izmir, although both have similar climates. In Izmir, buildings consume more energy for heating than in Greece, and the highest U-value for walls is 0.6 W/m^2 K. In contrast, for Izmir, it is

0.8 W/m^2 K. They also underlined that no A-class buildings were included in their study, and not one uses renewable energy resources. As they highlighted, in a warm climate like Izmir, existing buildings with low-energy-performance classes should be upgraded, and it should be monitored whether this affects their energy performances from B to A. Speaking of Greece, Droutsa et al. [20] mentioned that Hellenic residential buildings largely lacked thermal insulations and were installed with inefficient heating systems. Only 22% of the buildings take advantage of solar energy. For space heating, fuel oil is the primary source at 78%, and natural gas is at 14%.

Las-Heras-Casas et al. [21] focused on Aragón, in Spain, to understand the accuracy of energy assessment of the residential buildings in warm and relatively cold winters. Their study uncovered that 49.71% of the energy performance certificates in Aragón were inaccurate. They also targeted to define a correction algorithm for better energy performance assessment in the country depending on the regional characteristics. As Kazanasmaz et al. [19] implied, Aragón buildings before 1961 displayed 47.95% higher energy consumption and 61.04% higher CO_2 emissions. Buildings constructed between 1961 and 1980 had 33.19% higher energy consumption and 44.47% higher CO_2 emissions. Expectedly, buildings constructed between 1981 and 2007 had 16.32% and 19.20% more efficiency in energy consumption and CO_2 emissions, respectively, considering the building standards published in 2007. Only 9.49% of the buildings completed before 2007 had high energy consumption and CO_2 emissions performance. Besides, they compared the buildings' energy performances in rural and urban Aragón. They found that it was 4.95% higher in energy consumption and 2.55% higher in CO_2 emissions, which raised another issue within the geographical differentiation.

Buratti et al. [22] investigated the level of energy efficiency reached in the Umbria Region in Italy. They estimated based on the data of 6500 EPC-rated buildings. They found that, on average, it was 24.5 kg of CO_2 emission per unit of useful floor area per year (kg/m^2 per year), which concluded that the value was lower than the average of European countries and less than the average of Italy.

Nindartin et al. [23] examined the effectiveness of the G-SEED certification system in Korea (which stands for Green Standard for Energy and Environmental Design). They pointed out the regional differences. In the summer season, G-SEED-certified buildings in South Korea consume more energy compared to non-certified buildings and display less efficiency at saving energy, as low as 15% per year. This is because the climate is warmer in the south. However, the study also highlighted that increased thickness of thermal insulation also did not help decrease gas energy consumption.

Lartigue et al. [24] compared the French EPC (a.k.a. DPE—Energy Performance Diagnosis) system with The US Energy Star system. DPE is very similar to the generic EPC system, rating buildings' performances from G to A. The US Energy Star system scores buildings from 0 to 100 and compares a building with the same type of building with the same number of occupants. The resulting score would change with a different number of occupants and different building management systems. They highlight the example of the COVID-19 lockdown in 2020 and underline that the scores of some building types, such as hotels, have significantly increased due to the lockdown and the decrease in their utility bills. Lartigue et al. [24] also focused on the geographical differences in France and its effect on the EPC system and wrote that the least performing buildings in the class of F and G were located in the cold and mountains regions of the country, e.g., Mulhouse in east France. In numbers, 30% of the buildings rated F and G were in cold areas, whereas only 5% were in warm areas. This raises the following question: Which would be more appropriate to consider, the number of occupants or the regional differences? The French and US' systems work in different ways in this regard. The USA is a large country with diverse climate conditions and a large population compared to France.

The assessment of buildings through an EPC system heavily depends on software. In two decades, many countries uncovered lacking issues with their own EPC software system. Technical databases, catalogue information and software problems are among these issues. For example, EPA-ED software (version 1.4.10.30), which is used for the Energy

Performance Assessment of Existing Dwellings in Europe, was tested by Poel et al. [25] through the national libraries of Austria, Denmark, Greece and the Netherlands. The software mainly generates three output tables:

- Calculation of energy consumption per month: for space heating and cooling;
- Calculation of energy demand: for heating, cooling and domestic hot water;
- A summary: savings based on estimations (fuel consumption, electricity, CO_2 emissions, energy indicator) and cost (investment cost, payback period).

The software was a beta version that could be adapted to meet national requirements and modified to include new European standards as soon as they became available. It can provide some specific advice for measures to take to improve the energy performance of the residential unit of the building.

Namlı et al. [26] studied creating a classification model to determine building EPC with a minimum error and with an optimum number of independent variables. Harputlugil et al. [27] compared BEP-TR software (BEP-TR.V2) with other building energy simulations, including Relux. They stated that the results from both software were overlapping regarding lighting calculations. As they separately calculated the architectural, mechanical, and lighting systems modules, they concluded that the results were more accurate than the BEP-TR results. However, the calculation of net energy was noted, as it required an improvement to reach more accurate results. They underlined that BEP-TR was not designed software but a "performance confirmation tool".

Andelkovic et al. [28] conducted a study to reveal the difference resulting from the heating systems. They examined 135 buildings with District Heating System (DHS) and 16 with Individual Gas Boiler (IGS). They were built in 2014 in Novi Sad, Serbia. They found that EPC estimations were more comparable for the buildings with DHS. Six of the sixteen buildings with IGB were one class lower, and two of the sixteen were two classes lower than the EPC estimations. This implies that the type of heating system installed in the building highly affects the expected energy performance.

Pasichnyi et al. [29] point out the limitation of conventional EPC data quality and the failure to expose the essential problems and ensure effective use of the data. They highlight the significance of the interoperability of EPC datasets for thoroughly mapping building energy performance.

2.2.2. Problems in the Process of Issuing and Audit: Overestimations and Real Data

The most heavily pointed argument is the building energy performance gap, which is defined as "the difference between predicted and actual/measured building energy consumption, either for an individual building or for a large group of buildings" [30]. This issue is underlined as a critical barrier to achieving the energy performance goals in the building sector. Several studies uncovered the exaggerated numbers in the consumptions and savings based on the energy performance models used for classification. For example, Coyne and Danny [31] investigated the differences in energy use in a sample of 9923 households in Ireland from late 2014 to mid-2017 and compared their EPC classes. They revealed that homes with D, E, F and G classes in the Irish system (namely, BER, Building Energy Rating) had lower energy use than the average estimation that the systems predicted. The difference ranges from 24% for D-class homes and 56% for F and G-class homes. Unlike the generic EPC classification, the BER system goes into a more detailed classification on a 15-point scale from A1 to G based on the kWh/m^2 per annum. Another highlight of their study is that no validation system compares the estimation and actual billing.

Ahern and Norton [32] focused on the evaluation of existing buildings since the experts evaluate the walls and floors in buildings by using default values for thermal bridging transmittance coefficient (Y-value) and heat loss coefficients (U-values), which are defined in building codes and valid for new construction. However, many buildings are applied with material and façade adjustments that affect their energy performance. They called this a 'default effect' error in the EPC system. This potential difference can range between 22% and 70%. Regarding this issue, Raushan et al. [33] wrote that one in every six houses, 16%, in the Irish BER system (nearly a million buildings) was rated based on the default U-values, which is used for an unknown type of walling. They conducted an extensive study to determine realistic U-values that could help to rate the buildings more appropriately for their energy performances. Similarly, Wederhake et al. [34] wrote that building surveyors are tied with engineering-based quantification methods that largely standardized the data for energy performance ratings. However, quantification could be conducted by non-experts (occupiers) through data-driven methods (deep learning). They tested their energy rating system proposal on 25 thousand detached houses in Germany and found that the rating results displayed 35% better accuracy in energy consumption/saving estimations.

Cozza et al. [35] highlight that the thermal performance gap the system creates can lead to undermining the energy retrofit strategies for improvement. As they pointed out, using the default value creates a considerable variation in the amounts estimated. They examined 1172 buildings and compared their actual consumption with the estimation results according to the Swiss Cantonal Energy Certificate for Buildings (CECB). They found a negative 23% in actual energy consumption (more extensive than the estimated) in buildings without any retrofit. However, a positive 2% was achieved, meaning that the actual consumption was less than the estimated amount after some retrofits were applied to the buildings. This indicated a near overestimation of 37% in energy consumption of buildings. They also implied that proper energy savings can be calculated by comparing the real and estimated energy consumption, particularly after a retrofit application.

Few et al. [36] studied over 1374 gas-heated British households and compared the energy performance that British EPC modeling defined with annually measured values. They highlighted that A and B performance classes in the EPC system do not differ significantly. In contrast, the other classes' ratings are mismatched with the actual energy consumption and saving amounts. They laid out several reasons that caused the significant difference between the system results and the actual building's energy performances. These include the occupants' behavior differences (default use and post-occupancy use), inaccurate or lacking data input compared to the building materials' physical quality, false regulation methods in energy use calculations and overall building physics, and surveyors' errors in different issues. To understand the occupants' behavior effect on energy performance, Bakaloglou and Charlier [37] conducted a study to explain the energy performance gap from the socioeconomic aspects. They found that comfort over the economy was a significant driver of the difference, particularly for the poor households as they tend to encounter higher energy expenditures due to the poor energy performance of their houses, and this led them to limit their use (of gas), which dropped the amount of estimated consumption by up to 12%, which seems as saving but not from the aspect of buildings' physical conditions, which is the main target of the EPC scheme.

Crawley et al. [38] studied the differences in repeated evaluation results in the UK to highlight the assessment errors occurring in the EPC system. Their study found that 24% of houses rated in D class were rated as C class, 15% were rated as E class, 2% were rated as good as B class, and the other 2% were rated as bad as F class in their further assessments. Even worse, there were examples of houses reassessed from A to F class. This study proves the difference the surveyors' inputs make in the system. Dahlström et al. [39] wrote that around 30% of homes in the UK may be placed in the wrong energy class only due to surveyors disagreeing on input parameters such as wall type and building form. As Palladino [40] stated, the Energy Performance Gap (EPG) is a big issue that needs to be solved. Methods for EPG quantification or other correction methods should be examined and integrated into the EPC systems.

2.2.3. Perspective on the EPC System in the Building Sector: Who Cares about EPC?

Thinking from the perspective of the occupants, buyers, and builders in the market, the EPC needed to make the most of it in the last two decades, notwithstanding its legally declared energy policy goals. Otherwise, how would the main target be achieved if one cares about it? Accordingly, this section seeks the answer to this question.

Christensen et al. [41] investigated the Danish homeowners' experiences with the EPC and whether it influenced the decision on energy retrofit practices. They surveyed 738 living in a home with an EPC rating. It was found that the influence was minimal. A total of 68% remembered the recommendations they received with the EPC assessment, and the three recommendations most remembered were applying insulation in the roof and loft (66%), replacing with better quality glazing (52%) and applying insulation for walls (43%). A total of 32% of the 68% stated that they had not taken any action to apply any of the recommendations since then. Among the participants who applied renovations to their buildings, improving thermal comfort was the primary intention. A total of 90% remembered that they heard of the EPC mostly from an estate agent when buying the property. Collins and Curtis [42] focused on the benefits of the Irish BER system. They uncovered that the discrete performance thresholds in the system encouraged homeowners to upgrade their homes to achieve the next attainable threshold, which has a positive outcome for energy conservation. They highlighted this outcome as a lesson for other countries' EPC schemes to better structure their rating systems and also see this as an opportunity to educate homeowners and buyers on the importance of energy efficiency.

Chegut et al. [43] compared the influence of the EPC rating in England's and the Netherlands' markets. Their study revealed a severe effect on the market after 2015. In England, the EPC did not affect the values in 2012, while for 2015, a significant discount in values for D-, E- and F- relative to C-labeled dwellings was calculated. For the Netherlands, similarly, no significant relationship was found between energy efficiency and values in 2010, but in 2015, it was found that energy efficiency led to higher valuations. Properties with A and B energy labels displayed higher values than non-labeled or lower-labeled ones. Labeling added 7.1% more value to the property. Properties labelled with D to G had no difference in value compared to those with no label.

Dell'Anna et al. [44] utilized the hedonic price method to assess the effect of the EPC labeling on real estate market value and compared the results for two popular cities, Turin (Italy) and Barcelona (Spain). In Turin, almost all ads for sales had information about the EPC scores, whereas in Barcelona, this was provided in the notary process as mandatory information. Their study proved that buyers tend to pay for buildings associated with green characteristics. In Barcelona, each rating level from G to A increased the property price to 1.88%. In Turin, the model estimated an overall increase of 6.33%. Another outcome of the study was that buyers in the cold-climate regions tend to care more about the EPC rates and energy consumption. In contrast, those in the warmer-climate regions were not very interested in the predicted energy consumption for heating or cooling since they could handle it with air conditioning and swimming pools. The study of Marmolejo-Duarte and Chen [45] also found that each better rating increases the prices by 1.8%. A, B and C classifications help the prices climb by 7.5% on average for the building market and prices in Barcelona, Spain.

Murphy [3] researched to understand the influence of EPC assessment when buying or renting a property in the Netherlands. Since the EPC was first introduced in 2008, almost 30 thousand households were registered in the system, as they had an EPC rating for their properties. All were sent an online questionnaire, and only 10% of them stated that the EPC influenced their decision to buy their dwelling, and among this 10%, only 6 cases used the EPC to negotiate the property price.

3. Materials and Methods

This study investigates how the document was implemented in Turkey, the criteria of the buildings that received the certificate, their classification, the evaluation in the system and how the buildings were rated. The first stage of this study, which adopts the qualitative research approach, includes the review of the literature. At the end of this screening, inferences regarding the issues in the EPC systems of countries are made. At the end of this phase, a set of three research questions were derived as below:

I: What are the problems with the EPC system and calculation?

II: What are the problems in the process of issuing and auditing?

III: What is the perspective of the EPC system in the building sector?

A list of expert groups was identified (Table 1) as the study's second phase. The experts included engineers in private companies, municipalities and ministries in Turkey. When determining this group, the point was the inclusion of experts who were in charge in at least one of the implementation, control and certification stages. In this way, the inferences made through the literature review may be justified and elaborated in detail specifically to the Turkish EPC system. In total, eight semi-structured in-depth interviews were conducted by telephone calls. The interviewees received a short description and aim of the research at the beginning of the call. After their verbal consent, they were asked through an open-ended questionnaire regarding the list of questions above.

Table 1. The list of expert groups interviewed in this study.

	Profession	Company	Role in EPC System	City
1	Engineer	Private	Issuer	Bursa
2	Engineer	Private	Issuer	Bursa
3	Architect	Private	Obtainer	Bursa
4	Architect	Private	Obtainer	Bursa
5	Engineer	Public (Municipal)	Auditor	Kocaeli
6	Engineer	Public (Municipal)	Auditor	Kocaeli
7	Engineer	Public (Ministry)	Establisher	Ankara
8	Engineer	Public (Ministry)	Establisher	Ankara

In the third phase, a focus was made on the case of the EPC system in Turkey and the establishment through national standards and regulations was outlined to understand the progress in the energy efficiency targets of Turkey. As part of the outcomes of the interviews, exemptions in the EPC system, the evaluation of the system and ratings of the buildings were studied. This study revealed the problems and gaps in the EPC system in Turkey. The final review and recommendations for improvements in Turkey's case were made in light of the literature review in the discussion part.

4. Towards the EPC Establishment: The Case of Turkey

Nearly Zero Energy Building (NZEB) is an ambitious move, and all new public buildings should be NZEB in EU countries [1]. As part of the transition to the NZEB concept, the use of on-site renewable energy will be increased gradually after 2025, and by 2053, all buildings are aimed to be zero-energy buildings. As of 1 January 2023, NZEB must have an energy performance of B class or higher in the EPC system and meet renewable energy use (at least 10% of the building's primary energy need). Buildings with a total construction area of 2000 m^2 and above must be built as NZEB. It is obligatory to submit the EPC report prepared with the BEP-TR software, which shows the compliance of these buildings' architectural, mechanical and lighting projects with the regulation. BEP-TR expresses the energy performance class and rate of the building compared to the reference building, the greenhouse gas emission class and rate of the building compared to the reference building's primarily U-values for floors, roof, walls and windows varying into four climatic zones specific to Turkey, and the rate of RET systems used in the building [46]. With the Presidential Decree dated 16 August 2019, public buildings with energy managers assigned according to the Energy Efficiency Law No. 5627 are expected to procure energy savings of 15% until 2023, to use public resources efficiently and to reduce the burden of energy costs on the public sector [47].

Turkey has a "2053 net zero emission" target according to the country's environmentally oriented development goals. The Ministry of Environment, Urbanization and Climate Change has plans to protect nature and develop cities with the vision of a "Sustainable Environment, Civilization Living, Environmentally Respectful, and Climate-Friendly Cities". The strategic plans for 2023 and onwards include improving the BEP-TR and YES-TR software (V1.1) applications to reduce greenhouse gas emissions, ensuring energy efficiency and imposing the use of RET and the construction of NZEB by 2030 [48]. Turkey's Green Building Certification, similar to LEED, became legislation in 2022 [49]. Only four buildings received this certification in 2022; in 2023, 10 buildings received the Green Building Certification in Turkey [48]. In creating green buildings and settlements in Turkey, six modules have been defined regarding project planning, integrated design, preparation of construction documents, construction, control, commissioning and acceptance, operation, maintenance, measurement and facility management. The six modules include 'Integrated Building Design, Construction and Management' (BBT), 'Building Material and Life Cycle Assessment (YMD)', 'Indoor Environment Quality (IOC)', 'Energy Use and Efficiency (EKV)', 'Water and Waste Management (SAY)' and 'Innovation Building (INO) [50].

As of 1 January 2023, to reduce Turkey's energy import bill by TL 5 billion annually, it is obligatory to use 5% of renewable energy resources in parcels with a total construction area of more than 5 thousand square meters. As of 1 January 2025, it will be obligatory to expand this practice in all buildings over 2 thousand square meters and to provide at least 10 per cent of the energy used from renewable energy sources. Accordingly, as of 1 January 2025, the annual decrease in Turkey's energy imports is estimated to reach TL 7.5 billion [46]. It is aimed to save an average of 25 per cent from energy consumption by reducing the thermal need of the building. Increasing the minimum energy performance limit from "C" to "B" in buildings is aimed at improving the thermal insulation quality of the windows by increasing the thickness of thermal insulation materials from 5 cm to 7–8 cm in Istanbul and from 6 cm to 8–9 cm in Ankara [6]. Turkey has had a rapidly growing building stock as of October 2019. There are 9.5 million buildings, of which approximately 90% are residential. The number of housing units is around 24 million. According to occupancy permit statistics, more than 100 thousand new buildings are added annually to the building stock. High energy consumption in buildings is set to grow with continuous population growth and urbanization [7]. In this context, the government pushes possibilities to achieve energy savings in new buildings in addition to improving the energy efficiency of the existing buildings.

4.1. TS 825 Thermal Insulation Rules in Buildings

Since the adoption of the "TS 825 Thermal Insulation Rules in Buildings" standard on 13 February 1970, in Turkey, many mandatory regulations (Table 2) have been enacted to save on fuel consumption of buildings and reduce air pollution [8]. This is the first standard in the country to estimate the net energy needed for heating, set the related calculation models and define the limits of energy amount needed for a building in hand. It defines calculation models based on the coefficients and thermal U-values to be used for energy estimations. The EPC includes the titles of TS 825 Thermal Insulation Rules in Buildings and the calculation of energy needed for lighting, heating, cooling, ventilation, domestic hot water, photovoltaic, and cogeneration. This standard takes the U-value, which is a building unit's total thermal permeability coefficient ($W/m^2{\cdot}K$). The U-value depends on the heat transfer coefficient (λ) and the thickness of the direction of the heat transfer. The smaller the U-value is, the smaller the heat loss. The U-values in BEP-TR software are taken from TSE 825, which brings an average U-value depending on the thickness of the wall. The EPC system divides Turkey into four climate zones, and the U-value for each zone is given in Table 3. The detailed list of cities depending on the U-value is given in Appendix A.

Table 2. Energy and environment-related regulations in Turkey.

Regulation/Law Name	Date Enacted
Environment Law	11 August 1983
Energy Efficiency Law	2 May 2007
Central Heating and Hot-water Disperse Regulation	14 April 2008
Building Energy Performance Regulation	5 December 2008
Regulation on Energy Resources and Increasing Efficiency in Energy Use	27 October 2011
Building Materials Regulation	10 July 2013
TSE 825 Thermal Insulation Rules in Buildings	18 December 2013
National Energy Performance Calculation Method in Buildings	1 November 2017

Table 3. U-values defined for four climate zones in Turkey [51].

	UD $W/m^2{\cdot}K$	UT $W/m^2{\cdot}K$	Ut $W/m^2{\cdot}K$	UP $W/m^2{\cdot}K$
Zone 1	0.70	0.45	0.70	2.4
Zone 2	0.60	0.40	0.60	2.4
Zone 3	0.50	0.30	0.45	2.4
Zone 4	0.40	0.25	0.40	2.4

Energy Efficiency Law [52] forms the base of many contemporary energy-related regulations in Turkey. This law is comprehensive in terms of including the targets for energy savings by efficient production, use and distribution. Moreover, it targets diminishing the energy consumption's financial burden on the country's sources. Energy Efficiency Law forms the backbone of the Building Energy Performance Application, which is the software of the national calculation method used to prepare the EPC. It was introduced in 2011 with Version 1 (BEP-TR 1) as of the Building Energy Performance Regulation published in the Official Gazette on 5 December 2008 [53]. The second version of the BEP-TR program has started to be developed in line with the needs emerging throughout the process and has been in use since 2011 [9]. In this direction, Version 2 of the Energy Performance Application in Buildings (BEP-TR 2) was launched with the National Energy Performance Calculation Method in Buildings publication on 1 November 2017 [54].

4.2. Issuing of EPC in Turkey

In the current EPC system in Turkey, all new buildings and existing buildings are required to be issued with an EPC assessment, with exceptions given below:

- Buildings where production activities are carried out in industrial areas;
- Buildings designated with less than two years of lifetime for use;
- Buildings with less than 50 m^2 in total area;
- Agricultural buildings, greenhouses, and ateliers;
- Buildings built as single blocks do not require heating or cooling, including depots, warehouses, armouries, barns, etc.;
- All buildings in service for the Turkish Armed Forces, Ministry of Civil Defense and National Intelligence Service;
- Buildings with less than 1000 m^2 and located in the outer zone of any municipality;
- Buildings in service for worship;
- Buildings used for less than four months in a year;
- Heritage architecture and buildings under conservation.

Anyway, new buildings located in the outer zone of any municipality, built for habitation and up to two stories with less than 100 m^2, are not required to have U-values less than the standard of TS 825 defined and are not required to have a thermal insulation project unless the portion of total window area is 12% or less than the area of exterior walls. It is also not required to have a registration for thermal insulation applications for existing buildings to upgrade their energy performance class at least to C. If an existing building is planned to be installed with a solar renewable energy system only to provide its own energy needs, registration is not obligated.

All new buildings other than these exemptions are required to have at least C class in the EPC system. Existing buildings registered before 1 January 2011 are now required to have an EPC assessment as of the regulation in 2017. While existing buildings are also required to have an EPC, there is no minimum threshold requirement they must achieve. The assessment is valid for ten years, and if no EPC is documented in the registration, then no occupancy permission is allowed for that building. The requirement to present the EPC assessment before the sale and the rent was enacted after 1 January 2020.

For issuing EPCs, the registered architects, civil engineers, mechanical engineers, and electrical and electronics engineers are eligible after completing 24 h of theoretical education delivered by the Union of Chambers of Turkish Engineers and Architects. EPC experts also deliver the education. The education includes modules regarding the concept of energy efficiency, all the related regulations and laws, technical information on how to use BEP-TR software, with its two further applications, BEP-BUY and BEP-IS, and how to use the reference building for assessment and the interpretation of the final sheet of EPC. After completing their education, they are assigned as experts and registered in the Ministry of Environment, Urbanism and Climate Change system of Turkey.

In Turkey, EPC consists of three pages (Appendix B). The first page (Figure 2) contains information about the building, the image of the building, the energy consumption of the building, its energy performance and greenhouse gas emission classification, and information about the expert and the company that issued the document [9]. Net energy means the rough amount of energy demanded to heat and cool the whole building without considering the losses and efficiency of the mechanical systems in the building. The essential inputs required to estimate the net energy demand to heat and cool the whole building are given below:

- Local climate data;
- Building geometry;
- Features of the ventilation and thermal conditions of the building;
- The internal energy gain and solar power gain for the building;
- Description and features of the building materials and units;
- Conditions of the internal comfort of the building depend on the function (the amount of ventilation, humidity and heating);
- The information on zones and zone features depends on the building typology.

In the BEP-TR system, nine different building typologies are used for modeling, and there are 39 zone types in total defined under each building. Defined building types in BEP-TR 2 are detached houses, apartments, residences, offices (workplace, public), hospitals, education, hotels and shopping malls. The second page contains detailed information about the building materials, construction and the building envelope system in illustrations. The third page separately lays out the categorical scale of each parameter (heating, hot water, cooling, ventilation, lighting, co-generation and photovoltaic systems) that builds the base for the total energy performance categorization [9].

Total building area refers to the area that is modeled in the system. Areas such as balconies, terraces, etc., are not included in the model; hence, this amount can differ from the area declared for the total construction area. If the construction area is more than 2000 m^2 for new buildings, it is obligated to project a central heating system. For hospitality buildings, such as hotels, dorms, hospitals, and sports complexes, it is obligated to provide a central hot water supply system powered by solar energy. If the total cooling energy is greater than 250 kW for a building, except for residences, it must project a central cooling system.

Figure 2. The first page of EPC results in Turkey.

5. Findings of the EPC Case of Turkey and Recommendations

5.1. Status-Quo of EPC in Turkey and Models for EPC Scores

According to the data that interviewees #7 and #8 from the Ministry of Environment and Climate Change provided, the current distribution of the classes in the EPC system shows that the majority share belongs to A, B and C certificates (Tables 4 and 5), considering the valid class is C for all types of buildings. The use of RET is 7.61% among the total certificated buildings for the years between 2011 and 2022, but the use of RET increased, as the data up until March 2023 show that the value reached 8.51%. The number of buildings using RET increased by approximately 10,000. The number of EPCs generated for new buildings forms 75% of all certifications.

Table 4. The distribution of EPC classes in numbers is up to date depending on the building types (the data acquired from interviewees #7 and #8 in March 2023).

Status of the Building	EPC Classification				
	A	B	C	D	Total
Existing Building	70	50,711	184,562	72,842	345,967
New building	3493	317,202	816,744	-	1,123,065

In Turkey, residential buildings constitute 82% of the total building construction area. Single-family houses form 17% of the total, whereas multi-family apartments form 65%. The remaining 18% includes commercial, public, educational, hospitality and healthcare buildings [56]. The Turkish building stock has substantial energy-saving potential. EPC systems are significant energy policy procedures and can be reasonable solutions for determining the energy-saving potential [51].

As interviewees #7 and #8 indicated, in Turkey's EPC system, a reference model with a natural-gas-sourced heating system is used to evaluate the case study. In the pilot case studies from the educational documents of BEP-TR, the results reveal scores, as seen in Table 6. These pilot case studies were interpreted with the interviewees #1 and #2. To explain, in case a building uses coal for heating and hot water, it receives D. In case a building uses natural gas for heating, it receives C, and if it uses natural gas for hot water, it receives D. This suggests that using natural gas is acceptable for heating. However, it is unacceptable for hot water in the case of Turkey, considering the potential use of electricity-sourced heat pumping systems and solar water heating systems. As seen in Case Study 1, the building with the heating system of the electricity-sourced heat pumping resulted in A, as was the case in the total score. This is also because the building uses a boiler-assisted heat pumping system (natural gas sourced) [9].

Table 5. The distribution of EPC classes in numbers up to date [55].

EPC Classification	Total for Years between	2023 *		
	4 July 2011–31 December 2022	January	February	March
A	3609	9	6	5
B	338,279	2237	1613	2388
C	988,624	5924	4445	5544
D	76,699	80	75	80
E	26,777	49	35	46
F	10,423	9	9	13
G	2024	0	0	0

* The numbers change daily because the system automatically drops the rated building if the certificate exceeds ten years of validation.

Table 6. The pilot case studies from the educational document of BEP-TR [9].

System	Case Study 1 Office Building	Case Study 2 Detached House	Case Study 3 Multi-Family Apartment
Heating	A (Boiler assisted Heat pumping—Natural gas sourced)	C (advanced condensing boiler—Natural Gas)	D (Fossil fuel boiler-coal sourced)
Hot water	A (Heat pumping—Electric)	D (advanced condensing boiler—Natural Gas)	D (Fossil fuel boiler-coal sourced)
Cooling	D (Central air cooling)	F (Split system)	C (Split system)
Ventilation	G (Supply and exhaust system)	D (System N.A)	D (System N.A)
Lightning	B (Compact fluorescent + fluorescent)	C (Compact fluorescent)	G (Compact fluorescent + fluorescent + Incandescent light bulb)
Co-generation	Not applied	Not applied	Not applied
Photovoltaic	142 sqm	Not applied	Not applied
Total Score BEP-TR	**A**	**C**	**D**

However, to obtain A or B, using RET, e.g., heat pump air-sourced or solar-sourced, is compulsory. Solar energy power systems can be included in new buildings at the design stage. However, there are legal obstacles to building and using this kind of system as a whole or partially for the existing buildings. All households must agree and sign to install solar power panels on the rooftop of a multi-family apartment building.

The estimation in BEP-TR software has a detailed background; however, the outcome is not precise since only seven classes exist in the system. Appendix E gives the limit values for energy consumption for heating in EU standards and on a generic EPC scheme. In Turkey, the EPC final sheet only gives the overall performance result between 0 and 100, defined with a label at the end. This is the most easily captured understanding from the certificate. Secondly, the CO_2 emission estimation result is also given in an easy-to-read format, highlighting the carbon footprint.

Nevertheless, the performance based on the primary energy consumption, the leading data to label a building with a class, must be in a more easy-to-understand format. The Turkish EPC system uses the limit values given in Table 5. However, the estimations in BEP-TR are conducted by calculating the datasets in Appendices C and D. The Reference Indicator based on the primary energy source depends on the climate zones (considering the geographical differences). The type of buildings and the Energy Index (EI) based on the primary energy consumption is calculated according to Appendix E, which leads to labeling a building with an energy performance class. The final sheet has only the estimation result, but without showing the class range the building is labeled with. For example, A class indicates an overall performance between 0 and 39, B from 40 to 79, C from 80 to 99, and D from 100 to 119. In this regard, the classes of A, B and C in the Turkish EPC system cover quite a wide range of energy performance. In addition, the overall rating from A to G is calculated cumulatively by considering the performance of CO_2 emission, the Energy Index (EI) and the share of the energy savings from renewable energy systems, if they exist. Therefore, one cannot understand purely the effectiveness of the primary source of energy consumption and also cannot see how exactly the building performs within its class. For example, if it is labeled with B class, then to what extent does the Energy Index (EI) of the primary source of energy consumption affect the result? Would it be possible to upgrade to A with minor adaptations, or would the result be closer to the range of C class, so no modifications would be worth dealing with?

Currently, similar to the majority of EU member states' EPC applications, it is not compulsory to obtain EPC for factories and manufacturing buildings, buildings with temporary use (less than two years), buildings with less than four months of use in a year, buildings with areas less than 50 m^2, and agricultural buildings. However, Turkey is a hotspot for vacation time, particularly among visitors from EU countries and local tourists. Therefore, buildings planned for summertime use urge high energy consumption for cooling through air-conditioners and hot water. Disruption in the grid system is often experienced depending on the exceeding temporary population since the electricity infrastructure is built according to the permanent population's needs. Such niche concerns should be met in the EPC system, at least for the new buildings.

5.2. Recommendations for the EPC System in Turkey

The EPC system needs improvements technically and to be structured according to country-specific issues to capture the estimations more accurately. This section aims to bring a collective list of recommendations based on the literature and to the system in Turkey since it is understood that the rating of the EPC system in Turkey is not adapted to the country's requirements, which lays out similar handicaps in capturing the energy performance thoroughly. The EPC in Turkey has seven ratings from A to G, just like the generic model. However, some countries, such as Ireland and Portugal, have developed a detailed structure to reveal a more accurate labeling system for their benefit. Accordingly, the first suggestion should be to improve the rating structure in the certification system to better classify buildings according to their energy performances.

5.2.1. Problems in the EPC System and Calculation

It is possible to receive an A from EPC without using any RET. This does not overlap with the Ministry's goal for 2030. A class should not be issued for buildings without RET. If the energy performance of the building rates is high, A, B and C classes can have sub-levels, i.e., A1, A2, A3, B1, B2, B3 and C1, C2, C3, like in Ireland. RET use is obligatory only for buildings with over a certain area. Instead, adopting RET should be encouraged for all types of buildings, as was the case for interviewees #1, #2, #3, #4, #5 and #6. Furthermore, it is also arguable whether the EPC measurement reflects the actual energy consumption or energy savings in systems. This highlights that a more detailed measurement scale needs to be developed, particularly considering the country-specific geophysical features.

Remarkably, the classes indicating high energy performance are defined with their subcategories for Irish BER system A, B and C classes and Portuguese EPC system A and B classes. Knowing that the C class is the essential category that must be fulfilled for new constructions in most of the EU countries and also in Turkey, such detailing of high-performing classes could bring a better understanding of which unique details and installation differences in building lead to less energy consumption overall. For the Portuguese EPC system, the C class is defined as the base of energy consumption in an acceptable range from 100% to 150%, which indicates that better-performing classes in A and B consume less energy in percentage. In detail, B- consumes less energy between 75% and 100%, B consumes less energy between 50% and 75%, A consumes less energy between 25% and 50%, and the top performer, A+, consumes less than 25% of what C consumes. In the Irish BER system, the C class with acceptable energy consumption of 100% equals the B2 class, energy consumption of 125% equals B3, and energy consumption of 150% equals C1. C2 and C3 define 175% and 200% energy consumption, respectively. The B1 class defines less energy consumption as 75%, the A3 class defines less energy consumption as 50%, A2 defines less energy consumption as between 50% and 25%, and the top performer, the A1 class, defines energy consumption as less than 25%. Similarly, Kwiatkowski and Rucinska [57] suggested adding an A+ class in the Polish EPC system to encourage the transformation of buildings to reach better energy performances.

Passive systems are critical in terms of energy efficiency. The suitable systems, the right materials and insulation details, and the use of climate-sensitive designs and passive systems should be underlined, and both architects, engineers, and all building sector actors should be conscious of this issue. It should be mandatory to prepare reports on the passive system used in EPC, as interviewees #1, #2, #3 and #4 highlighted. For example, correct lighting is vital during the day in classrooms. No need for artificial lighting reduces energy consumption. Window sizes and numbers should be evaluated regarding lighting [58]. In Turkey, it is positive to have a building design with south-facing openings in terms of energy efficiency. However, in the current model, lighting does not influence the overall rating score as much as heating and hot water systems do. Moreover, rather than insulation systems, the façade openings and windows are more significant players in receiving higher EPC ratings.

A design guide for architects who do not hold a license for EPC evaluation can be prepared to provide recommendations to benefit at the early design stages, as interviewees #3 and #4 indicated. This guide can include various recommendations under “must have” and “nice to have” to achieve better energy performance. This would be useful for architects without a license who require an engineer’s consultation regarding the EPC rating at the end of the design stage because, at the end of the design stage, it is often too late to consider and adjust the project according to the results of the EPC evaluation.

Despite 39 zone types in the BEP-TR system, geographical differences exist within the same province. For example, as interviewees #1 and #2 stated, in Bursa, the district of Karacabey displays different climatic conditions for the coastal area and in the forest area that may affect the energy performance of the buildings. However, in the current zoning types, this difference needs to be considered. Further zoning investigations should be conducted and included in Appendix A.

5.2.2. Problems in the Process of Issuing and Audit

Koengkan et al. [59] highlight that the literature does not explore the determinants of EPC in Portugal, and there is a need to better understand the relationships between these determinants in a country-specific context. The issue is the same for Turkey. There needs to be more research in the literature to uncover the problems regarding the energy performance gap and the weight of the primary energy consumption for heating, hot water, cooling, ventilation, lighting, cogeneration and photovoltaic, although they appear in the system. As one of the significant coal-mining countries, having a natural-gas-sourced heating system in Turkey is considered a better performance, whereas most European countries aim to decrease and possibly abandon utilizing natural-gas-sourced heating systems in their buildings. Despite the EPC system referring to renewable energy use in buildings, there needs to be more incentive to make builders and buyers care about such systems. It should be promoted for new building construction to install renewable mechanical systems for energy consumption, such as photovoltaic panels, heat pumping systems and solar collectors. This type of investment by private sector builders can be promoted by reimbursing some amount of the investment by the municipalities, or the EPC can be delivered for ten years duration while conventional buildings with no renewable energy systems receive their certificate for five years or less and expect to upgrade until the renewal stage. In addition, according to Turkey's regulations, obtaining an EPC to rent and sell properties as of 1 January 2020 is required. However, in practice, the process is skipped and not inspected strictly, as interviewees #5 and #6 implied. This regulation must be enforced immediately.

There is also another lacking part in the Turkish EPC system: no list of recommendations is attached to the EPC report. Caceres [60] underlined that for existing buildings, a list of recommendation measures should be proposed to outline the possible cost-optimal or cost-effective improvement of the energy performance of a building. Ferrantelli and Kurnitski [61] focused on the effect of renovation of historic buildings in Europe and its share in achieving the target of energy performances. They concluded that if the renovation of existing buildings was completed on time, it would be possible to meet the European Climate Target Plan by 2033. The EU countries favor renovations of buildings from G to F by 2027–2030 and from F to E by 2033. Hence, the renovation of the existing building stock is of paramount interest to achieve the EU's paramount objective, which is to combat climate change.

In Turkey, new buildings with a construction permit after 1 January 2011 must have at least C-class energy consumption and CO_2 emissions. In our experience, it appears better to have shorter validation to ensure some improvements in the buildings, particularly for B and C classes. B and C should be validated for five years instead of ten years. The owners and occupants should be expected to improve the building's energy performance to receive a better class in the following evaluation after five years, i.e., C can receive B, B can receive A, or there can be detailed classes as exemplified by Irish and Portuguese systems. Compared to LEED, a new building can receive a green building certificate valid for life, but LEED certification must be renewed every three years for an existing building. A similar approach can be adopted for the case of Turkey. Platten et al. [62] also indicated a similar suggestion. They highlighted that since the validation of ten years had passed for some buildings, it should be looked at how the occupants adapted their buildings during this period for better energy performances, whether they took actions or not, before issuing a further ten-year certificate.

Any architect or engineer who succeeded in the EPC education provided by public or private enterprise becomes a licensed EPC evaluator. This can lead to misuse. In the current regulation, it is strictly stated that if such a case is detected and proven, the license of the expert is suspended, and the information of the expert and the project are sent to the Ministry, to the local authority in charge and the Chamber of Engineers and Architects. If the misuse is detected three times in one year, the license is cancelled for a lifetime. Although this is well thought through in the regulation, further mechanisms of control should be developed, e.g., independent inspectors can be assigned to the projects anonymously through the system of BEP-TR. According to interviewees #1 and #2 as engineers and #3 and #4 as architects, the input of the building information into the system is only completed by the licensed evaluator. However, there is no further on-site inspection to check the input data and construction. For example, as the interviewers indicated, the licensed evaluator enters the information on heating systems, ventilating systems and thermal insulation values. However, the on-site construction can vary far from the input values. Interviewees #5 and #6 confirmed and highlighted that there is no legal obligation to inspect the system information and the building construction on site. It remains to their sensitivity and ability to take initiatives considering this issue.

5.2.3. Perspective on the EPC System in the Building Sector

Considering that Turkey is a popular tourism destination with its Aegean and Mediterranean coasts for holidaymakers, it often comes into the discussion that the population of urban areas on these coasts (e.g., Bodrum, Marmaris, Kuşadasi, etc.) increases rapidly, and this causes a sharp electricity demand (for hotels, villas, summer apartments and so on). In that case, the infrastructure becomes insufficient to power all demand. As seen in the exception list of buildings in 4.2, summer apartments and tiny houses built outside the municipality areas do not require EPC validation. Many hotel buildings do not have their self-sufficient renewable energy systems. Although the cities on these two coastlines are mostly categorized in the same category (Appendix A: 1. Zone), they need a particular and specific requirement. The lack of thermal insulation in most of the existing buildings is a serious obstacle to achieving the energy targets in Turkey. There is a loan system for applying thermal insulation to the existing building, but this scheme should be promoted well. This approach should be adapted to similar issues specific to local priorities according to regional differences in Turkey. In addition, for the spread use of solar heating systems (e.g., the hybrid thermosolar system) [63] instead of fossil-fuel-sourced systems in residential buildings, further financial models and loans should be developed; region-based investment reimbursement or investment share models can be developed. Energy is an issue for rural areas, and ground-sourced heat pumping systems can also be encouraged to be used instead of coal or other fossil-fuel-sourced heating.

It is also a new argument that the EPC system can be used for developing better urban energy performance. Johansson et al. [5] highlighted that the EPC dataset can be used for road maps and can be integrated into urban models to reach the national target of energy use on the city/district level as they examine a Municipal Energy Model in their research. They suggest that developing urban energy models can be a valuable tool for decision-makers, real estate companies and urban planners. Johari et al. [64] wrote that Urban Building Energy Models (UBEMs) can be considered as applicable tools for urban energy planning. Dahlström et al. [39] brought into discussion the data used from EPC systems for developing UBEMs. As they suggested, UBEMs can be applied to quantify and forecast the future energy demand in the entire building stock. They can also be used to design new urban energy systems based on new climate change adaptation scenarios. There is an increasing demand for studies focusing on such scenarios and to show how potentially UBEMs can help us design our future energy-efficient cities. Pasichnyi et al. [29] reviewed the studies published regarding the issues in the EPC systems and the studies employing EPC datasets as auxiliary data to drive beneficial results for larger-scale use (e.g., investment analysis, energy planning, decision-making in the real estate market, etc.) and to improve the lacking parts of the system (e.g., EPC data validation and quality assessment, performance gap, predicting future energy and CO_2 emissions, occupant behavior influence on building energy performance and design of new buildings, etc.). Unlike existing buildings, BEP-TR can be improved and developed with Building Information Modeling (BIM) systems for new buildings. This can provide a more transparent process for appropriate inspection between the registration offices and the EPC evaluation system.

Last but not least, even though there are studies to reveal the impact of the EPC system on the building sector in terms of defining property values, no such study was found for Turkey. It would be beneficial to conduct more research to understand the influence of EPC assessment when buying or renting a property in Turkey.

6. Conclusions

This paper reviewed the development of the EPC in EU member states and Turkey. The paper discussed the utilization of the EPC on the urban scale in Turkey, the identification of the existing problems and shortcomings in the current EPC system and a list of proposals for future improvements of EPC. In Turkey, adopting the EPC system mainly follows the EU member states' cases. The original software BEP-TR is widely used since issuing an EPC is mandatory for new and existing buildings. The paper reviewed the problems with the EPC system and calculation (the software background, the rating structure, and geographical and technical differences), the problems in the process of issuing and audit (overestimations with real data), and the perspective of the EPC system in the building sector from occupants, buyers and the builders, to provide improvements.

Energy efficiency can begin from the buildings in cities since the occupants consume excessive energy. Several factors contribute to excessive consumption, such as thermal comfort, the number of pieces of electrical equipment, the local climate conditions, etc. EPC can play a role other than just being a rating system and a paper with adaptations according to requirements and sourcing lacking parts. More country-based and region-based scientific research needs to be conducted with more extensive data, and local authorities and municipalities should fund such studies. This paper illustrates the energy dependency of Turkey. The energy production and consumption habits must be replaced with those provided primarily with renewable and environmental energy sources. Local authorities, mainly the municipalities, have the potential to move towards productive energy management and start by transforming their headquarters with such infrastructure and educating their personnel. In addition, more extensive financial loan schemes should be developed to address local priorities differing from country to country and on a smaller scale, as in Turkey. The expert interviews revealed significant outcomes. The first one is that a focus should be made on using renewable energy, considering Turkey's geographical advantage. The second one is that a more detailed micro-zoning study is required, considering the country's regional differences. As the third one, the authorities should introduce a better control mechanism for the EPC system. Even with the requirement of obtaining EPC to rent and sell properties as of 1 January 2020 in Turkey, in practice, the process needs to be completed and inspected more strictly. This regulation must be enforced immediately. The article also brings further suggestions for developing EPC in Turkey to make it comparable with the systems in EU countries.

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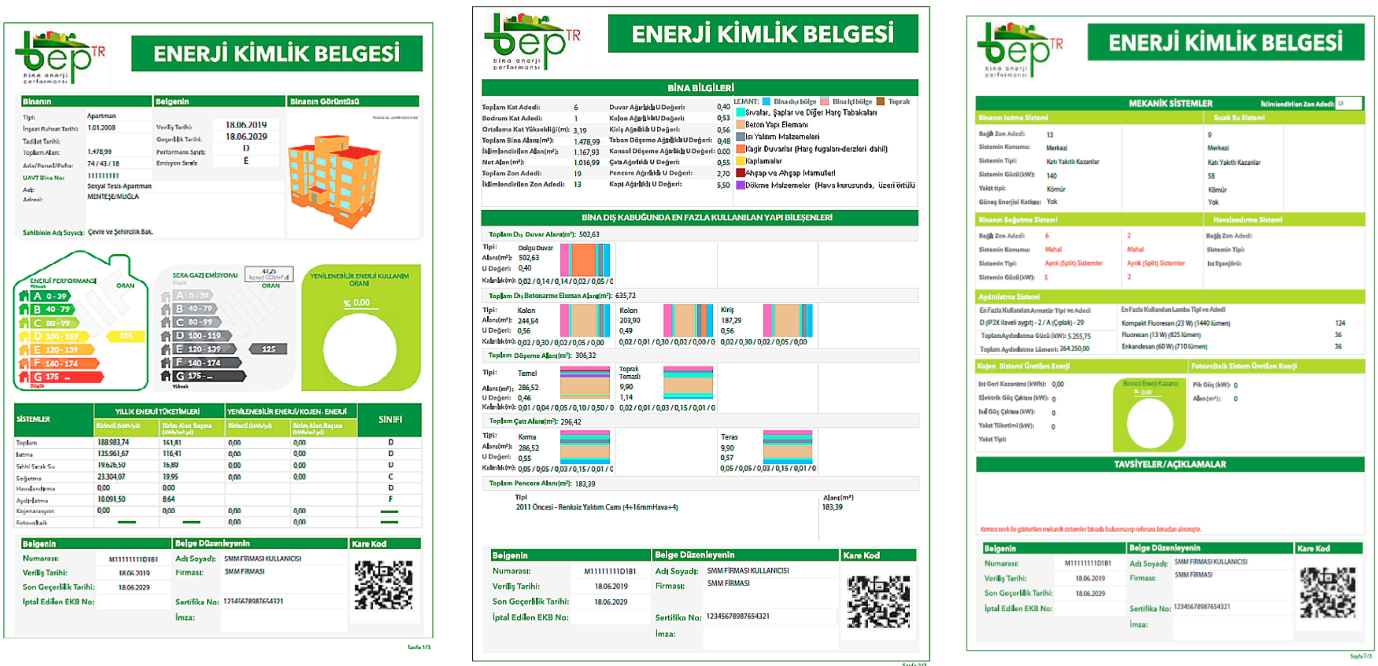
Appendix A

The table shows the categories of cities and some municipalities for daylight/climate differences as used in the EPC system in Turkey. It currently has 81 cities.

Categories of Cities and Some Municipalities for Daylight/Climate Differences in EPC
1. **Zone:** Adana, Antalya, Aydın, Hatay, Mersin, İzmir, Osmaniye **Exceptional municipalities (despite the city it belongs to is 2. Zone):** Ayvalık (Balıkesir), Dalaman (Muğla), Fethiye (Muğla), Marmaris (Muğla), Bodrum (Muğla), Datça (Muğla), Köyceğiz (Muğla), Milas (Muğla), Gökova (Muğla)
2. **Zone:** Sakarya, Çanakkale, Denizli, Kilis, Rize, Trabzon, Adıyaman, Samsun, Kahramanmaraş, Yalova, Amasya, Diyarbakır, Kocaeli, Siirt, Zonguldak, Balıkesir, Edirne, Manisa, Sinop, Düzce, Bartın, Gaziantep, Mardin, Şanlıurfa, Şırnak, Batman, Giresun, Muğla, Şırnak, Bursa, İstanbul, Ordu, Tekirdağ **Exceptional municipalities (despite the city it belongs to is 3. Zone):** Hopa (Artvin), Arhavi (Artvin) **Exceptional municipalities (despite the city it belongs to is 4. Zone):** Abana (Kastamonu), Bozkurt (Kastamonu), Doğanyurt (Kastamonu), İnebolu (Kastamonu), Cide (Kastamonu), Çatalzayetin (Kastamonu)
3. **Zone:** Afyon, Ankara, Aksaray, Artvin, Bilecik, Bingöl, Bolu, Burdur, Çankırı, Çorum, Elazığ, Eskişehir, Iğdır, Isparta, Karabük, Karaman, Kırıkkale, Kırklareli, Konya, Kütahya, Malatya, Nevşehir, Niğde, Tokat, Tunceli, Uşak, Bolu. **Exceptional municipalities (despite the city it belongs to is 1. Zone):** Pozantı (Adana), Korkuteli (Antalya) **Exceptional municipalities (despite the city it belongs to is 2. Zone):** Merzifon (Amasya), Dursunbey (Balıkesir), Ulus (Bartın) **Exceptional municipalities (despite the city it belongs to is 4. Zone):** Tosya (Kastamonu)
4. **Zone:** Ağrı, Ardahan, Erzurum, Kayseri, Muş, Gümüşhane, Bayburt, Hakkari, Sivas, Erzincan, Kars, Kastamonu, Van, Yozgat, Bitlis **Exceptional municipalities (despite the city it belongs to is 2. Zone):** Keles (Bursa), Uludağ (Bursa), Afşin (Kahramanmaraş), Şebinkarahisar (Giresun), Elbistan (Kahramanmaraş), Göksun (Kahramanmaraş), Mesudiye (Ordu) **Exceptional municipalities (despite the city it belongs to is 3. Zone):** Kığı (Bingöl), Pülümür (Tunceli), Solhan (Bingöl)

Appendix B

The three-page structure of EPC results in Turkey (in Turkish).



Appendix C

The Reference Indicator based on the primary source of energy (RI) in (kWh/m^2-year). Degree zones can be checked in Appendix A.

Building Types	*Function/Use*	*1. Degree Heating Zone*	*2. Degree Heating Zone*	*3. Degree Heating Zone*	*4. Degree Heating Zone*
Residences:	Single-family houses Twin family houses	165	240	285	420
	Multistorey Apartment blocks	180	255	300	435
Service buildings:	Office and Bureau buildings	240	300	360	495
	Education buildings (Schools, Dormitories, Spor complexes etc.)	180	255	300	450
	Health facilities (Hospitals, Nursing homes, Orphanages etc.)	600			
Business buildings:	Hotels, restaurants etc.	540			
	Shopping malls	750			

Appendix D

The Energy Index (EI) based on the primary energy consumption.

Energy Performance Category	Energy Index Based on the Primary Energy Consumption (EI)
A	EI < 0.4 × RI
B	0.4 × RI ≤ EI < 0.8 × RI
C	0.8 × RI ≤ EI < RI
D	RI ≤ EI < 1.20 × RI
E	1.20 × RI ≤ EI < 1.40 × RI
F	1.40 × RI ≤ EI < 1.75 × RI
G	1.75 × RI ≤ EI

Appendix E

The limit values for energy consumption for heating in a generic EPC system with EU standards.

Energy Efficiency Class	Limit Values for Energy Consumption for Heating EU_H (kWh/m^2)		
A		$EU_H \leq$	45
B	45	$< EU_H \leq$	65
C	65	$< EU_H \leq$	95
D	95	$< EU_H \leq$	130
E	130	$< EU_H \leq$	185
F	185	$< EU_H \leq$	265
G	265	$< EU_H \leq$	

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