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Energy Performance Certificate of buildings as a tool for sustainability of energy and environment in Ghana

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Abstract:

Proper management of the built environment is a key tool in achieving environmental sustainability. The world today is challenged with a lot of activities that have adverse effect on the environment and if not managed well, the world will become uninhabitable. The European Union (EU) in 2008 instituted the Energy Performance Certificate (EPC) for buildings to bring about energy efficiency and reduce CO_2 emissions from buildings on sale and on rent. This has brought about significant reduction in energy use in Europe. This research analysed the viability of EPC usage in the residential estate markets in Ghana using a case study building. It was realised that the Standard Assessment Procedure (SAP) used in the UK was not applicable due to differences in conditions pertaining to the built environment. A customised procedure named Building Energy Assessment Procedure (BEAP) was therefore developed specifically for this research. The results of the case study show that the building will make financial gains of $184.00 after 10 years of installing a solar module of 250Wp. The conclusion from the findings shows that EPCs in Ghana can advice developers' on ways of improving buildings for sustainability and obtaining financial gains. This is because developers can use energy efficiency as a marketing tool whiles clients or home buyers will benefit financially through savings on energy. This research also gives a new direction for policies to be set.

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Introduction

The quality of an environment is a limit of environmental disturbance that determines the maximum allowable degradation or pollution of any medium in the natural environment. This quality is determined by assessing the impact of any activity or development with an environmental impact assessment. Environmental impact assessments (EIAs) have often been criticized for having too narrow scope and presently no procedure has been specified for determining a boundary for the assessment. The only existing boundary is determined by the applicant and the lead assessor, but in practice, almost all EIAs address the direct, on-site effects alone. [1]. Apart from direct effects, there is a great deal of indirect effects through consumption of goods and services, production of building materials and machinery, additional land use for activities of various manufacturing and industrial services. The indirect effects of developments are often of a higher magnitude than the direct effects assessed by EIA. Large projects such as airports or ship yards cause wide ranging national as well as international environmental effects and should be taken into consideration during the decision-making process. [2].

All these indirect effects shows how broad and multi disciplinary Environmental Impact Assessment is and therefore all stakeholders and professionals must be brought on board to engineer the environment. Research has proven that, buildings contribute a higher percentage to CO_2 emissions. This is a major issue when it comes to air pollution in the world. Globally, buildings are responsible for approximately one-third of global energy-related CO_2 (including indirect) and three-fifth of halocarbon emissions.[3]. CO_2 emissions are a major environmental challenge in the world now and the mitigation of certain building practices must be employed to reduce its emissions.

There is a paradigm shift all over the world to sustainable or green building to help curb CO_2 emission from buildings. This shift is aimed at making buildings more energy efficient, thereby reducing the financial and environmental costs during their operation and maintenance. To promote this agenda, the EU passed a law in 2008, which required every home sold in the EU to have an Energy Performance Certificate (EPC). Later this was applied to rented homes as well. This certificate is supposed to be displayed with the property being sold or rented out. The certificate shows the energy efficiency of the building as well as the environmental impact in terms of CO_2 emissions. An energy performance certificate uses a 120-point scale which is divided into seven categories. These categories range from A (most efficient) to G (least efficient). These grades are also done with comparison of the cost of installation as against the potential savings cost over a period of 10 years. [4]. This means that apart from mitigating CO_2 emissions from buildings, the owner or user of a building will also have some monetary savings.

The Real Estate market in Ghana is rapidly growing and there is already a growing demand of energy for domestic, commercial and industrial use which is estimated at a rate of 12-13% per annum. The country currently has a deficit on the energy produced as against its demand and therefore there is an existing load shedding of power especially during peak hours. With this trend, demand will continue to surpass supply and this problem might is likely to continue into the foreseeable future. The question now asked is, how can the built environment be sustained if energy is not available for use in buildings? This research therefore seeks to assess the possible effects EPC can have on the energy demand from the built environment if introduced into Ghana. In Ghana, the energy commission is operating a Mandatory Appliance Standards and Labelling regime under which importers and retailers of Room Air Conditioners and Compact Fluorescent Lamps (CFL) are required to import and sell only products that meet minimum efficiency and performance standards approved by the Ghana Standards Board. This is under the Ghana Appliance Energy Efficiency Standards and Labelling Programme. The minimum energy efficiency standard for air conditioners acceptable in Ghana is an Energy Efficiency Ratio (EER) of 2.8 watts of cooling per watt of electricity input. The Energy Commission in September 2012 introduced a scheme to encourage consumers to turn in their used fridges for new ones at discount. After a pilot project in Accra, the Commission has started rolling out the scheme to all parts of the country. [5]. This is a great step by Ghana towards energy efficiency.

However, most residential estates in Ghana are not sold with furnishes. The client buys his or her own furnishing, while the developer mostly decides on the building design and fabric. With the Ghana Appliance Energy Efficiency Standards and Labelling Programme, most people tend to buy energy efficient gadgets for their homes. This research therefore focussed mostly on the building fabric for energy efficiency in the analysis. Appliances within the Ghana Appliance Energy Efficiency Standards and Labelling Programme were, however used for the analysis.

Methodology

In UK where EPC is largely used, Standard Assessment Procedure (SAP) is used to collect data and give points. However since SAP does not take into consideration the orientation or location of buildings, the accuracy of these certificates are questionable. Other issues like insulations, double glazing and boiler usage are not applicable to a tropical country like Ghana. Therefore for this research, a unique procedure was developed. This procedure has been developed specifically with this research by the first author and is named Building Energy Assessment Procedure (BEAP). Case study approach combined with experimental was used. Experimental method was to bring out the strengths and weaknesses of the procedure developed. The purpose of adopting a case study approach was to illuminate the general by looking at the particular and to study an issue in detail. [6].

The procedure for BEAP is as follows:

1. Weather data of the location of the building is collected including weather files of any building simulation software to be used. Psychometric analysis is done to determine the thermal comfort zone. The average of the thermal comfort zone is used as the design temperature for simulation.
2. Data on the building in question is also collected. This data includes architectural drawings with details, photographs and measurements of existing situation. This measurement is

taken and compared with architectural drawings as a check. The material constituents of the entire building and their respective U-values is searched for and documented. Data on occupancy and equipment schedule is to be collected as well.

3. Building simulation analysis is done at this point with suitable software. Please note that some of the softwares are more widely accepted than others. For the analysis, different results are expected and therefore different software can be used for each category. Each category is awarded certain points to total to 120 point scale. These points are then applied unto the A-G 120 point scale that exists with EPCs. Calculation of carbon footprints for each category will also be shown. Below is a table showing the categories.

Category	Name or Description	Maximum Points
1	Cooling Energy For Thermal Comfort	60
2	Lighting Energy For Good Vision	30
3	Energy From Renewables	20
4	Greenery On Site	10
Total		120

Table 1. Categories for BEAP and their respective points.

Points are then allocated to the results from the simulation to establish where the building falls on the 120 point scale. Details of analysis on all categories are discussed below.

(a) For category 1, emphasis is on additional mechanical cooling as the climate of Ghana requires cooling for thermal comfort. Looking at the psychometric chart in figure 2, it is clear that the climate of Ghana requires mostly cooling. This means natural ventilation should be factored in when simulating. Also occupancy and equipment schedule must be included for a more accurate result. The more energy a building needs to cool down for thermal comfort, the lower the points. The table below shows how points under category 1 can be achieved.

Total yearly energy needed to cool building for thermal comfort in kWh	Points achieved
0 – 50	60
51 – 150	40
151 – 300	30
301 – 600	10
600+	0

Table 2. Breakdown of category 1 and how to achieve points.

The ranges in table 2 were developed by adopting the residential customer class of the approved residential end user electricity tariffs as at October 2013 in Ghana. [7]. This was also used for category 2. Calculation of carbon footprints was done using the equation below.

Carbon emissions = Total annual energy consumption (kWh) x 0.025 metric tons / year (1)

This was achieved by using data on the website of EDF which states that hydro emits an average of 0.002 metric tons per kWh per year whiles thermal emits 0.0487.

[8]. Adding these two and striking an average give the value 0.025 metric tons per kWh per year. This is because currently Ghana has almost an equal share of hydro and thermal. [9].

(b) Category 2 focuses on how much energy is used on artificial lighting in buildings during the day. A building using more energy on lighting during the day gets less point while a building using little or no energy for lighting during the day gains high points. The day in this procedure uses the sun shine hours of each day. The table below outlines the details. For carbon footprint calculations, equation (1) is used.

Total yearly energy needed for artificial lighting during the day in kWh	Points achieved
0 - 50	30
51 - 150	15
151 - 300	10
301 - 600	5
600+	0

Table 3. Breakdown of category 2 and how to achieve points.

(c) Generation of energy through renewable sources is the focus of category 3. In considering points for renewables, energy needed to run a very efficient house was taken into account. Assuming a very energy efficient house will consume an average of 100kWh of energy per month, a total of 1200kWh of energy will be needed for this house per year. 1200kWh or more energy from renewable energy should be enough to sustain such a house. Any house producing this amount of renewable energy or more is classified to gain the highest point in this category. There was a further breakdown of points for lower producing houses. The Net Metering system being introduced by the Energy Commission of Ghana has made this very easy as problems of storage is dealt with.

Calculation of carbon footprints is done using the equation below.

Carbon emissions = Total annual energy consumption (kWh) x 0.00042 metric tons / year (2)

This was achieved by using data on the website of EDF which states that solar emits an average of 0.00011 metric tons per kWh per year whiles thermal emits 0.00072. Adding these two and striking an average give the value 0.00042 metric tons per kWh per year. This is figure is added to that of category 1 and 2 then an average is struck for the actual figure. This is because the renewable energy replaces a certain proportion of energy used.

Total yearly energy generated by renewables on building in kWh	Points achieved
1 - 300	5
301 - 600	8
601 - 900	12
901 - 1200	16
1201+	20

Table 4. Breakdown of category 3 and how to achieve points.

(d) This elaborates on category 4 which awards a maximum of 10 points for the integration of greenery into the building. Lands full of vegetation are cleared and replaced with buildings. These vegetative cover play a major role in the absorption of CO_2 from the environment and therefore in cooperating them in our buildings should also be encourage for environmental sustainability. Plants also play a major role in the cooling of buildings and this is needed in a tropical country like Ghana. Plants and greenery prevents the reradiating of heat from the sun to form a heat sink around buildings. Based on this information, a well designed land should have its building covering 60% of land, 10% for hard landscape and 30% for soft landscape.

Percentage of land being used for soft landscape	Points achieved
1 - 5	1
6 - 15	4
16 - 29	8
30 +	10

Table 5. Breakdown of category 4 and how to achieve points.

Carbon footprints from category 4 will actually be used as a reduction. This is because greenery absorbs carbon and therefore will be an offset to carbon from other categories. A lot of research was done on this but a publication by Zirkle et al indicated that forest and farms had carbon absorption of averagely 0.33 metric tons per acre per year, well catered for lawns had an average of 1.3 metric tons per acre per year. [10]. Based on this, equation below is deduced:

Carbon emissions = Total Land covered by green (acres) x 0.82 metric tons / year (3)

The 0.82 is a result of an average between the forest value and that off the lawn. This is because not all houses will take very good care of their lawns. Moreover, a lot of home will plant trees as well for shade and this sometimes reduces the quality of lawns around the trees.

(e) After evaluating both the energy efficiency and carbon footprints, possible upgrades for less energy usage and carbon reduction are looked at. The category 1 in which the building scored the lowest point should be looked at first. The cost of upgrade should be documented and compared to cost of energy saved after upgrade over a minimum of 10 years. This will inform the client the monetary benefit whether positive or negative after upgrade.

Using the above procedure which has been named BEAP, one should gain all necessary data to produce an EPC. For carbon footprints, lower values might be recorded because energy produced in Ghana are mostly not from fossil sources. A selected case study building was taken through this process and discussed.

Weather Data Analysis

Weather data files for Energy plus was downloaded from the website of US Department of Energy. This was imported into Ecotect for weather data analysis.

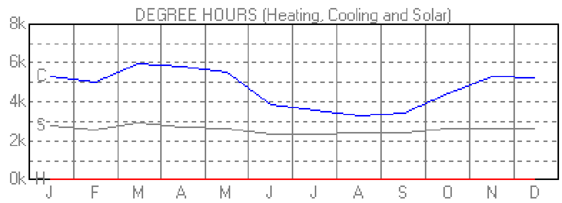

Figure 1. Image of Degree hours of Heating, Cooling and Solar (Source: Ecotect Weather Tool).

The image in figure 1 buttresses the fact that the climate of Ghana requires cooling and not heating. It can be seen that heating which in red lies flat at 0 throughout the whole year. But on the other hand cooling which is blue is needed all through the year. However, there is a drop from June to September and this can be attributed to solar dropping in those months.

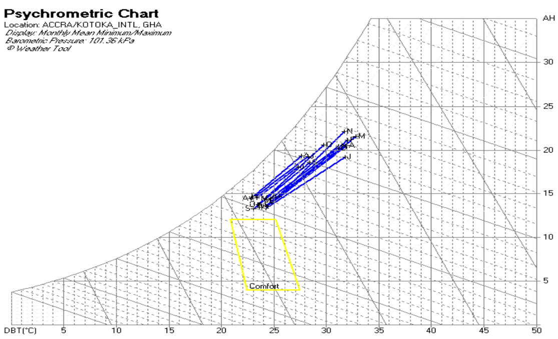

Figure 2. Image of Psychometric chart showing comfort zone (Source: Ecotect Weather Tool).

It is clear from figure 2 that none of the monthly temperature ranges fall within the comfort zone. They are either of higher temperature or humidity. Therefore to bring one into comfort zone cooling with a little reduction in humidity is needed. The comfort zone as shown above in yellow falls between 21ºC and 26ºC an average of 24ºC chosen as design temperature for simulations.

Case study building.

The chosen building was from VALCO Estates at Tema community 12 Ghana. This estate is among the most recent developments and has been in existence for about 15 years. This, as the name implies is for VALCO (Volta Aluminium Company Ltd) and was built purposely for their staff. The buildings mostly adhere to the standards of tropical building design. With regards to orientation, the rectangular plan has the longer sides facing either the north or south. The area of a house is approximately 12 meters by 9 meters (108m^2), but since it is a semi-detached structure, the full block is 24 meters by 9 meters (216m^2) . There are two bedrooms in one house and both share one toilet and bath. One of these two bedrooms is bigger and is assumed to be the masters' bedroom. The other spaces are a living room and kitchen. The windows of each space painted wooden frame and glass louvers with netting. The materials used the building was mostly the basic standard materials used in Ghana for the construction of houses as shown in table 6 below. Due to the fact that the building is simulated in Energy plus, the thermal properties as well as the U-values were required. A research was done on these materials to determine their u-values.

Building Component	Material Used	U-Value (W/mºC)
Roof	Aluminium Roofing Sheets	1.273
Walls	200mm sandcrete wall with plaster	1.135
Window pane	4mm plane glass louvers with netting	4.798
Window frame	Wooden frame	3.878
Door Panel	25mm hard wood	3.196
Door frame	50mm hard wood	2.848
Floor	150mm concrete slab with 50mm screed.	0.282

Table 6. Building Material and their U-values.

Building Simiulation Analysis

The simulation of this research was done in Energy plus. Energy plus is a building simulation software programme of the United States Department of Energy (DOE) and this is promoted through the Energy Efficiency and Renewable Energy Office (EERE). It has become widespread and it is used all over the world due to its robustness and open access use. [11]. Data already collected on the case study building was entered into Energy plus and simulated for results. Emphasis was placed on the cooling and lighting loads. The results were outputted into Microsoft excel and analysed.

Results and Discussion

The result of this research is mainly data from simulations and some calculations. These were done sequentially using BEAP. Therefore the first result to look at is cooling energy for thermal comfort (category 1).

Cooling Energy for Thermal Comfort (Category 1)

As described earlier, BEAP focuses on energy needed to cool a building for thermal comfort after natural ventilation; occupancy and equipment schedule has been applied. Cooling load from the case study building shown in figure 3 below duplicates almost the same trend as the Degree Hours in the weather data analysis. The highest is in March as the sunshine hours are at highest in that month. The table also shows the total yearly cooling needed in kWh and this would be used in BEAP for points.

MONTH	COOLING (Wh)
January	6500
February	6320
March	7010
April	6803
May	6500
June	5102
July	4600
August	4100
September	4200
October	5430
November	6210
December	6150
TOTAL	68,925
In kWh	68.9 kWh
AVERAGE	5.7 kWh

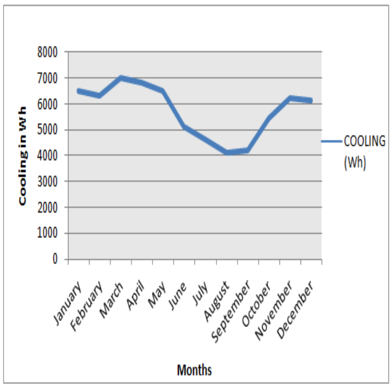

Figure 3. Table and graph showing the cooling load for the case study building.

Therefore total yearly cooling energy = 68.9kWh

Points achieved by the case study building = 40 points

Carbon footprint is calculated using equation (1):

Total annual energy consumption on cooling (kWh) x 0.025 metric tons

= 68.9kWh x 0.025

= 1.73 tons of CO_2 emissions per year.

Lighting Energy for good vision (Category 2)

From data collected from the building lighting and simulation done, artificial lighting during sunshine hours was on for only 4 hours in a day. This was a 15W energy saving bulb and therefore below is a table showing its consumption.

Month	Lighting (Wh)
January	1860
February	1680
March	1860
April	1800
May	1860
June	1800
July	1860
August	1860
September	1800
October	1860
November	1800
December	1860
Total	21,900
In kWh	21.9kWh

Table 7. Table of lighting load per month.

The points gain by this case study in category 2 is 20. This is because the total yearly consumption of lighting during sunshine hours is 21.9kWh and it falls within the highest group. CO_2 emissions are:

Total annual energy consumption on lighting (kWh) x 0.025 metric tons

= 21.9kWh x 0.025

= 0.55 tons of CO_2 emissions per year.

The building had no renewable energy integrated and therefore category 4 was treated next.

Percentage of land being used for soft landscaping

Based on the carbon calculation equation outlined for category 4 in BEAP, an average of 0.82 metric tons per acre per year was used. The land size allocated to the case study building is 30m x 21m which equals to 630m^2. With the area covered by soft landscape been 176m^2 which represents 28% of the total land, 8 points was awarded. To know the actual amount of carbon absorbed, the acreage was inputted into the derived equation.

Carbon absorbed = 0.82 metric tons x 0.05 acres per year.

= 0.04 metric tonnes of carbon absorbed per year.

Total points and CO_2 emissions by case study building.

Category	Name or description	Maximum points
1	Cooling energy for thermal comfort	40
2	Lighting energy for good vision	30
3	Energy from renewables	0
4	Greenery on site	8
Total		78

Table 8. Categories for BEAP and their respective points gained by case study building

From the above table, the case study building is classified under class C on the A-G 120 points scale rating. This means that the case study building is above average when it comes to energy efficiency. On CO_2 emissions, it is still rated at class C using the existing carbon scale.

CO_2 emissions = Category 1 CO_2 emissions + Category 2 CO_2 emissions - Category 4 CO_2 absorptions

= 1.73 metric tons + 0.55 metric tons – 0.04 metric tons

= 2.24 metric tons per year.

Potential home improvements and savings

The more energy efficient a building is, the less its running cost. Therefore even though this case study building is rated above average in terms of its energy efficiency, further improvements must be looked at for better financial benefits. This building has a potential of gaining more points from the use of renewable energy. This is because that is the category that did not do well and therefore any improvements in that category can have a great impact on the points scored.

Item	Modules	System Power	Price for Grid Connected
1.	80 x 250w	2kW	8,000 USD
2.	200 x 250w	4kW	15,000 USD
3.	600 x 250w	10kW	30,000 USD

Source: www.nyansaposolar.com.[12].

Table 9. Table of solar PV home starter costs

Using item 1 which has the lowest system power on the table above and just one module of 250Wp, the total energy produced by the case study building with this solar PV as home improvements will be 250W x 2555 hours for the whole year. This will be 638,750 W and 639kWh per year. This much of energy produced by the case study building will increase its points to 93. Therefore a class A will rather be achieved instead of class C. It is obvious that the case study building has the potential of being a class A instead of class C with the integration of just one solar panel at 250Wp system power. From figure 4, the cost of 80 modules of 250Wp per each module is $8000.00 and therefore the cost for 1 module will be $100.00. The table below shows the financial returns if the case study building should integrated a PV panel of 250Wp and the tariff per kWh is GH¢0.17p ($0.06 cents).

Home improve-ment type	Indicative cost (USD)	Financial returns for 10 years (USD)	Savings for 10 years (USD)
Installation of a 250Wp solar PV	100.00	284.00	184.00

Table 10. Home improvement and financial returns.

Recommendations and Conclusion

The sustainability of energy and environment should not be compromised in any country. Energy is an essential requirement for the development of any country. However, this should not be at the detriment of the environment we live in. The demand for shelter and energy need not comprise the ability of future generations to meet their needs. Various researches have established that the initial cost of green energy and building solutions are always high but with proper financial analysis to show break even time, investors could be encouraged into their use. [13-19] This research has established the fact that EPC can serve this purpose if instituted in Ghana through the home improvement aspects it presents. This home improvements as seen in table 9 presents to the owner or buyer of building the expected time of financial gains or break even time. EPC is also good and should be encourage because as a building tries to achieve a higher ranking status, less energy is used by the building and therefore less carbon emissions. However certain recommendations should be adhered to with the use of BEAP for accuracy and sustainability. It is highly recommended that further research should be done and with the use of BEAP for EPC. This will be to test and evaluate BEAP and recommendations adopted to strengthen it. Also it is recommended that common software platform should be developed for BEAP to prevent differences in assessment results.

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