Achieving Sustainable Buildings via Energy Efficiency Retrofit: Case Study of a Hotel Building

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Abstract. Recent studies show that demand for green buildings with minimal environmental impact is increasing. Among the buildings in anywhere, existing buildings consume more energy than new ones. Because of that, building energy efficiency retrofit plays a very important role for achieving sustainable building targets. In addition to creating possibilities to reduce energy consumption, retrofitting also improves occupants' health and comfort. Tourism sector is one of the largest energy consuming sectors in the world. However conducted energy retrofit studies mainly focused on domestic buildings so far. The focus of this paper is to make a literature review of energy efficiency retrofits and present an approach to find the most appropriate, energy efficient and cost effective way renovate a hotel building. In this paper, a hotel building is energy efficiently retrofitted according to the TSE Green Building Certificate standards. Results from the analysis ensure that energy efficiency retrofit, helped to reduce energy consumption of the building and decreased in operational costs and CO_2 emissions.

Keywords: Green buildings · Sustainable design · Energy efficiency retrofit

Nomenclature

BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
DGNB	German Suitable Building Council
HVAC	Heating, Ventilating, and Air Conditioning
LEED	Leadership in Energy and Environmental Design
TOE	Tonne of Oil Equivalent
TSE	Turkish Standards Institution
PW	Net Present Worth
n	Service life (years)
i	Interest rate
A	Annual expenditure
C_o	Initial investment
RP	Repayment period
R_1, R_2, R_n	Cash flow (annual cost savings)
R	Annual energy cost savings

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1 Introduction

Global warming, environmental pollution, extinction of fossil fuels and the price of energy rises are the biggest problems of the humanity. Construction industry consumes of the 40% of global resources, 12% of potable water reserves, 55% of wood products, 45–65% produced waste, 40% raw materials, and the emission of 48% of hazardous greenhouse emissions, which results to environmental pollution and global warming [1].

As a result, many countries have introduced green building rating systems for sustainable construction. These include but not limited to United States' Leadership in Energy and Environmental Design (LEED), United Kingdom's BREEAM and Turkey's TSE Green and Secure Building.

Over the past years, as being the 17th largest economy in the world, Turkey has experienced considerable growth and energy use has grown at an annual rate of about 4.5% from 2013 to 2015 [2]. According to the Turkish Statistical Institute's "2014 Energy Consumption Statistics of Turkey", service sectors consumed 14 million 597 thousand TOE energy in 2014 [3]. For this reason, energy efficiency is a critical issue for Turkey.

Among the buildings in anywhere, existing buildings consume more energy than the new ones. As a result, building energy efficiency refurbishment plays a mandatory role in order to achieve green building goals. The term "retrofit" has been used to describe a variety of improvements to an existing building or group of buildings [4]. According to Ibn-Mohammad et al., retrofitting existing building stock can decrease CO_2 emissions 15 times more by 2050 than their demolition and today's technological improvements offer promising refurbishment solutions [5]. The outcome of this paper is energy efficiency retrofit of an existing hotel building facility with optimal heating, ventilation and air conditioning (HVAC) system solutions which can meet the demands of the users. And eventually, prove that sustainably renovated buildings can generate numerous benefits in terms of energy and CO_2 reduction, cost savings and healthier environments.

Results from the assessment ensure that energy efficiency refurbishment, helped to decrease in energy consumption of the building and consequently reduced operational costs and CO_2 emissions in a very short payback period. Obtained results might be generalized to other similar realities and encourage investors and building owners to renovate.

1.1 Green Buildings

Over the past years, Turkey's economy has expanded and it became the 17th largest economy in the world. As a result, energy consumption increased considerably. Since, Turkey imports nearly all of its energy resources, it has to minimize its energy consumption. About 40% of whole energy consumption in Turkey belongs to building sector while it has a large saving potential, as a result, improvement of building energy performance seems inevitable [2]. Green building is a method which is environmentally responsible, supports resource efficiency throughout the buildings life cycle: during design, construction, maintenance, renovation and demolition [6]. In other words, a green building is one, whose construction and lifetime of operation assure the healthiest environment while minimizing resource utilization and greenhouse gas emissions [7]. There are numerous sustainable assessment schemes all around the world which aim to rate a building's environmental performance. Some of the widely used green building assessment schemes are GBTool (Canada), CASBEE (Japan), BREEAM (Britain), BEAM (Hong Kong), Green Star (Australia), LEED (USA), DNGB (Germany), and TSE Green and Secure Buildings (Turkey). Generally, they aim to assess the impact of the building on its environment. During the assessment, local conditions and regional priorities should take into consideration. For instance, as stated in a study of Suzer [8], the environmental concern priorities for buildings located in Middle East and Northern America may differ since both regions have different climatic conditions and natural resources. In order to assess a building's energy performance accurately, it is better to use the country's own assessment scheme. As a result of that, Turkish Standards Institution (TSE) prepared a national green building certification (TSE Green and Safe Building Certificate) according to Turkey's priorities and requirements. This certificate aims to measure sustainability, fire, earthquake and domestic safety of the buildings. However, other international certifications mostly do not take into account earthquake safety since it is not a threat for them. It is better to evaluate buildings with the certifications which prepared according to national conditions. Below, LEED and TSE Green Building Certificate categories and their weights are shown in Tables 1 and 2. Improving energy efficiency of existing buildings plays a vital role in order to achieve the goals of sustainable buildings. Energy retrofitting reduces CO_2 emissions, utility bills and maintenance costs and create jobs and career opportunities [9]. There are a number of approaches of building retrofitting such as installation of renewable energy systems, enhancing building envelope and upgrading HVAC systems [10]. HVAC system is the highest energy consuming component in a building, therefore improving HVAC system contributes in greater energy savings within the building [11]. In this study, significant attention has been paid to improve the energy efficiency of building's HVAC system.

Table 1. LEED NC, v.3 categories and their weights

LEED NC, v.3 categories	Category weights (points)	Percentage
Sustainable sites	26	23.6
Water efficiency	10	9.1
Energy and atmosphere	35	31.8
Materials and resources	14	12.7
Indoor environmental quality	15	13.6
Innovation	6	5.6
Regional priority	4	3.6
Total	110	100

Table 2. TSE Green Certificate categories and weightings

TSE Green Building Certificate categories	Category weights (points)	Percentage
Sustainable sites	30	9.77
Water efficiency	33	10.74
Energy and atmosphere	120	39.08
Materials and resources	33	10.74
Health, safety and comfort	34	11.07
Innovation	6	1.95
Carbon footprint	5	1.62
Facility management	13	4.23
Premium points	25	8.14
Land choice	8	2.60
Total	307	100

2 Methodology

As the 6th most popular tourist destination in the world, Turkey generates almost 30 billion USD from tourism sector, annually. By the end of 2015, there were 13,615 accommodation facilities in Turkey [12]. Since hotels are the most energy intensive of all building categories, their energy use and environmental impact can be quite large, especially in popular tourist destinations [13]. As a result, improving energy efficiency of existing hotel buildings is a necessary action in terms of reducing CO_2 reduction and improving thermal comfort levels for occupants. In order to identify the most suitable retrofitting actions and assess their effectiveness when implemented in a building, it is necessary to have available specific information on the energy characteristics, thermal performance, comfort conditions and existing problems [14]. The methodology of this paper is described below;

- Selection of the case study building
- Identify climate conditions
- Identify major energy losses (Survey of existing envelope, thermographic inspection, lighting etc.)
- Create an energy profile of the building by using available data on monthly electric and fossil fuel use
- List retrofit options according to Green and Secure Building Standards
- Make a cost/benefit analysis.

2.1 Selection of the Case Study Building

Thermal hotel facility which is located in Oylat, Bursa was selected in this study to serve the research purpose. Famous thermal water springs of Oylat has been using in the hotel's spa and baths. Hotel facility has 252 rooms and 5 floors above ground with a total floor area of 11,808 m^2 (Fig. 1). In particular, coal is used for the facility heating and thermal water is used in baths and spas.

2.2 Climate Conditions

The Turkish State Meteorological Service and TSE (Turkish Standards Institution) classified Turkish climate regions as "Thermal Insulation Regions" by using a degree-day method which was developed by the Turkish State Meteorological Service. In Turkey, there are four thermal zones and each zone demand different envelope characteristics. The limited U value of building envelope in different degree-day zones is shown in Table 3. Based on TS 825-2013, Bursa is the representative city for second climate zone.

Fig. 1. Hotel building

2.3 Thermographic Inspection

As means of uncovering inefficiencies in the HVAC system and building envelope, a thermographic inspection of the case study building was performed by using an infrared camera. Infrared images produced during the inspection were analyzed for heat loss. According to the visual inspection, building envelope appears to be in good condition and meet the current regulation demands. The inspection also revealed that mechanical installation is a significant source of heat loss and has a high potential for energy efficiency improvements. Due to TS-2164 thermal installation regulation, temperature difference between insulated surface and indoor air supposed to be of a maximum of 5 °C. However, thermographic inspection revealed that temperature difference is between 9 and 12 °C (Fig. 2). As a result of that, most of the pipelines have been replaced with pre-insulated geothermal pipes.

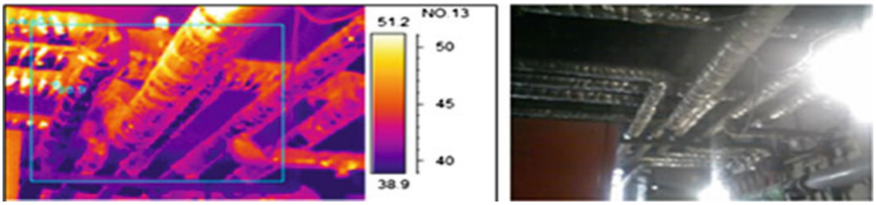


Fig. 2. Thermographic inspection of installation systems

Table 3. The limit U values different degree-day zones

	U exterior wall (W/m^2 K)	U ceiling (W/m^2 K)	U ground floor (W/m^2 K)	U windows (W/m^2 K)
1. DDZ	0.66	0.43	0.66	1.8
2. DDZ	0.57	0.38	0.57	1.8
3. DDZ	0.48	0.28	0.43	1.8
4. DDZ	0.38	0.23	0.38	1.8
5. DDZ	0.36	0.21	0.36	1.8

2.4 Lighting Audit

Energy conversation from artificial lighting is very important in hotels, since several areas of the building remain with the lights on throughout the night hours [14]. Almost 21.3% of the electricity that generated in Turkey is consumed for lighting, and if a good design is made, the total energy consumption for lighting purposes can be reduced by 20%. In order to investigate the efficiency of the lighting system, light measurement is made by using a lux meter. According to the measurements, lighting levels of the interior spaces need to be enhanced in terms of safety and comfort (Fig. 3).

Fig. 3. Hotel lobby lighting

2.5 Energy Audit Results Before the Retrofit

Based on the collected bills of 2015, annual energy consumption of the hotel is shown in Table 4. According to the investigation, the annual total electricity consumption is 1,140,685 kWh and annual consumption of coal is 669,210 kg. Data refer to the whole building consumption show a predominant use of coal with respect to electricity.

Table 4. Annual energy consumption of the hotel building

Energy	Annual consumption		Annual cost	
		TOE	TL	TL/TOE
Electricity	1,140,685 kWh	98.10	220,427	2247
Coal	669,210 kg	468.45	428,294	914.29

2.6 Proposed Retrofit Actions

There are a number of approaches of the building retrofitting and previous studies have predominantly focused on the technological aspects such as the installation of renewable energy systems, enhancing building envelope etc. [10]. The HVAC systems are one of the biggest energy consumers in hotel buildings. In this study, significant attention is paid to HVAC systems in order to transform an existing building to a green building.

The heat source of the building is coal and central heating system was used for the building. Annually, 670 t of standard coal is required for heating the building. Water source heat pumps (WSHP) have gained an increasing level of application in Turkey due to their higher COP values. Therefore WSHP with 3.8 COP was selected as the heat source of the retrofit. In addition to WSP, a condensing, fuel fired boiler was selected.

Since hotel building is located in Oylat, thermal water with a daily capacity of 4300 t can be reused by WSHP. Thermal water flow from the source at approximately 40 °C and it is discharged after using baths and spas of the hotel facility at 30 °C. Thermal water that discharged at 30 °C after being used in baths and spas, will be collected and pumped to WSHP in order to use the waste heat. Waste water will enter WSHP at 30 °C and exit at 70 °C. By this way energy consumption will be reduced and operational cost will be saved.

2.7 Energy Audit Results After the Retrofit

After retrofit implementations, the annual primary energy use and the cost of saved energy is presented in Table 5. According to the results, after retrofit, reduction of annual energy consumption is 528.57 TOE and reduction of annual energy cost is 294,000 TL.

Table 5. Energy consumption and energy cost after retrofit

	Energy	After retrofit		
		Annual energy consumption		Annual energy cost (TL)
Heat pump	Electricity	255,194 kWh/year	21.95 TOE	112,285
Boiler	Natural gas	19,430 m^3/year	16.03 TOE	21,917

2.8 Evaluation of the Building According to TSE Green Building Certificate

In this part of the study, TSE Green Building Certificate energy category evaluation is applied to the hotel building. According to category requirements, renovated building is evaluated and scored. Scores after the evaluation is shown in Table 6.

For classification of buildings according to primary energy, CO_2 emissions, to set minimum energy performance requirements for major renovations of existing buildings, to evaluate feasibility of renewable energy sources, to provide inspection of heating and cooling systems, to limit greenhouse gas emissions, to determine building energy performance measures and to protect environment, Turkish Building Energy Performance Regulation came into force in December 2008 [2]. Eventually, obtaining an energy performance certificate for new and existing buildings is mandatory.

In order to be evaluated according to Energy category credits of TSE Green Building Certificate, Turkish Building Energy Performance Certificate document must be provided. After applying retrofit actions, hotel building's annual energy consumption and greenhouse gas emissions shown in Fig. 4. According to this certificate, the hotel building's energy performance class is B and CO_2 gas emission class is C.

2.9 Economic Analysis of the Retrofit

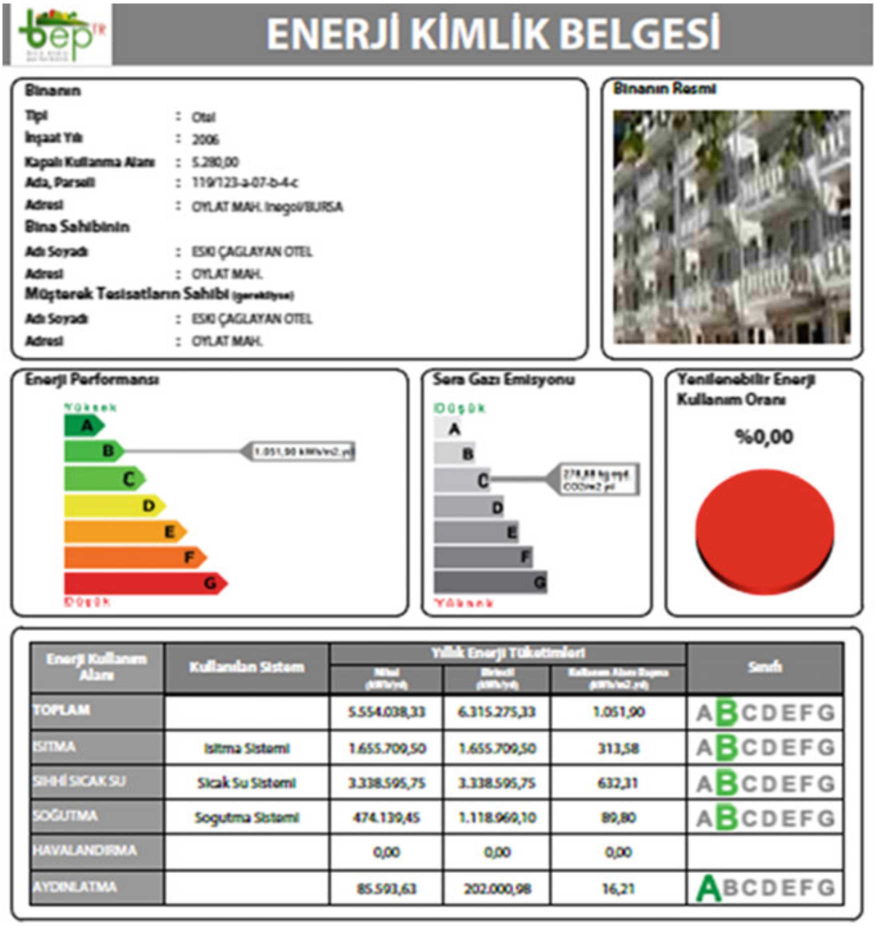
The economic problem of allocating limited resources to various needs often requires making cost-benefit analysis where costs and benefits over the lifetime of the project are evaluated and investments with positive net benefits are considered to be acceptable [15].

In this section, costs related to the investment is estimated and appropriateness of the investment is determined.

Before making an investment, present worth analysis (PW) should take into consideration (Eq. 1);

$$\mathrm{PW} = -\mathrm{C}_0 + \frac{R1}{(1+i)^1} + \frac{R2}{(1+i)^2} + \cdots + \frac{Rn}{(1+i)^n} \tag{1}$$

Present worth analysis (PW) is a formula to calculate an estimate of how profitable the project or investment will be [16]. The $-\mathrm{C}_0$ is the initial investment, which is a negative cash flow showing that money is going out as opposed to coming in [16]. Considering that the money going out is subtracted from the discounted sum of cash flows coming


ENERJİ KİMLİK BELGESİ

Binanın
Tipi : Otel
İnşaat Yılı : 2006
Kapalı Kullanma Alanı : 5.280,00
Ada, Parseli : 119/123-a-07-b-4-c
Adresi : OYLAT MAH. Inegol/BURSA
Bina Sahibinin
Adı Soyadı : ESKİ ÇAGLAYAN OTEL
Adresi : OYLAT MAH.
Müşterek Tesisatların Sahibi (gerekliyse)
Adı Soyadı : ESKİ ÇAGLAYAN OTEL
Adresi : OYLAT MAH.

Binanın Resmi

Enerji Performansı
Yüksek
A B C D E F G
Düşük

Sera Gazı Emisyonu
Düşük
A B C D E F G
Yüksek

Yenilenebilir Enerji Kullanım Oranı
%0,00

Enerji Kullanım Alanı	Kullanılan Sistem	Yıllık Enerji Tüketimleri			Sınıfı
		Nihai (kWh/yıl)	Birincil (kWh/yıl)	Kullanım Alanı Başına (kWh/m2.yıl)	
TOPLAM		5.554.038,33	6.315.275,33	1.051,90	ABCDEFG
ISITMA	Isıtma Sistemi	1.655.709,50	1.655.709,50	313,58	ABCDEFG
SIHHİ SICAK SU	Sıcak Su Sistemi	3.338.595,75	3.338.595,75	632,31	ABCDEFG
SOĞUTMA	Soğutma Sistemi	474.139,45	1.118.969,10	89,80	ABCDEFG
HAVALANDIRMA		0,00	0,00	0,00	
AYDINLATMA		85.593,63	202.000,98	16,21	ABCDEFG

Fig. 4. Energy performance certificate of the hotel building

in, the net present value would need to be positive in order to be considered a valuable investment [16].

In Table 7, Net present worth analysis of the investment is made and since the present net value is positive, the investment would be considered a valuable one. In addition to Present Worth Value analysis, calculating repayment period will be also beneficial in terms of investigating the feasibility of a project. Repayment period of a project can be calculated as stated below (Eq. 2);

$$RP = C_o/(R - A) \tag{2}$$

According to Eq. (2), RP value of the case study is 3.4 years.

Table 6. Evaluation of the building according to TSE certificate

Energy category criteria	Required documents	Category total score	Hotel building's score
Building class	–TSE Energy performance certificate	18	12
Energy efficiency		21	12
Renewable energy usage		48	33
Energy security and quality		3	2
Greenhouse gas emissions	–TSE Energy class document	5	3
Energy efficient appliances		4	3
Operating HVAC system		21	15
Total		120	80

Table 7. Net present worth analysis of the investment

(TL)	0	1	2	3	4	5	6	7
Initial investment	−1,000,000							
Energy cost savings		+294,000	+294,000	+294,000	+294,000	+294,000	+294,000	+294,000
Additional costs		−1000	−1000	−1000	−1000	−1000	−1000	−1000
Salvage								+1000
Cash flow (CF)	−1,000,000	+293,000	+293,000	+293,000	+293,000	+293,000	+293,000	+294,000
Present worth (PW)	$\frac{1}{(1+0.07)^0}$	$\frac{1}{(1+0.07)^1}$	$\frac{1}{(1+0.07)^2}$	$\frac{1}{(1+0.07)^3}$	$\frac{1}{(1+0.07)^4}$	$\frac{1}{(1+0.07)^5}$	$\frac{1}{(1+0.07)^6}$	$\frac{1}{(1+0.07)^7}$
CF × PW	−1,000,000	273,831	255,997	239,175	223,528	208,904	195,238	183,088
ε (CF × PW)	−1,000,000	−726,179	−470,182	−231,007	−7479	201,425	396,663	579,751

3 Conclusion

This paper provides a literature review about green building assessment schemes in particular LEED and Turkish Standards Institute, Green Building Certificate. Additionally building energy efficient retrofitting is examined via a case study of a hotel building. The experience of the case study of a hotel building has emphasized that how HVAC retrofitting according to green building standards, can increase energy efficiency and decrease operational costs. In this study, as a result of the retrofitting, the annual energy cost decreased by 50%.

The unpredictable nature of energy prices offers a compelling argument for improving energy efficiency of Turkey's building stock. Energy retrofitting according to green building assessment schemes energy related standards undoubtedly play a vital role in achieving energy efficiency goals of Turkey. As a result, comprehensive retrofit programs should be developed to achieve Turkey's energy targets.

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