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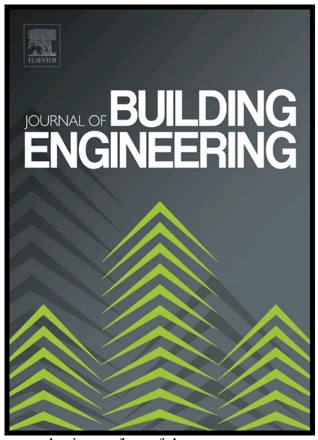

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PII: S2352-7102(18)30164-5
DOI: https://doi.org/10.1016/j.jobe.2018.04.017
Reference: JOBE462

To appear in: *Journal of Building Engineering*

Received date: 10 February 2018
Revised date: 16 April 2018
Accepted date: 19 April 2018

Cite this article as: Luay N. Dwaikat and Kherun N. Ali, The economic benefits of a green building – evidence from Malaysia, *Journal of Building Engineering,* https://doi.org/10.1016/j.jobe.2018.04.017

The economic benefits of a green building – evidence from Malaysia

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Abstract

Due to significant environmental and economic benefits associated with reduced energy consumption in green buildings, energy efficiency is considered a key driver for the green building movement. However, factors related to the actual building performance and future energy prices highly impact the actual energy cost of a green building. This research evaluates the actual economic performance of a green building in use in term of energy consumption and examines how different scenarios for energy price inflation would affect the cost saving associated with reduced energy consumption in the building throughout its whole life cycle. Based on actual data record, it is found in the research that the investigated green building saves around 71.1% of energy compared to the industry baseline. From life cycle perspective, the green building saves around 5,756 kWh/m^2 which corresponds to $2,796,451 at 1% average annual increase in energy price and it is more than fourfold at 5% average annual increase in energy price and reaches around $12,107,060. This research provides an empirical evidence for the economic benefits associated with reduced energy consumption in the green building.

Keywords: Green buildings; Energy saving; Actual economic performance; Whole life cycle; Energy price inflation.

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1. Introduction

The population of the world is expected to increase from 7 billion to 9 billion by 2050 [1]. Undoubtedly, this growth in population is associated with higher demand for water, energy, and natural resources which in return will overburden the ecosystems and increasingly deteriorates the environment. Since more than two decades, an urgent call was raised by the General Assembly of the United Nations to formulate *a global agenda for change* to achieve several strategic goals related to long-term environmental issues. This call to change by the United Nations triggered the concept of sustainable development, or sustainability, on March 20, 1987, by Brundtland Commission in their report entitled *Our Common Future,* in which sustainable development was defined as meeting our needs considering the ability of future generations to meet their own needs [2]. This classical and common definition for sustainable development implies a rational use of natural resources, and technically, bridges development with the environment. Since then, sustainable development has gained significant global attention [3].

Among the other production and manufacturing sectors, the construction sector is placed at the forefront of the sectors that must embrace sustainability, and this was the main driver of sustainable construction and green buildings movement. There is almost a consensus in the literature that green buildings outperform conventional (non-green) buildings in several performance areas. Lower energy and water consumption, improved indoor air quality, enhanced health and productivity, increased property value, among others, are frequently cited benefits associated with green building [4–7].

However, despite the numerous benefits associated with green building, research indicates that building owners and real estate investors are still reluctant to adhere to green solutions [6,8,9]. Issues related to exaggerated higher construction cost, lack of building owners interest of future costs and benefits, lack of proper education about green building practices and benefits are frequently cited barriers for green building [1,4,6,10–12].

This research addresses the economic benefits associated with energy saving in green building by analyzing the actual energy performance of a green building in use. For an elapsed period of 7 years, the actual economic performance of a green building was analyzed and quantified, then based on the current building performance, the economic benefits associated with reduced energy consumption were analyzed and quantified along the whole life cycle of the building. An economic analysis was conducted to investigate how different scenarios for energy price inflation would affect the future cost saving associated with reduced energy consumption throughout the whole building life cycle.

2. Background information

2.1 The Concept of a green building

Sustainable construction and green buildings are two interchangeable terms emerged from the concept of sustainable development [13]. Green building represents the response from the construction industry to sustainability requirements, and therefore, energy and water efficiency, reduced natural resource consumption, in addition to improved health and environment are key characteristics of a green building [5,14]. Although green building is being promoted as a high potential solution to reduce the negative environmental impacts of the construction industry, yet there is no operational and measurable definition for the term *green building.* Kibert [13] suggests that the term *green building* is used to label the building that is designed and built in accordance with the principles of sustainable construction. He suggests that the green building is: "a h*ealthy facilities designed and built in resource-efficient manner, using ecologically based principles*". Yudelson [5] defines the green building as: "a *high-performance property that considers and reduces its impact on the environment and human health*".

Since globally recognized performance targets for green building have not been agreed upon yet, several countries in the world have developed their own tools and systems to evaluate the performance of green buildings. According to these tools and systems, which are known as building environmental assessment methods (BEAM) [15,16], a building is rated *green* if it meets a set of performance targets specified by the adopted green rating system. The British Research Establishment Environmental Assessment Method (BREEAM) and the American Leadership in Energy and Environmental Buildings (LEED) can be cited as widely accepted and used green rating systems for green buildings [17,18].

The term *zero energy building* is being discussed in the literature [19–21]. The concept of zero energy building is that a building does not need to use fossil fuels, rather all the required energy is supplied from renewable energy sources such as solar energy, and this can be achieved in conjunction with various design strategies to reduce the energy demand in the building [13,14].

2.2 Benefits of a green building

The list of green building merits and benefits is extensive and varied and covers the three bottom-line of sustainability which are environmental, economical, and social aspects [22,23]. From building life cycle perspective, advocates of green buildings contend that a green building outperforms its conventional (non-green) counterpart; they identified numerous benefits associated with a green building. Kats et al. [4] argue that the financial benefits gained from reduced energy and water consumption, lower maintenance cost, in addition to improved health and productivity are 10 times higher than the additional construction cost required to meet green design criteria. Kats et al. [4] further argue that the average energy saving in green buildings is around 30%. Yudelson [5] says that green buildings use from 30% - 50% less energy and water than conventional (non-green) buildings. Based on Australian and international case studies and research, Madew [24] reports 60% decrease of energy and water consumption in green buildings which implies a significant reduction of building annual operating costs. He adds that green building has a higher market value reaches 10%, and a higher rental rate ranges from 5% - 10%. Torcellini et al [19] found that six green buildings are using from 25% - 75% less energy than energy code-compliant buildings in the United States. Ries et al. [7] found that energy consumption decreased about 30% and productivity increased about 25% in a green manufacturing facility certified by Leadership in Energy and Environmental Buildings (LEED) green rating system.

3. Research methodology

This research investigates the actual and future energy cost performance of a green building in use. Therefore, the research can be classified as a case study research. Case study approach allows an in depth investigation of contemporary phenomena over which the researcher has little or no control [25,26]. The case study is located in Kuala Lumpur in Malaysia and it was selected because it is an information-rich case study. Methodologically, the current and future building performance was measured against the industry baseline as determined by the Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (the Malaysian Standard MS1525:2007). As a reference guide, the International Standard ISO 15686-5:2008 [27] was used as a reference to identify the life cycle cost components and elements.

3.1 *Case study description*

Located in Kuala Lumpur, the case study which was investigated in the research is the Malaysia Energy Center currently known as GEO (Green Energy Office) Building. The building was commissioned in 2008 as the first officially certified green building by the Green Building Index (GBI) which is the first established and officially adopted green rating system in the Malaysian marketplace [28].

The GEO Building embraces eco-friendly features including thermal insulation, 100% daylight, energy efficient lighting system, storm water harvesting system, building energy management system (BEMS), and floor cooling system. The building is capable to generate 50% of its energy demand through an integrated photovoltaic (BIPV) system that generates around 120,000 kWh/year. The Photovoltaic (PV) panels are installed on the roof and in the external car park area to serve as a shading device for cars as illustrated in figure 1. The BIPV system is connected to the national grid to export surplus electricity [29].

According to the used green rating system, which is the Green Building Index (GBI), the building scored full points for energy efficiency and innovation criteria [28]. Figure 1 is a general view for the case study.

Figure 1**:** General view for the GEO Building, from [29]

3.2 Data Collection

Longitudinal data for the past building performance were collected from the building owners. The data contain information about the actual energy consumption and cost, and cover the actual building performance since its commissioning in 2008 up to the end of 2014. The energy cost data were available in the local currency of Malaysia. The energy cost data were converted to the American dollar (US$) using the average exchange rate for the year 2015 which, according to the Central Bank of Malaysia [30], was equal 3.91 RM/US$. Table 1 shows the collected actual energy consumption and costs of the building.

Table 1: Actual energy consumption and cost data.

Year	Annual energy consumption (kWh/year)	Average monthly consumption (kWh/month)	Actual Energy cost (US$/year)
2008	243,900	20,325	24,764
2009	151,284	12,607	15,361
2010	140,160	11,680	14,231
2011	127,068	10,589	12,902
2012	165,960	13,830	16,851
2013	175,224	14,602	17,791
2014	172,176	14,348	17,482
Total	1,175,772 kWh		$119,382

4. Building energy and cost performance analysis

4.1 Current energy saving benefits

The actual energy performance of the building was measured against the industry baseline as determined by the Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (the Malaysian Standard MS1525:2007). Despite that a standard building energy index (BEI) of 135 kWh/m^2/year was inferred from the national standard requirements for office buildings [31–33], it is claimed that the energy consumption of a typical office building in Malaysia ranges from 200 – 300 kWh/m^2/year [29,32,34].

However, there is not much empirical evidence supports these claims through a national energy audit. Saidur [35] conducted an energy audit for 68 office buildings and reported a building energy index (BEI) of 130 kWh/m^2/year for office buildings in Malaysia. Although the author in his research did not conduct inferential statistics to generalize the findings, his reported building energy index is close to the industry baseline set by the national standard (MS1525:2007).

The building energy index (BEI), also known as energy efficiency index (EEI) [36], or energy use intensity (EUI) [19,37], is a common performance indicator used to measure the total annual end-use energy consumption in a building. The building energy index is expressed as kWh/m^2/year and it can be calculated by dividing the total annual energy used in a building by its gross floor area measured in square meters [36].

As illustrated in Figure 2, the average building energy index (BEI) of the GEO Building is around 39 kWh/m^2/year calculated based on the actual energy consumption in the building during each elapsed building operating year, which is far below the industry baseline.

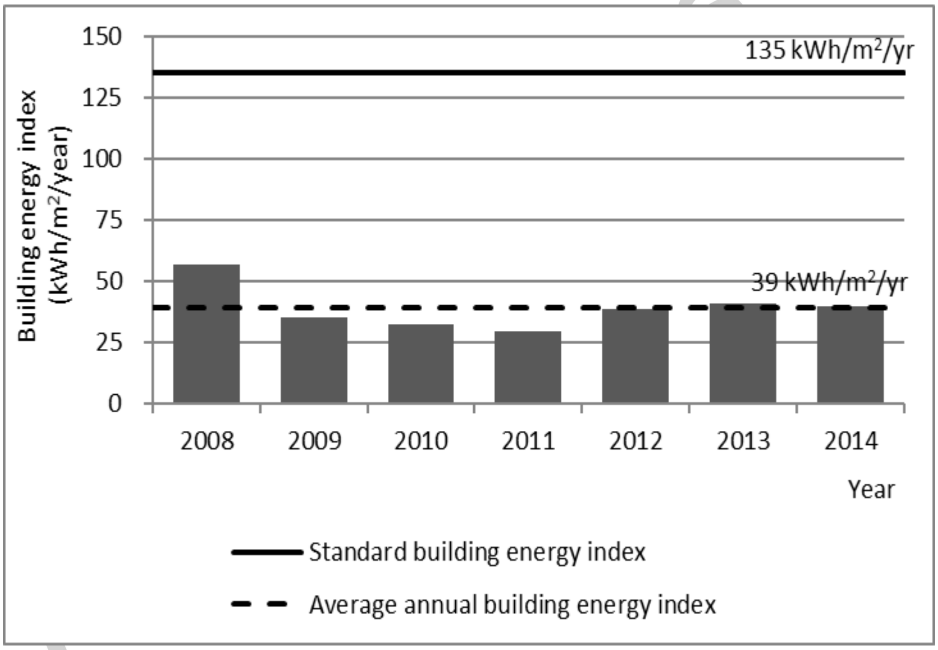

Figure 2: Building energy consumption compared to industry baseline

Based on the building energy index set by the national standard (MS1525:2007), the estimated annual energy consumption in the GEO building is around 580,500 kWh/year. This figure represents the energy consumption baseline for the building, and it was calculated by multiplying the building energy index set by the national code, (135 kWh/m^2/year) by the building area (4,300 m^2).

According to the applied energy rates in the elapsed building operating years, the baseline annual energy costs were calculated by multiplying the baseline annual energy consumption by the applied energy rate in the corresponding year as illustrated in Table 2. Accordingly, the total cumulative baseline energy cost up to the end of 2014 equals $408,672. This figure was compared with the actual energy cost in the building since its commissioning in 2008 which is around $119,382. The comparison yields a cumulative cost saving equals $289,290 starting from the building commissioning. The corresponding total energy saving in the building in comparison to the baseline is around 2,887,728 kWh, which is the difference between the baseline energy consumption (4,063,500 kWh) and the actual energy consumption (1,175,772 kWh).

The average annual cost saving is around $41,327 which corresponds to 70.8%, while the percentage of energy saving in comparison to the baseline is around 71.1%. The actual energy cost data shows that the average actual annual energy cost is around $17,055, while the average annual energy cost would have been around $58,382 if the building had been designed following the industry baseline. Table 2 shows annual performance analysis of the current building performance in term of energy consumption and cost.

Table 2: Actual energy consumption and cost data.

Year	*Baseline energy consumption (kWh/year) (A)*	*Baseline energy rate ($/kWh) (B)*	*Baseline annual energy cost (US$) C = (A x B)*	*Actual energy consumption (kWh/year) (D)*	*Actual energy cost (US$) (E)*	*Energy Saving (kWh/year) F=(A - D)*	*Cost saving (US$/year) G=(C - E)*
2008	580,500	0.100	58,050	243,900	24,764	336,600	33,286
2009	580,500	0.096	55,728	151,284	15,361	429,216	40,367
2010	580,500	0.096	55,728	140,160	14,231	440,340	41,497
2011	580,500	0.098	56,889	127,068	12,902	453,432	43,987
2012	580,500	0.104	60,372	165,960	16,851	414,540	43,521
2013	580,500	0.105	60,953	175,224	17,791	405,276	43,162
2014	580,500	0.105	60,953	172,176	17,482	408,324	43,471
Total	4,063,500		408,672	1,175,772	119,382	2,887,728	289,290
Average	580,500	0.101	58,382	167,967	17,055	412,533	41,327

4.2 Life cycle energy cost saving compared to the industry baseline

As discussed in the preceding section, the current building performance analysis shows a significant energy cost saving in the building. However, maintaining the energy saving benefits in the future is highly dependent on two factors: the first factor is related to future energy consumption in the building, while the other is related to future energy prices. To quantify the cost saving associated with reduced energy consumption throughout the whole life cycle of the building, the current building energy performance was compared to the performance baseline using different scenarios for energy price inflation rates.

Before proceeding further in the analysis, it is worthy to mention that within the context of life cycle costing, the period of analysis is a critical variable that significantly affects the results of the analysis. The period of analysis refers to the time span over which the life cycle cost is analyzed. Several life cycle costing scholars suggest that a life cycle cost analysis should include the whole life cycle of a building, or a product [38–41], which is determined by its service life. The service life of a building refers to the period of time during which a building satisfies the minimum acceptable performance levels [42]. The International standard ISO 15686-5:2008 mandates that the service life of a building should not be less than its design life [27]. As a concrete structure, the whole building life cycle which is expected to extend at least for 60 years as determined by the design life of concrete structures [43].

Based on the current building performance, the average annual energy consumption in the building is around 167,967 kWh. This yields a total life cycle energy demand equals 10,078,020 kWh along the whole building life cycle which is expected to extend at least for 60 years as discussed earlier. While according to the baseline energy consumption, the life cycle energy demand is estimated to be around 34,830,000 kWh, estimated by multiplying the industry baseline (135 kWh/m^2/year) by the building area (4,300 m^2) by the building life cycle (60 years). This implies that the total energy saving along the whole building life cycle is around 24,751,980 kWh, which corresponds to around 5,756 kWh/m^2. It is worth mentioning that these estimates remain reasonable provided that energy use pattern in the building remains unchanged. However, predicting how energy use pattern may change remains uncertain and falls beyond the scope of this research.

Translating the above life cycle energy estimate to cost is highly dependent on energy price inflation rates. The average annual increase of energy prices in Malaysia is around 2.4%. This rate, according to the Department of Statics Malaysia [44], covers a period starting from 1980 – 2014 inclusive. Since there are not officially published forecasts for energy prices in Malaysia, the life cycle cost of energy was estimated using different scenarios for energy price inflation range from 0% - 5% with 1% increase. The purpose of including 0% as the lower limit for inflation rate, which is unlikely to happen along a period of 60 years, is to quantify the benefit associated with energy saving in the real terms (excluding the effect of energy price inflation on the estimated future cost) [27,45]. The upper limit of inflation rate was determined by 5% because this limit is almost the double of the average historical energy inflation rate.

The building commissioning year (2008) was used as the base year to quantify the economic benefits associated with reduced energy consumption in the building along its whole life cycle. At the beginning of 2008, the applied energy tariff for the building category was around 0.083 $/kWh, and this rate was applicable for all kWh used in a month [46]. Accordingly, the baseline energy cost for the base year was estimated to be around $48,182 (580,500 kWh x 0.083 $/kWh). Similarly, based on the average annual energy consumption in the elapsed building operating period which equals 167,967 kWh/year, the energy cost in the base year was estimated to be around $13,941 (167,967 kWh x 0.083 $/kWh). Considering different scenarios for energy price inflation, these estimates for the base year were projected over the whole building life cycle, starting from 2008 up to 2067 inclusive, using the following equation 1 [27,47]:

$$\boldsymbol{F = P(1 + e)^{n}} \qquad \textbf{(1)}$$

Where:

F: future value (nominal cost)
P: cost in the base year
e: expected percentage of annual cost increase
n: number of years between the base date and the occurrence of the cost

Figure 3 shows baseline energy life cycle cost at different energy price inflation rates as well as it shows the life cycle cost of energy based on the current building performance using the same inflation rates. It can be observed form Figure 3 below that the gap between the building energy life cycle cost and the baseline energy life cycle cost drastically increases as energy inflation rate increases. This is, however, natural since higher energy inflation rates have higher exponential effect on the life cycle cost [45].

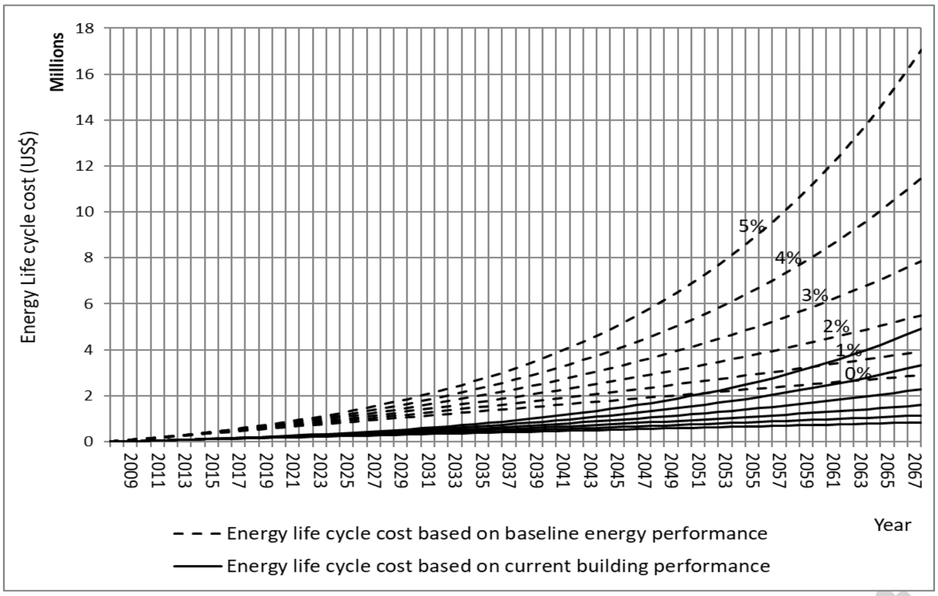

Figure 3: Energy life cycle cost based on baseline energy consumption versus energy life cycle cost based on current energy consumption.

The life cycle calculations and the graphical information in Figure 3 is shown in Table 3 below which shows the estimated energy life cycle cost at different energy inflation rates for both the baseline and for the current building performance. Table 3 also shows the cost saving associated with reduced energy consumption throughout the whole building life cycle at different energy inflation rates. In the real terms (without the effect of energy price inflation), the economic benefits of reduced energy consumption throughout the whole building life cycle is around $2,054,460. While, in the nominal terms, it is around $2,796,451 at 1% average annual energy price increase, and reaches around $12,107,060 at 5% average annual increase of energy prices. The nominal cost refers to the cost that is estimated considering the effect of price inflation/deflation, or technology improvement for example; it refers to the cost when its due to be paid [27].

Table 3: Economic life cycle benefits of reduced energy consumption at different energy inflation rates

Average annual inflation rate (%)	Energy life cycle cost based on baseline energy performance (US$)	Energy life cycle cost based on current energy performance (US$)	Life cycle cost saving (US$)
0.0	2,890,920	836,460	2,054,460
1.0	3,935,008	1,138,557	2,796,451
2.0	5,495,231	1,589,993	3,905,239
3.0	7,856,241	2,273,128	5,583,113
4.0	11,466,867	3,317,828	8,149,039
5.0	17,036,371	4,929,311	12,107,060

Figure 4 is a graphical representation of energy life cycle cost saving at different scenarios for energy price inflation rates. It can be observed that the energy life cycle cost remains at the lower third of the baseline and the energy life cycle cost saving is drastically increases at higher energy inflation rates and this is natural, as mentioned earlier, due to the exponential effect of energy price inflation rate.

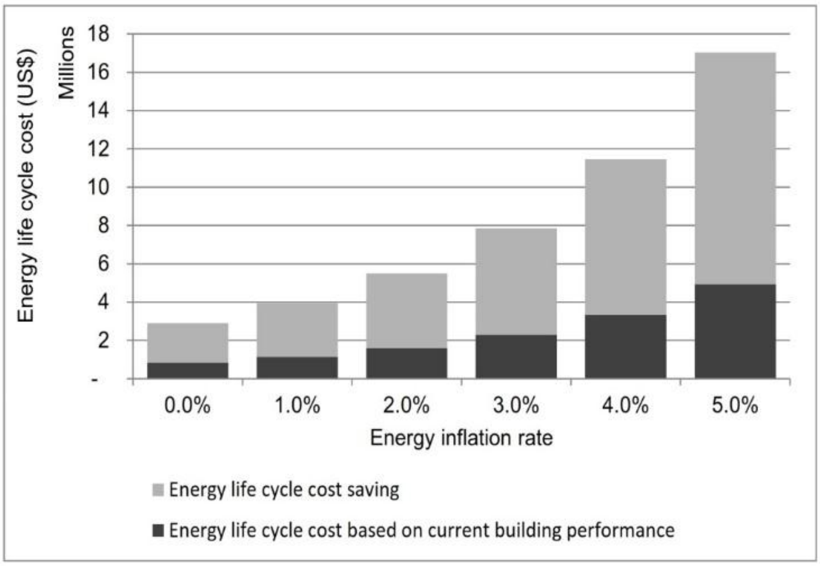

Figure 4: Graphical representation of life cycle energy cost saving at different inflation rates.

The former analysis was conducted based on different scenarios for average energy price escalation rates which are aligned with the historical trend of energy price in Malaysia which is increasing at an average of 2.4% per year [44]. Although it is unlikely to happen based on the historical trend, the same analysis was repeated considering a 2% average annual decrease in energy price. It is found that the energy life cycle cost based on the baseline energy consumption drops to $1,692,321, while it drops to $489,695 based on the current energy performance. This yields a total energy life cycle cost saving of $1,202,626. At 5% average annual decrease in energy price, the total energy life cycle cost saving drops to $653,345. Indeed, these results were expected since decreased energy price leads to lower life cycle cost saving. However, taking into account the positive environmental impact of the energy saving as non-economic factor, the green building as a design alternative is still appealing to be considered.

5. Conclusion

In this research, the current and future economic performance of a green building in use was measured against the industry baseline. Based on recorded data for the past building performance, it is empirically found that the current energy saving in the investigated green building is around 2,887,728 kWh which corresponds to a percentage of 71.1% in comparison to the industry baseline.

The empirical investigation also shows that the average annual energy saving is around 412,533 kWh/year which is equivalent to an average cost saving of 41,327 $/year. In seven years, the building has saved around $289,290 of energy cost which corresponds to 70.8% in comparison to the industry baseline.

From life cycle perspective, the building saves around 5,756 kWh/m^2 along its whole life cycle compared to the industry baseline, which is equivalent to a cost saving of $2,054,460 in the real terms (excluding the effect of energy price inflation). In the nominal terms (including the effect of energy price inflation), at 1% average annual increase of energy price, the cost saving of reduced energy consumption in the building is around $2,796,451. At 5% average annual increase in energy prices, it is more than fourfold and reaches $12,107,060. At 2% and 5% average annual decrease in energy price, which is unlikely to happen based on the historical trend in energy price, the green building still saves $1,202,626 and $653,345 respectively throughout its whole life cycle.

Empirically, it can be argued that the economic benefits associated with reduced energy consumption in the green building worth consideration from building owners and investors, the global drastic increase of energy prices makes the green building more attractive investment alternative. This research provides an empirical evidence for the economic benefits associated with reduced energy consumption in a green building. However, this research adopts case study as a research methodology, therefore, the findings cannot be generalized for a larger population.

Data availability statement:

All data generated or analyzed during the study are included in published paper.

Acknowledgment:

The authors acknowledge the financial support provided by the Malaysian Ministry of Higher Education. The authors also thank the Malaysian Green Technology Corporation for providing the required data to conduct the research.

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Highlights:

- We examined the actual economic performance of a green building in use in term of energy consumption.
- We found that investigated green building saves around 71.1% of energy compared to the industry baseline.
- For a period of 60 years, we found that the investigated green building saves around 24,751,980 kWh of energy, which corresponds to 5,756 kWh/m^2.
- At 1% average annual increase in energy price, the energy saving corresponds to US$2,796,451 throughout the whole building life cycle.

At 5% average annual increase in energy price, the energy saving corresponds to US$12,107,060 throughout the whole building life cycle.