Turkish Journal of Electrical Engineering & Computer Sciences

http://journals.tubitak.gov.tr/elektrik/

Research Article

Turk J Elec Eng & Comp Sci
(2016) 24: 4839 – 4848

doi:10.3906/elk-1407-87

Assessment of energy performance certificate systems: a case study for residential buildings in Turkey

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Received: 16.07.2014 • **Accepted/Published Online:** 18.09.2015 • **Final Version:** 06.12.2016

Abstract: The importance of sustainable development and energy efficiency efforts has increased in the construction sector. Energy-saving efforts for buildings have become more important due to the global energy crisis, and energy rating systems have been developed globally for assessment of energy performance. In this study, international green building certificate and energy performance certificate (EPC) systems are presented. The official EPC system for buildings in Turkey is illustrated with case studies. Energy consumption and greenhouse gas emissions from residential buildings are calculated using the official national software, which is called BEP-TR. The impact of lighting on the total energy performance of residential buildings is also examined. Changes in energy performance values are discussed for various cases. As a result of this study, it was determined that residential buildings constructed before 2000 consume more energy than those constructed after 2000; they are a lower energy performance class of buildings. Use of energy-saving lamps has also had a positive impact on both lighting and total energy performance classes. This paper aims to contribute to the promotion of building energy certification systems and energy efficiency issues for the construction sector.

Key words: Building, energy performance certificate, lighting, energy efficiency

1. Introduction

Energy performance rating systems and energy efficiency activities have become more important for the construction sector due to the global energy crisis and climate change [1,2]. Today, buildings are responsible for about 40% of worldwide energy consumption, and the volume of the residential sector will increase to 67% by 2050. In order to reduce energy consumption and minimize environmental pollution from buildings, countries have begun to develop green building rating and energy performance certification (EPC) systems [3–5]. As a result of increasing interest in addressing global problems, a variety of standards and regulations are being prepared [6]. These rating and certification systems include various topics such as high performance, energy efficiency, health, and environmental sustainability [7,8].

There are a number of building assessment tools in the literature. The Building Research Establishment Environmental Assessment Method (BREEAM) was the first of these green building certification systems, introduced by the Building Research Establishment (BRE) in England. Leadership in Energy and Environmental Design (LEED, USA), Green Mark for Buildings (Singapore), the Hong Kong Building Environmental As-

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sessment Method (HK-BEAM) and Comprehensive Environmental Performance Assessment Scheme (CEPAS, Hong Kong), the Comprehensive Assessment System for Building Environment Efficiency (CASBEE, Japan), EcoProfile (Norway), PromisE (Finland), Green Star (Australia), SBAT (South Africa), and Environmental Status (Swedish) are some widely known green building rating systems [9–14]. They are generally voluntary procedures intended to promote sustainability. There are various simulation programs for green building design that can be applied in many countries. On the other hand, some countries have implemented their own EPC classification systems, and they use their own software programs for calculating energy performance levels. EPC systems are also mandatory in many countries [15–19]. EPCs give information about heating, cooling, hot water, ventilation, lighting, and CO_2 emission values of buildings; they are required during the processes of purchasing, selling, and leasing buildings. In addition to EPCs, experts must be involved, consisting of architect and engineer groups [20].

There are many studies of green building rating systems in the literature. Son and Kim developed a model to predict the cost and schedule performance of green building projects [21]. Stankovic et al. compared LEED, BREEAM, and CASBEE in terms of lighting design criteria [22]. Lee and Burnett compared the HK-BEAM, BREEAM, and LEED certificates with each other [23]. Donghwana et al. examined the influence of LEED certification on urban temperature [24]. Wong and Abe examined the perceptions, motivations, incentives, and barriers of the CASBEE certificate system [25]. Ali and Al Nsairat studied international green building assessment tools and then suggested new assessment items for Jordan [26].

Several researchers concentrate on EPCs for buildings. Andaloro et al. examined the extent to which EPC systems have been implemented by EU countries [27]. Stankevicius et al. examined the arrangement of the building certification system in Lithuania [28]. Murphy investigated the influence of EPCs in the Netherlands [29]. Gelegenis et al. evaluated EPCs in Greece in terms of market trends [30]. Tronchin and Fabbri reported on the EPC systems and relative energy ratings of buildings in Italy [31]. Christensen et al. examined Danish homeowners' experiences with EPCs [32].

Previous studies on energy performance rating systems for buildings have involved the impact of the certification systems. However, the EPC system in Turkey has not been considered in these studies. This paper focuses on the official EPC system for buildings in Turkey. In this study, different case studies are considered for the calculation of the energy performance of buildings. Total energy performance classes and energy consumption of residential buildings are analyzed. Official national software is used during the building simulations. Changes in energy performance levels are discussed. The aim of the present study is to comprehensively assess the EPCs in Turkey. The results of this study contribute to a better understanding of the energy efficiency potential of residential buildings by examining the EPC systems.

The remainder of this paper is organized as follows. In Section 2, reviews of the energy performance certification procedure are given. In Section 3, data collection and case studies for the energy performance analysis of buildings are described. Section 4 gives the results of this analysis. The conclusion of the study is presented in Section 5.

2. EPC procedure for Turkey

A number of standards and regulations for buildings are being prepared due to the increasing interest in energy efficiency activities. EPCs became mandatory for European countries under the Energy Performance Building Directive (EPBD, Directive 2002/91/EC) in 2006 [33–35]. In this context, many legal arrangements were made in Turkey, such as the Energy Efficiency Law, Regulation of Energy Performance of Buildings, Regulation of Promotion of the Energy Resources and End-Use Efficiency, and the Energy Efficiency Strategy Paper. EU Directive 2002/91/EC on the energy performance of buildings was used during the preparation of these regulations. In these government schemes, the aim is to reduce energy intensity at least 20% by 2023 [36–39]. One such building energy efficiency activity is the EPC system in Turkey. This application was started 1 January 2011. Primary energy consumption and greenhouse gas emissions (GHGs) are expected to be limited with this application. EPCs give general information about a variety of topics such as building area, energy performance classes, GHGs, and annual energy consumption for heating, cooling, ventilation, hot water, and lighting of buildings. Buildings constructed before 1 January 2011 are defined as existing buildings, and those constructed after are defined as new buildings. The EPC will be required for all existing buildings by 5 February 2017 at the latest [40]. In the EPC system, the energy classification of buildings is based on 5 classes, from A to G. Class A refers to the lowest energy consumption and class G refers to the highest energy consumption. The energy performance classification of new buildings has to be class C or better. EPCs are valid for 10 years from the date of issue and are required during the processes of purchasing, selling, and leasing buildings [41]. EPC experts have to be certified by an accredited foundation, and they have to be architects, civil engineers, mechanical engineers, electrical engineers, electronics engineers, or electrical-electronics engineers [42].

The calculations of the energy performance class in the EPC are based on the BEP-TR, which is the official national simulation software of Turkey. This software was developed for the assessment of energy efficiency and determination of the energy performance of buildings; it runs on a web server. EPC experts calculate the energy performance of buildings with this software [43,44]. Design stages of the EPC are given in Figure 1.

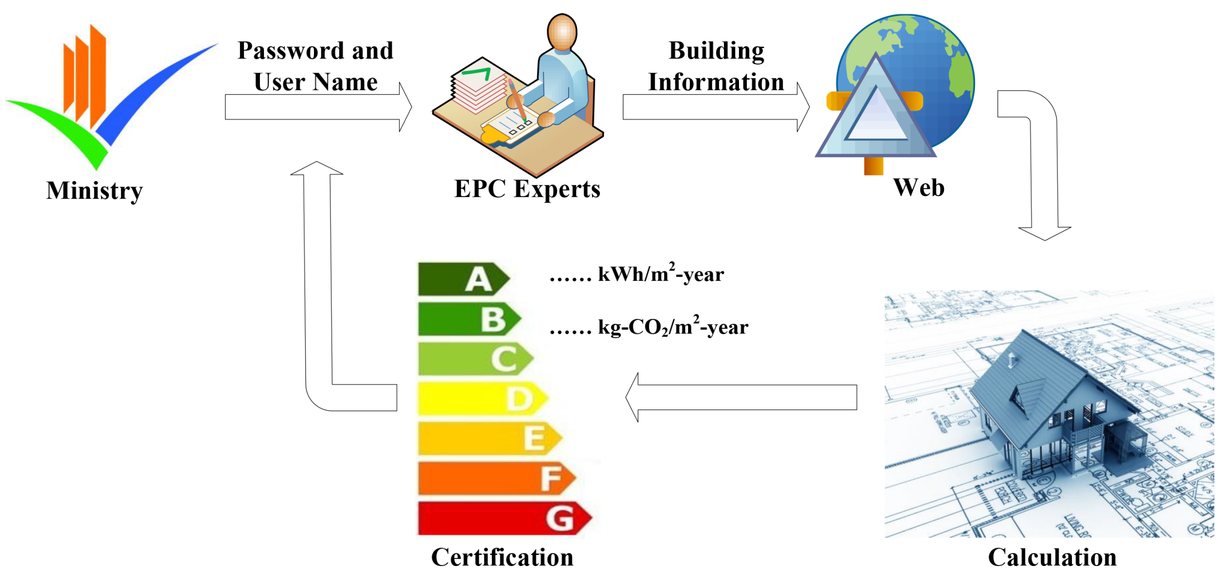

Figure 1. Design stages of EPC system.

The national calculation methodology is used to assess the energy consumption and related GHGs of residential buildings, office buildings, educational buildings, health care buildings, hotels, shopping, and commercial centers. This methodology is based on various standards, such as EN 13790, EN 13789, EN 15251, TS 825, EN ISO 14683, EN 10456, BS EN 12524, BR 443, TS 2164, DIN 18599, EN 13370, and 2005 ASHRAE. According to the calculation methodology, the actual building and the reference building need to be created for the classification of energy consumption and related GHGs of buildings. Energy performance of buildings is calculated by the following formula for energy consumption:

$$E_{p,EP} = 100(\frac{EP_a}{EP_r}). \quad (1)$$

GHGs are calculated from the following formula:

$$E_{p,SEG} = 100(\frac{SEG_a}{SEG_r}). \quad (2)$$

Here, SEG is the amount of GHGs released from a building (kg CO_2/m^2 year); E_p is the energy performance of the building; EP is the amount of the primary energy consumption of the building (kWh/m^2 year); r is the reference building; and a is the actual building. The same table is used for classification of both energy consumption and GHGs [45]. According to E_p values, energy performance classifications of buildings are shown in Table 1.

Table 1. Energy performance classes of buildings.

Class of energy	Ranges of E_p
A	0–39
B	40–79
C	80–99
D	100–119
E	120–139
F	140–174
G	175–...

3. Data collection and case study

In order to create an energy performance analysis, current situations of residential buildings are examined. The main goal in collecting related data is to make a better assessment of the energy performance of buildings and to present a comparison of different scenarios. The developed building model was mainly established by using data stored in the Turkish Statistical Institute (TÜİK), State Statistics Institute (DİE), and General Directorate of Renewable Energy (YEGM) databases in Turkey [46,47]. These databases contain information about Turkish building stock. According to this information, there are 19,481,678 residential buildings, and 22% of households lived in houses constructed after 2000. The average household size is 4, and 73% of residential buildings have a floor area between 80 m^2 and 120 m^2. Incandescent lamps (ILs), energy-efficient lamps, and both lamp types are used in 13.5%, 44.4%, and 42.1% of residential buildings, respectively. Approximately 8 lamps are used per house; 23 W compact fluorescent lamps (CFLs) have generally replaced the 100 W ILs to improve the buildings' energy efficiency.

In this study, 2 main case studies are performed. Two residential buildings (constructed before and after 2000) are modeled considering structural components such as walls, ceiling, floor, windows, etc. Three lighting scenarios are also created for each building model. For lighting scenario A, only 8 ILs (100 W; 1360 lm) are used. Both lamp types—4 ILs (100 W; 1360 lm) and 4 CFLs (23 W; 1400 lm)—are used for lighting scenario B. Only 8 CFLs (23 W; 1400 lm) are used for lighting scenario C. In the residential building simulations, standard values are used for the heating and cooling systems. Natural ventilation is also included in the ventilation system. The reason for considering this approach is that these building models coincide with the definition in the stored data. These databases are used to develop EPC scenarios that show ways to make the Turkish residential building stock much more energy-efficient.

All the necessary building information such as architectural, structural, mechanical, and electrical data is defined in BEP-TR to calculate the energy performance of residential buildings. A portion of the data used for building simulations is given in Table 2.

Table 2. Some of the data used for EPC scenarios.

Simulation data	Scenario 1	Scenario 2
Building floor area	100 m^2	100 m^2
Window components	Default window built before 2000 (U = 3.87W/m^2K)	Default window built after 2000 (U = 2.6W/m^2K)
Wall components	Default wall built before 2000 (U = 1.12W/m^2K)	Default wall built after 2000 (U = 0.6W/m^2K)
Ceilings and floor components	The default floor /ceiling built before 2000 (U = 1.57W/m^2K)	The default floor /ceiling built after 2000 (U = 0.6W/m^2K)

Finally, 6 EPCs were produced for the different cases. These scenarios are also summarized in Figure 2.

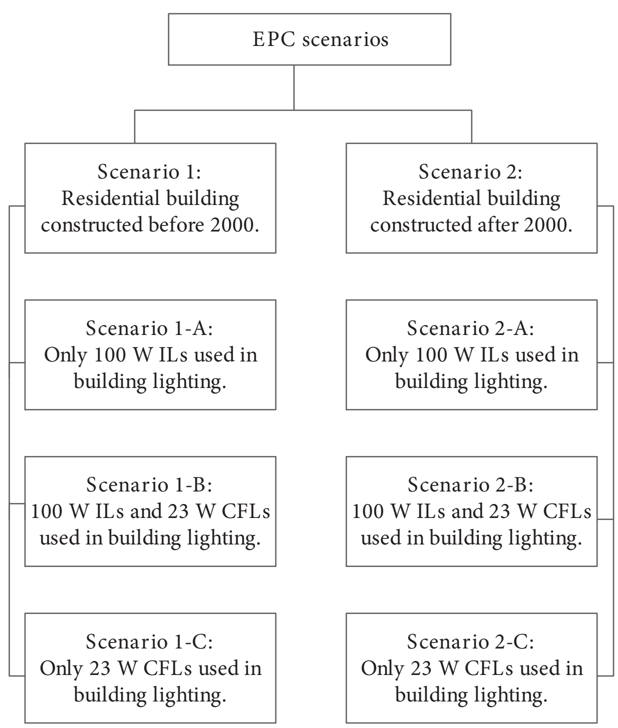

Figure 2. EPC scenarios.

4. Results and discussion

The results of the energy performance analysis of buildings are presented in this section. The main goal of this study is to show what the consumption of residential building stock is and how energy can be saved. Energy consumption and GHGs of residential buildings were calculated using BEP-TR. A total of 6 EPCs were produced; simulation results of building energy performance scenarios are given in Table 3.

Table 3. The results of EPC scenarios.

Scenarios	Use of energy field	Final energy consumption (kWh/year)	Final energy consumption (kWh/m^2/year)	Energy performance class
Scenario 1-A	TOTAL	27,290.17	272.9	G
	Lighting	2385.58	23.86	G
	GHGs	-	54.92	D
Scenario 1-B	TOTAL	26,579.23	265.79	F
	Lighting	1467.13	14.67	E
	GHGs	-	54.86	D
Scenario 1-C	TOTAL	25,870.63	258.71	F
	Lighting	548.68	5.49	B
	GHGs	-	54.79	C
Scenario 2-A	TOTAL	16,290.04	162.9	C
	Lighting	2385.58	23.86	G
	GHGs	-	56.5	D
Scenario 2-B	TOTAL	15,465.36	154.65	C
	Lighting	1467.13	14.67	E
	GHGs	-	56.47	D
Scenario 2-C	TOTAL	14,648.32	146.48	C
	Lighting	548.68	5.49	B
	GHGs	-	56.45	C

As can be seen from Table 3, the total energy performance classification of the residential building is in energy class G and the GHG classification is in class D for scenario 1-A. Total energy performance classification is in class F and GHG classification is in class D in scenario 1-B. Total energy performance classification is in class F and GHG classification is in class C in scenario 1-C. The results of scenario 2-A show that the total energy performance classification of the residential building is in energy class C and GHG classification is in class D. Total energy performance classification is in class C and GHG classification is in class D in scenario 2-B. Total energy performance classification is in class C and GHGs classification is in class C in scenario 2-C. The simulation results show that the average energy consumption is 155 kWh/m^2 per year and total annual energy consumption is about 15,500 kWh in residential buildings constructed after 2000. The energy consumption of residential buildings constructed before 2000 is 265 kWh/m^2 per year; their consumption is about 26,500 kWh of energy annually. These numbers mean that residential buildings constructed after 2000 consume less energy by 11,000 kWh (42%) per year, and they have a better energy performance class compared to others. Comparisons of the total energy consumption of buildings in the scenarios are also shown in Figure 3.

The average yearly 23 kWh/m^2 energy use for lighting in residential buildings is used only for ILs. Residential lighting energy consumption is calculated to be 14 kWh/m^2 per year when both types of lighting (ILs and CFLs) are used together. The energy consumption in residential lighting is about 5 kWh/m^2 per year when only CFLs are used. It can be said that energy-efficient lamps could reduce energy consumption from lighting by 88%. Comparison of the rates of residential lighting energy consumption is shown in Figure 4.

According to results of the analysis, there are no differences among buildings of different construction dates in terms of their GHGs. Emissions from residential buildings are calculated to be approximately 55 kg CO_2eq./m^2/year. Use of energy-efficient lighting can help to reduce GHGs from buildings.

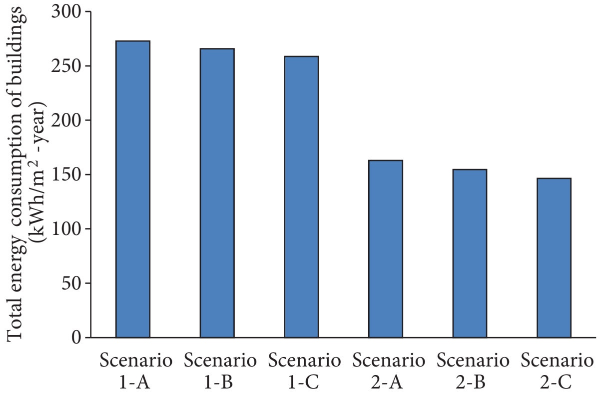

Figure 3. Comparison of the total energy consumption of buildings.

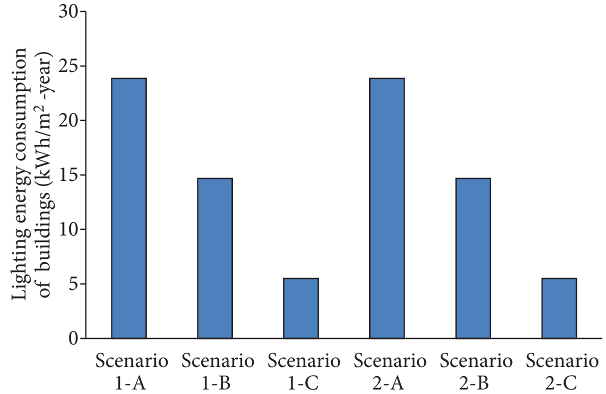

Figure 4. Comparison of residential lighting energy consumption.

Consequently, it can be said that for the Turkish residential building stock, the energy performance class of 4,285,969 buildings constructed after 2000 is class C or better. The energy performance classification of 15,195,709 buildings is class D or worse. These figures mean that only 22% of buildings meet the minimum requirement for the energy performance standard for new buildings. The greatest energy-saving potential is for 78% of the residential building stock. The use of energy-saving lamps can be an effective method for improving the energy efficiency of buildings. These lamps will not only reduce energy usage but will also improve the energy performance class of buildings. By replacing all ILs with CFLs in 2,630,026 residential buildings in which only ILs are used, 4829 GWh/year energy could be saved. Likewise, from 8,201,786 residential buildings in which both ILs and CFLs are used, 7529 GWh/year of energy could be saved. Approximately 12,358 GWh/year energy-saving potential for lighting can be achieved by replacing all traditional lamps with energy-saving lamps in residential building stock. This is equivalent to 5% of the total of Turkey's electrical energy consumption, and about 3 times the electricity that was imported in 2012. This study shows that important energy-saving potential is available for buildings in the form of lighting. EPC application can be an opportunity for determining energy-saving potential and to model different scenarios for the efficient renovation of building stock. To achieve this potential, energy efficiency policies should be implemented efficiently by governments.

5. Conclusions

Increases in energy consumption and air pollution in the construction sector have triggered building energy efficiency initiatives, regulations, and EPC schemes worldwide. Turkey is highly dependent on imported energy, and residential buildings are responsible for approximately 35% of total energy consumption. The Turkish building stock has important energy-saving potential. EPC systems are significant energy policy procedures, and they can be good solutions for determining the energy-saving potential, energy consumption, and GHGs of buildings.

In this study, the energy performance, energy classification, energy-saving potential, and GHG issues of buildings in Turkey are presented. The energy performance of residential buildings was predicted using official national software calibrated against an available database. Two residential buildings (constructed before and after 2000) were modeled. Three lighting scenarios were then created for each building model. Finally, 6 EPCs were produced under the different building simulation conditions. The simulation results show that residential buildings constructed before 2000 consume 11,000 kWh/year more energy than those constructed after 2000. In particular, buildings constructed before 2000 do not meet the minimum acceptable level for new construction, and they need refurbishment due to the potential for significant energy saving of 42%. The use of energy-efficient lighting would also contribute to reducing the energy consumption of and environmental pollution from buildings.

With the continuous development of urbanization and new technologies, building energy consumption will rise further. Governments and private sectors play a significant role in a sustainable energy future. They should be promoting energy efficiency and increasing awareness of energy use in buildings. Today, several EPC systems, both mandatory and voluntary, are used in many countries. EPC systems should be implemented for all buildings in order to draw a roadmap for improving the energy efficiency of building stock. This study can contribute to the better understanding of the importance of EPC systems for building stock. These energy performance certification procedures may also contribute to improving energy efficiency in other sectors.

Acknowledgment

The authors wish to express their appreciation to the Gürışık Energy Efficiency and Management Consulting Firm for their kind help and contributions with BEP-TR software in this study.

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