# Economic Analysis of Smart Buildings in Nigeria: A Case Study

**Omorogiuwa Eseosa, Folorunsho Isaac Temitope**

***Abstract*-Economic analysis of Building Management Systems (BMS) for efficient energy consumption and reduction of operating and running cost has been adopted as cost and energy effective solution in advanced countries, hence the need to look into the economics of this method to ascertain its viability as an option for adoption in Nigeria's industrial and commercial facilities. In order to determine the best alternative between with and without BMS (w-BMS and w/o-BMS), two economic indicators – Benefit/Cost (B/C) ratio and Life Cycle Cost Analysis (LCCA) were evaluated, and the environmental impact of energy savings is realized from the use of BMS calculated over a 5-year period. Upon completion of analysis, it was observed that Envoy Hotel recorded about 63% energy savings through the use of lighting BMS in the first five (5) years of operation, and this translated to annual monetary savings of about N1, 380,000.00. B/C ratio was determined to be greater than 1 in favor of w-BMS (1.63)and LCC over a useful life of 25 years and a 12% interest rate of w-BMS (N67,826,620.00) was lesser than w/o-BMS (N68,438,710.00), thus justifying the use of lighting BMS by the management of Envoy Hotel.The newly launched Building Energy Efficiency Code by Federal Ministry of Works is indicative of the need to reduce energy consumption in buildings through efficient designs.**

***Index Terms*— B/C, BMS, LCCA, w-BMS**

## I. Introduction

Consumption of energy in all classes of buildings (residential, commercial and industrial) has become of prime interest towards environmental conservation and the achievement of sustainable development across all nations of the world. This is because of the percentage of generated energy consumed by buildings and the huge amount of greenhouse gases released to the atmosphere. Research has shown that an average of 40% of electricity supply is consumed by buildings around the world and the rate keeps growing especially for developing countries due to increasing economic activity and rural–urban migration (Pervez et al. 2018. Commercial and industrial buildings have been observed to consume a greater part of generated energy in Nigeria as highlighted by Federal Ministry of Works (Sweet Crude Report, 2017). Thus, it has become pertinent that energy consumption in Nigerian buildings be optimized such that both energy conservation and environmental preservation be promoted. In Nigeria, little or no attention has been paid to energy consumption pattern and its impacts on our environment as compared to Europe and other developed parts of the world where energy consumption pattern and the need to cut down on energy use so as to preserve the environment is of great importance to both government and individuals. In developed countries there are various bodies and regulatory agencies set up to monitor, set rules and standards to enforce compliance to energy conservation. An example is United State Green Building council (USGBC), this is the body that issues Leadership in Energy Efficient Design (LEED). Credits to buildings in United States (Iwaro and Mwasha, 2010). This awareness in developed countries has led to development of various technologies and methods to conserve energy in buildings. One of such method is the development of BAS though yet to be fully developed in Nigerian built industry (Iwuagwu, 2014). The prompt rise in world's energy consumption has been observed for last two decades and is estimated to rise by53% until 2030 (International Energy Agency, 2007).Besides the impact of energy consumption in Nigeria on our environment, it is also important to look into saving energy conservation methods in the built environment because of the deficit energy supply in the country. Therefore, it has become necessary to scrutinize energy consumption in the evolving built environment in Nigeria, and also promote energy conscious measures in the short and long term by encouraging adoption of advance technology systems like BMS for energy conservation in buildings. In the course of planning for this study, it was observed that most private and government owned buildings facilities do not have BMS installed and very little or no information is collected regarding energy consumption and building performance data. Such information is what BAS is able to keep and help building owners to decide on maintenance schedule, plan budget and make good decision on operational cost. BMS can also automate demand side management; an initiative and technology that encourage consumers to optimize their energy use by setting algorithms that meet planned strategy in BMS management software and are executed automatically to achieve optimum result. In 2016, Building Energy Efficiency Code (BEEC) was launched. The policy was proposed to gear the nation towards an energy conscious building development. The aim of BEEC is to set minimum requirements on Building Energy Efficiency and to provide for their proper implementation, control and enforcement. Though the implementation of this policy has been ineffective on the larger part due to poor supply of power in the nation. It is estimated by the guideline to save over 2500 MW of energy over a 10-year period and about 30 – 40% energy consumption rate in buildings where the code is implemented (ARUP, 2016).To complement BEEC, this study examines the use of BMS as a tool for efficient energy consumption in Nigeria commercial and industrial buildings, by analyzing the economic performance of implementing BMS in commercial buildings and also seeks to promote minimized operating and running cost of electromechanical systems installed in buildings.

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## II. REVIEW OF BMS TECHNOLOGY

While BMS have become smart in recent years, the concept is certainly not new and has gradually evolved over the last 50+ years and into the 21st century systems as at today. BMS has always been boosted by technological developments of the time, but today's smart building technology is influencing BMS like nothing before. BMS is essentially a computer-based control system that monitors and manages building's mechanical and electrical equipment, including ventilation, lighting, power, fire and security systems. Various subsystems in a building have traditionally been operated separately, each with their own IT structure. However, as the number of subsystems increased the case for integrated solutions also grew. In particular, the addition of fluctuating renewable energy generation and energy storage capacity added a new level of complexity, one which demanded a new form of management in buildings, in order to reduce rising overall costs (Memoori, 2017). The driving force of this evolution is energy efficiency. With 40% of total energy consumption coming from buildings the case for greater efficiency is strong. Modern BMS systems allow for historical trend analysis to be paired with real-time data collection to optimize subsystems such as lighting and HVAC. These mountains of 'big data' are continuously growing, and ability to analyze them give more meaning to the data, thus the greater the application of intelligence and optimization in terms of energy utilization. By constantly observing and controlling air quality, for example, BMS can create indoor environment that boosts employee health and productivity. Furthermore, by monitoring different machine health parameters, BMS can optimize maintenance scheduling and reduce costly downtime (Memoori, 2017). Connectivity also enables remote monitoring and control of BMS. Not only does this create greater flexibility for building managers, it also increases safety and security for building's occupants and assets. Alarms coupled to connected HVAC, fire, security systems, as well as access control permit immediate and effective responses to a wide variety of emergency situations. All of these developments can be attributed to the emergence of Internet of Things (IoT) in smart buildings in recent years. The trends promoting growth in BMS market are now directly linked to IoT movement(ISO (2004). Similar and simultaneous development in the industrial IoT has advanced data and connectivity for industrial purposes. This is also feeding back into BMS development in the form of lower cost of 'things' with embedded intelligence, advances in predictive analytics, as well as the growth of cloud based services (i-Scoop, 2018). It is worthy to note that there are tremendous changes at the construction phase of buildings through the rise of building information management (BIM) as shown in figure 1.0. Each generation of BIM further eases the integration of complex building systems into architecture, engineering, and construction workflows. BIM allows for the incorporation of BMS solutions at the project design phase. This enhances BMS integration, thus reducing building operating cost. As BMS and IoT continue to grow, there will be greater cost savings and novel features, thus creating unparalleled value from the building. The rise of BMS to become the core of smart buildings is inevitable since the future of buildings is unequivocally data and connectivity.

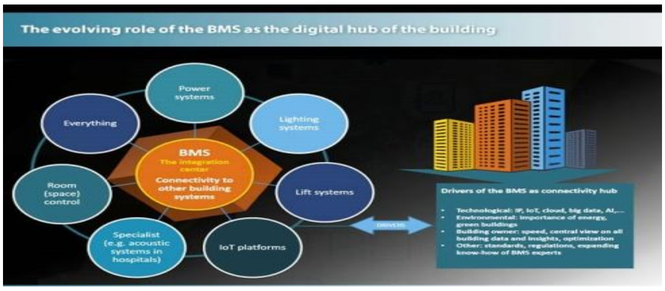



Figure 1.0: The Evolving Role of BMS (Source: i-Scoop, 2018

It is observed that BMS is gaining popularity in the built environment. Though initial cost may cause some hesitation at first glance, however, when the benefits of investment becomes clear, implementing BAS often become a no-brainer, especially for owners of commercial and industrial buildings, such as ware houses, office buildings, schools and government buildings etc.

## III. RESEARCH METHODOLOGY

In order to have a holistic view of the economic evaluation of the lighting system of both alternatives (with and without BMS (*w-BMS & w/o-BMS*), Envoy hotel situated in the federal capital territory(FCT),Abuja in Nigeria was evaluated over a 25-year analysis period – a time period that corresponds to the average useful life of a hotel building.

The economic analysis used interest rate of 12% which was the current rate used by the Central Bank of Nigeria (CBN) as of the period this analysis was carried out. Moreso, the cost of energy usage over the analysis period was calculated using Abuja Disco electricity tariff (Class C3) which is presently at ₦45.72/kWh as of the period in which this analysis was carried out.

For the estimation of the economic consequences of both alternatives (*w-BMS & w/o-BMS*), the Ruegg's and Marshall's *Building Economics—Theory and Practice* was adopted.

The cost of energy usage is calculated using equations 1-3 respectively:

$$E_m = P * t_m \quad (1)$$

$$EB_m = E_m * tarrif \quad (2)$$

$$EB_y = EB_m * 12 \quad (3)$$

Where;

$EB_y$ = Yearly electricity bill/cost (₦)

$EB_m$ = Monthly electricity bill/cost (₦)

$E_m$ = Monthly lighting power consumption (kWh)

$P$ = Power consumed (kW)

$t_m$ = Operational hour per month (h)

$tarrif$ = ₦45.72/kWh (Abuja Disco Electricity Class C3)

Subsequent to the determination of the energy consumption of both alternatives, three (3) economic analysis tools were used to compare the two alternatives:

- ✓ Benefit – Cost Ratio (BCR)
- ✓ Life Cycle Cost Analysis (LCCA)
- ✓ Payback Period (PBP)

In order to use the listed economic analysis tools, the following set of data was gathered, and critical assumptions made for each alternative:

Table 1.0a: Cost Data for Economic Analysis (*w-BMS*)

| **Alternative 1 – Envoy Hotel with BMS Installation** | | | |
|---|---|---|---|
| S/N | **Type of Cost** | **Description** | **Amount (₦)** |
| **1** | Capital | Lighting System | 50,000,000.00 |
| **2** | Maintenance | Lighting System | 100,000.00/year |
| **3** | Capital | BMS | 8,000,000.00 |
| **4** | Maintenance | BMS Equipment | 130,000/year |
| **5** | Residual Value | BMS + Lighting System | 8,200,000 |

Table 1.0b: Cost Data for Economic Analysis (*w/o-BMS*)

| **Alternative 2 – Envoy Hotel without BMS Installation** | | | |
|---|---|---|---|
| S/N | **Type of Cost** | **Description** | **Amount (₦)** |
| **1** | Capital | Lighting System | 50,000,000.00 |
| **2** | Maintenance | Lighting System | 160,000.00/year |
| **3** | Residual Value | Lighting System | 3,000,000 |

**Assumptions**

**a)** All other associated costs of Envoy hotel were not considered in the economic analysis since it is assumed equal for both alternatives.

**b)** For the *w/o-BMS*, it is assumed that 30% of the occupants leave both light circuits (LC-1 & LC-2) ON during bedtime, 30% turns LC-1 OFF but leaves LC-2 ON, while the remaining 40% turns both LC-1 and LC-2 OFF.

Since the use of energy has considerable environmental and social impact, a study was conducted to determine the green gas emissions that arose from the use of both alternatives, and also, compare and contrast this value. In addition to this, the social benefit of having BMS installed was conducted.

## IV. RESULTS & DISCUSSIONS

Having completed the economic evaluation of BMS installation on commercial buildings (Envoy hotel as case study), results obtained from energy audit of the building's lighting system, comparative analysis between facilities (*w-BMS* and *w/o-BMS)* using economic analysis tools, and the social and environmental benefits derived from the use of BMS on the studied facility are analyzed.

Having audited energy usage of the lighting system over a 5-year period, Table 2.0a and 2.0b shows tabulated results of energy consumption (in kwh)under both operational cases of Envoy Hotel i.e. both *w/o-BMS* and *w-BMS*.

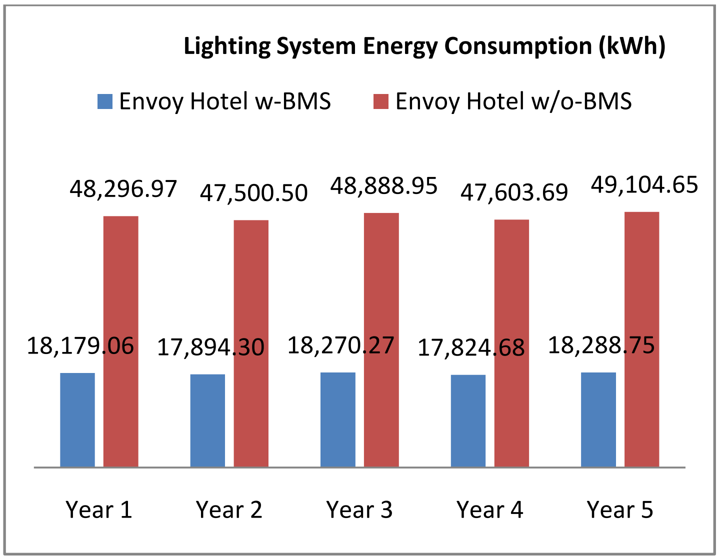
Table 2.0a: Energy Audit Result (*w/o-BMS*)

| **Lighting Energy Consumption under *w/o-BMS* Operational Case** | |
|---|---|
| **Year** | **Energy Consumption (kWh)** |
| **1** | 48,296.97 |
| **2** | 47,500.50 |
| **3** | 48,888.95 |
| **4** | 47,603.69 |
| **5** | 49,104.65 |
| **TOTAL** | 241,394.80 |

Table 2.0b: Energy Audit Result (*w-BMS*)

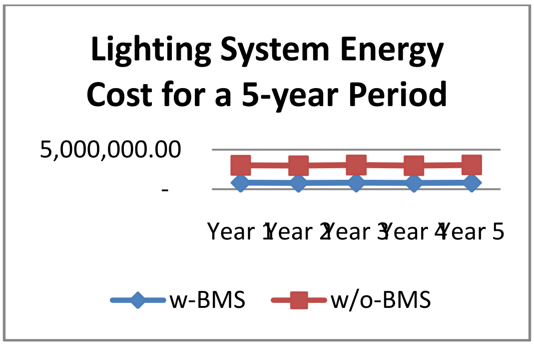
| **Lighting Energy Consumption under *w-BMS* Operational Case** | | | | |
|---|---|---|---|---|
| **Year** | **Scenario 1 (kWh)** | **Scenario 2 (kWh)** | **Scenario 3 (kWh)** | **Total by Year (kWh)** |
| **1** | 9280.50 | 6735.55 | 2163.02 | 18179.06 |
| **2** | 9077.50 | 6656.43 | 2160.36 | 17894.30 |
| **3** | 9503.30 | 6589.95 | 2177.02 | 18270.27 |
| **4** | 9215.48 | 6478.35 | 2130.85 | 17824.68 |
| **5** | 9628.94 | 6506.25 | 2153.56 | 18288.75 |
| **TOTAL** | 46,705.73 | 32,966.53 | 10,784.81 | 90,457.06 |

From the tabulated results, it can be seen that the total amount of energy consumed by the lighting system under*w-BMS* operational case is about 37% of the total energy consumption under *w/o-BMS* operational case. This confirms the established fact that about 40% energy-saving benefit is derived from the use of BMS as recorded in several literatures. Fig. 2.0 presents a more pictorial view of the consumption rate of both alternatives over a 5-year period.

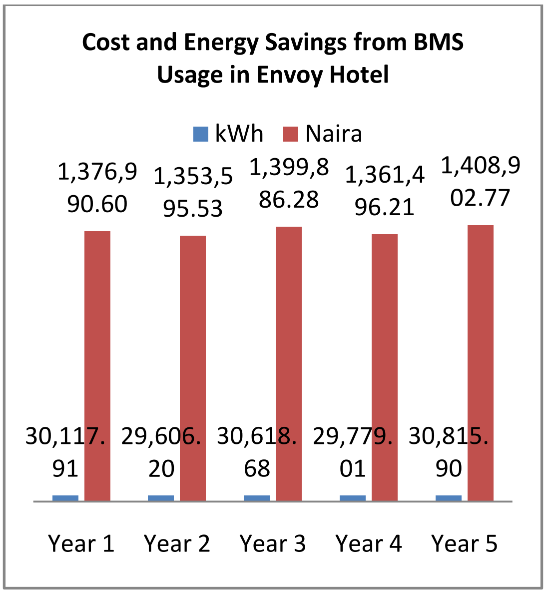



a) *Figure 2.0: Bar chart showing Energy Consumption for both w-BMS and w/o-BMS*

In terms of monetary value, Fig.3.0a shows a 5-year monetary electricity bill incurred from the use of lighting system, while Fig.3.0b shows the cost and energy savings made on a yearly basis from the use of BMS in Envoy Hotel.




b) *Figure 3.0a: Lighting System Energy Cost for a 5-year Period*




c) *Figure 3.0b: Cost & Energy Savings from BMS Usage in Envoy Hotel*

*B. 4.1 Economic Analysis*

Though *w-BMS* alternative has showed a lot of benefits in terms of energy and cost savings as both alternatives were further subjected to economic analysis using both Benefits-Cost Ratio and Life Cycle Cost Analysis as the economic tools of choice. Table 3.0 shows cost summary for both w-BMS & w/o-BMS alternatives.

Table 3.0: Cost Summary for both Lighting System Alternatives

| | **Envoy Hotel w/o-BMS (Alternative 1)** | **Envoy Hotel w-BMS (Alternative 2)** |
|---|---|---|
| **Capital Cost – Lighting System** | N 50,000,000.00 | N 50,000,000.00 |
| **Maintenance per year – Lighting System** | N 160,000.00 | N 100,000.00 |
| **Capital Cost – BMS** | - | N8,000,000.00 |
| **Maintenance Cost per year – BMS** | - | N130,000.00 |
| **Energy Cost per year** | N 2,213,468.00 | N 829,388.00 |
| **Residual Value** | N 3,000,000.00 | N 8,200,000.00 |
| **Interest Rate** | 12% | 12% |
| **Useful Life** | 25 years | 25 years |

*1) 4.2 Benefits-Cost Ratio (BCR)*

The main objective of using this method is to determine the desirability of both alternatives as far as the expected benefits on the lighting system investment is concerned. Utilizing the EUAC (Equivalent Uniform Annual Cost) method, the costs to be used in the B/C ratio are the capital, maintenance and energy cost:

- ***Costs***

$$\boldsymbol{EUACAlt1} = 50{,}000{,}000\,(A/P, 12\%, 25) + 160{,}000 = \boldsymbol{N6,535,000}$$

$$\boldsymbol{EUACAlt2} = 50{,}000{,}000\,(A/P, 12\%, 25) + 8{,}000{,}000\,(A/P, 12\%, 25) + 100{,}000 + 130{,}000 = \boldsymbol{N7,625,000}$$

- ***Benefits***

The benefits are represented by the difference in the energy costs if an alternative is selected over another and the residual value of each alternative.

***Energy Savings Benefit***

$$EnerrgyCost\ (Alt\ 1) – EnergyCost\ (Alt\ 2) = N2{,}213{,}468 – N829{,}388 = \boldsymbol{N1,384,080}$$

Hence, Alt. 2 has a benefit of $N1{,}384{,}080$ over Alt. 1 in terms of energy cost

***Residual Value Benefit***

Annualizing the resale value of each alternative yields:

$$EUABAlt\ 1 = 3{,}000{,}000\,(A/F, 12\%, 25) = \boldsymbol{N22,500}$$
$$EUABAlt\ 2 = 8{,}200{,}000\,(A/F, 12\%, 25) = \boldsymbol{N61,500}$$

The difference between both resale benefit = $\boldsymbol{N39,000}$

Thus:

$$\boldsymbol{Benefits} = Energysavingsbenefit + Resalevaluebenefit = \boldsymbol{N1,774,080}$$

The costs associated with these benefits are shown by the difference between the annual costs of w-BMS and w/o-BMS.

Thus:

$$\boldsymbol{Costs} = EUACAlt\ 1 - EUACAlt\ 2 = \boldsymbol{N1,090,000}$$

**NB**: The alternative that costs more (w-BMS) is the one that provides the benefits. Hence, the B/C ratio can be computed as:

$$\frac{\boldsymbol{Benefits}}{\boldsymbol{Cost}} = \frac{\boldsymbol{1,774,080}}{\boldsymbol{1,090,000}} = \boldsymbol{1.63}$$

Since the B/C ratio is > 1, Alternative 2 (***w-BMS***) is the economically viable choice.

*2) 4.2.2 Life Cycle Cost Analysis (LCCA)*

LCCA was used to compare initial investment options and also identify the least-cost alternatives for a twenty five (25) year period.

$$LCC\ (PV) = capitalcost + lifetimeenergycost + lifetimemaintenancecosts - residualvalue$$

In order to determine the LCC, all costs were converted to their present value using the 12% discount rate.

$$LCC = \text{Capital} + Annualenergycost\ (P/A, 12\%, 25) + Annualmaint.cost\ (P/A, 12\%, 25) - Futureresidualvalue\ (P/F, 12\%, 25)$$

***Alternative 1 (w/o-BMS)***

$$LCCAlt\ 1 = 50{,}000{,}000 + 2{,}213{,}468\ (7.843) + 160{,}000\ (7.843) - 3{,}000{,}000\ (0.0588)$$

$$\boldsymbol{LCCAlt1 = ₦68,438,710}$$

***Alternative 2 (w-BMS)***

$$LCCAlt\ 2 = 60{,}000{,}000 + 829{,}388\ (7.843) + 230{,}000\ (7.843) - 8{,}200{,}000\ (0.0588)$$

$$\boldsymbol{LCCAlt2 = ₦67,826,620}$$

$$\boldsymbol{LCCAlt1} > LCCAlt\ 2$$

Based on the calculated values of LCC for both alternatives, it is clear that the obvious choice is Alternative 1 (w-BMS) since it has a lesser LCC as compared to Alternative 1.

Though the difference between the LCC of both alternatives is a meager₦ 612,090, this is due to the high discount rate of 12% which was utilized during the calculations.

### *C. 4.3 Environmental & Social Considerations*

To evaluate the impact of energy savings made through the use of BMS for the lighting system in Envoy Hotel, the total energy savings made in the 1st five (5) years of operation (150,937.74 kWh) was inputted into an online resource (http://selene-ny.org/lightcost/index.php) which calculates the impact of light usage on the environment.

The volume of emissions prevented from harming the environment through the use of BMS for Envoy's Hotel lighting system is as shown in Table 4.3 below.

Table 4.0: Environmental Savings made through the use of BMS in Envoy Hotel

| Type of Emission | Amount |
|---|---|
| $^*CO_2$ | 213,741 pounds |
| $SO_2$ | 2,420 pounds |
| $NO_X$ | 1,476 pounds |
| *Mercury | 1,496 ounces |

*represents emissions from power generation used to power the lights.

In a more practical note, these emissions can be compared to that emitted from driving a car which gets 20 miles/gallon for 174,246 miles. Also, to provide a natural solution for cleaning the air of the $CO_2$ emissions will require planting about 345 trees over the 5-year period.The social benefits of the use of BMS for controlling lighting system in Envoy Hotel are resident in the improved quality of life which it gives the guests which resides in the hotel. For example, because the lighting system automatically dims the lamps at bed-time, there is no disruption and delay in the production of melatonin which is central to a healthy sleep and a healthy life. Also, this single act of dimming the lights can on a larger scale help reduce the risk of depression and metabolic dysfunction which could result from an unhealthy sleep cycle.

## V. CONCLUSION AND RECOMMENDATION

The installed lighting BMS was able to save the hotel about 160,000 kW/h of energy over a 5-year period, thus justifying the use of lighting BMS in the hotel for energy savings. In Nigeria, this energy-savings is greatly beneficial because of the inadequate and epileptic power generation and supply which has been lingering over 20 years.Monetary savings can be made through the use of BMS as evidenced by an annual savings of about N1, 380,000.00 in utility (electricity) bills. A B/C ratio analysis of both alternatives shows that *w-BMS* alternative is the most economically viable option as evidenced by the value of B/C ratio > 1. Though installed BMS requires a higher maintenance costs over the life cycle of the building, LCCA showed that it is still a more economically viable option when compared to the same building without a BMS. Social and environmental benefits of using BMS to affect energy-savings in a facility cannot be overemphasized. This is exemplified by the huge volume of emissions avoided in as little as 5 years through the use of lighting BMS in Envoy hotel.

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