Reducing Carbon Emissions in a Third Level Educational Institution in Sub-Sahara Africa

Izael Da Silva, Geoffrey Ronoh, Clint Ouma and Caren Jerono

Abstract

The effort to reduce carbon emissions as the arguably most prevalent cause of global warming has been a positive trend in most African countries. One of the most successful strategies towards reaching that goal is the shift from fossil fuel power generation to renewable sources of energy such as wind, hydro, geothermal and solar. As Kenya sits on the equator it enjoys an all year round insolation between 5 and 6 kW/m^2/day which is more than double of the average insulation in Germany, a country where solar energy is widely used. Taking advantage of a green line of financial support created by the French Government, Strathmore University embarked in a project to install a 600 kW roof-top, grid connected solar PV system to cater for its electricity needs. Having as a background of the newly instituted Feed-in-Tariff regulation, the system is designed to produce more than the required self-consumption such that the extra power can be sold to the utility via a PPA (power purchase agreement) and the revenue used to pay for the electricity used by the university at night. This paper describes the whole process from the technical, regulatory, educational and financial aspect highlighting the positive and negative events along the path such that it can be useful for other private sector institutions interested in greening

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their sources of energy, invest in renewable energy and thus reduce their operation costs. The authors have written this work having in mind not only countries in Africa but all other countries which sit in the so called "solar belt".

Keywords
Sustainability · Carbon emissions · Solar PV technology

1 Introduction

The concentration of GHG emissions has been on the increase over the years in line with the temperature of the earth which was determined to have risen by 0.8° between the years 1900 and 2005. Despite a rising awareness on greenhouse gas (GHG) emissions, Diabat et al. (2010) show that, over the last 150 years, the last decade was recorded as the hottest with the year 2005 being the hottest year. As a result, concerns over global warming have penetrated all parts of society such as the corporate and industrial world and recently institutions of higher learning.

In 2008, CO_2 emissions in Sub Saharan Africa (SSA) was reported at 0.84 metric tons per capita (Trading Economics 2013). These carbon emissions were generated by burning of fossil fuels to generate electricity, drive the transport industry, and to run industrial processes such as cement manufacturing. The current trend is that higher institutions of learning are taking a leadership role in driving sustainability initiatives. Thus, they are well placed in playing the role of fighting climate change since their focus is to educate future generations of leaders. This responsibility covers the institutions' carbon emission reduction, conservation of energy and water and other sustainability initiatives. Velazquez et al. (2006) define a sustainable university as a higher institution of learning that involves, addresses and promotes on a global and regional basis, the reduction of negative environmental, societal, economic, and health effects that result from the use of their given resources to meet their functions in outreach and partnership, teaching, research and stewardship to help society to achieve a transition to sustainable lifestyles.

This paper outlines sustainability initiatives that Strathmore University has put into place to reduce carbon emissions and ensure a green environment around campus. Through these initiatives, Strathmore University aims innovatively create awareness amongst its 5,000 student plus population. The paper focuses on a solar photovoltaic (PV) project that the University invested in to replace electricity provided by the national utility. A description is made of the process followed from the technical, regulatory, and financial aspects highlighting the positive and negative events along the path such that it can be useful for other tertiary educational institutions interested in greening their sources of energy, invest in renewable energy and thus reduce their operation costs. The paper also aims to serve as a case study to other institutions of higher learning on the processes and challenges in undertaking a sustainability initiative in a commercial manner.

Fig. 1 Management science building at Strathmore University

2 Sustainability Initiatives at Strathmore University

Strathmore University (SU) is a higher learning institution which was established in 1961 as a college and has over the years grown into a renowned private university. The University has an established policy of integrating business with environmental conservation which has been embraced by all employees towards environmental sustainability. With regards to its built environment, the University has adopted green buildings as a way of improving the benefits to students, staff, workers, the community, its bottom line.

The Student Centre (SC), Management Science Building (MSB) and the Strathmore Business School (SBS) which add up to 22,000 square meter of space were constructed using the LEED (Leadership in Energy and Environmental Design) standards. These green buildings consist of mainly offices, lecture halls, conference halls, recreational facilities and a cafeteria. Compared to conventional buildings, the energy consumption has been reduced by 40 % (Da Silva and Ssekulima 2011). A Building Management System (BMS) is integrated into the buildings to control the resource utilization. The BMS used is based on SNAP PAC System Architecture with OPTO-SNAP controllers. User defined control-programming is used to define the functioning of the various components such as motion detectors, power cards and lighting control. The BMS uses room orientation and time-of-day to disable lighting fixtures that are close to the windows when sufficient natural lighting is available. It also disables all lighting in individual rooms when the BMS Motion Detectors indicate that the area has been vacated (Fig. 1).

The buildings have in place a full-building voltage stabilizer to help protect all electronics, including the light ballasts from the recurrent voltage fluctuation on the National Grid. In addition, the buildings have incorporated water evaporation cooling system in addition to natural ventilation. Other sustainability initiatives in the University include:

- Landscaped flower beds with ornamental shrubs and trees to increase the aesthetic value of its landscape.
- On-site waste separation, processing and location of bins in strategic places around the University.
- Common printing system aimed at reducing paper use in the university. A user password is utilized within the system to ensure wastage during printing is controlled.
- Water conservation through rain water harvesting from roof catchments through incorporation of pervious paving systems. Harvested rain water is utilized in irrigating flower gardens. Part of the rain water is pre-treated to be used for non-drinking purposes.
- Green roofs help reducing temperature in the buildings and a 10 kW solar PV roof-mounted, grid-connected is installed in the Student Centre to help offsetting the base load.

3 University Electrical Load Profile

The University spends approximately US $300,000 per annum on electricity costs. Major electrical loads mainly comprise of lighting, cooking, air ventilation, hot water heating, lifts, escalators, computers and other appliances. During the week the demand increases from around 04:30 h and peaks at around 11:15 h and then drops at around 20:45 h. On weekends and holidays, the demand is low due to reduced number of activities (Fig. 2).

Month-by-month consumption varies from lows of 80 MWh to highs of 140 MWh as shown in below:

In order to reduce its operational costs, the University is constructing a grid-connected roof top solar-PV system designed to supply Strathmore University's entire campus with electrical energy, for a period of no less than 20 years. In this regard, Strathmore University is set to be the first carbon neutral University in Sub Saharan Africa (Fig. 3).

4 The Strathmore University Solar PV Project

In December 2012, the Strathmore University Council approved the development of a roof-top grid-tied solar PV project as part of its sustainability initiative. A number of factors were important in the decision to invest in a solar PV power plant at the University:

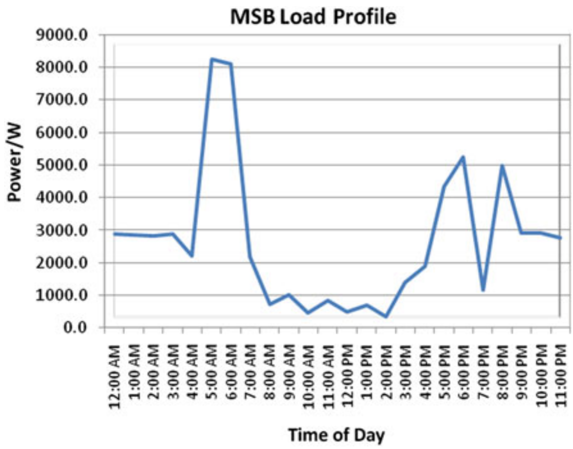

Fig. 2 Daily load profile for the MSB building

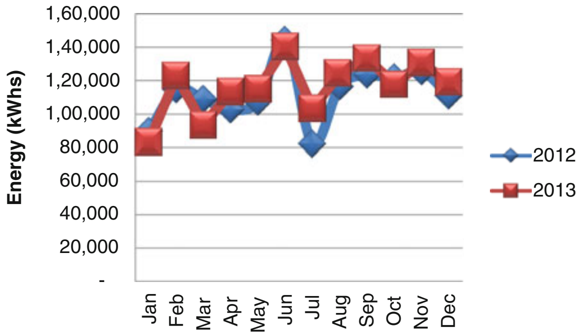

Fig. 3 Monthly consumption for the entire university for 2012 and 2013

- Awareness and knowledge of the University's senior management about solar PV technology, and its pioneering spirit.
- The University's location close to the equator giving it an advantage in tapping solar power due to the average insolation of 4–6 kWh/m^2/day without the need for sun tracking.
- The existence of a green energy facility, set up by the French Development Agency, offering project financing at concessional rates.
- Additionally, the existing feed-in-tariff regime allowed the possibility of a grid-connected system without the need for storage which is always expensive and availing the possibility of selling to the utility excess energy.

4.1 Regulatory Processes

The initial concept behind the project was that the national utility, Kenya Power (KPLC), would accept to partner with the University in piloting an Electricity Banking Arrangement (EBA) which would have allowed the University to store excess energy in the grid. In the end, the discussions with KPLC on the EBA were not successful. Instead, KPLC referred Strathmore to the existing possibility of signing a Power Purchasing Agreement (PPA), under the feed-in-tariff regime, that would commit KPLC to purchase surplus solar power from Strathmore at $0.12/kWh (Fig. 4).

The FiT route presented a number of challenges, namely:

- The PPA process is lengthy and costly as is best suited for large-scale projects aimed primarily at selling power to the grid. The processes consist of three major steps, all of which require substantial investment in funds and time.
- A number of procedures still need to be streamlined, using process tools to maximize efficiency of the FiT approval process. For example, guidelines on how project developers can access the required data to be used for grid connection from the utility within a reasonable period of time.
- While a standardized PPA exists for projects below 10 MW, it is not suited for projects in which a large percentage of the energy generated is utilized for captive use on site. A number of clauses need to be amended and negotiated, which leads to delays.

4.2 Impact of the Value Added Tax (VAT) Bill, 2013

On September 2, 2013, the Kenya Government gazetted the new VAT bill which introduced 16 % VAT on hitherto exempted goods. Included in this category is specialized solar PV equipment and related products e.g. deep cycle batteries.

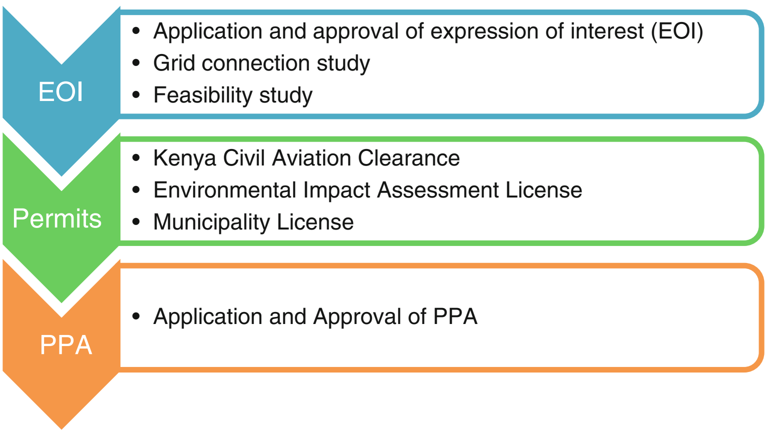

Fig. 4 The PPA process in Kenya

The impact of this new regulation was to introduce an additional cost of 16 % into the project (or approximately US $220,000). This development jeopardized the financial viability of the project. At the time of writing this paper, special negotiations are on-going to obtain a VAT-exemption on the project.

4.3 Project Sizing

The high costs of electricity in Kenya, averaging $0.225/kWh presents an opportunity for replacing electricity from the grid with "cheaper" solar PV electricity thus reducing operating costs. An optimal system size will maximize on-site consumption and minimize excess sales to the grid due to relatively low FiT of $0.12 per kWh.

The minimum plant size eligible for the FiT regime in Kenya in 500 kW, thus, this represented the smallest size that the University could consider. To arrive at an optimal plant size, modeling tools were applied to various plant sizes. The sizing analysis was undertaken through two models, namely;

- SAM (a renewable energy application designed by the National Renewable Energy Laboratory, an agency of the US Government); and
- A financial model in Excel that takes some of the results from the R model to calculate Net Present Value (NPV) of systems of various sizes.

Assuming a basic system cost of $2.40 per watt plus VAT, as well as current energy prices of $0.225 per kWh, and a feed-in tariff of $0.12 per kWh, the optimal size is 600 kW as shown below:

Figure 5 above shows how the NPV varies as system size changes. Beyond 600 kW the losses from energy exported to KPLC at a lower price than the Levelized Cost of Electricity (LCOE) begin eating into the savings achieved by Self Consumption (SC) of PV electricity. A system that is too small will not reap all possible savings offered by the $0.225 tariff.

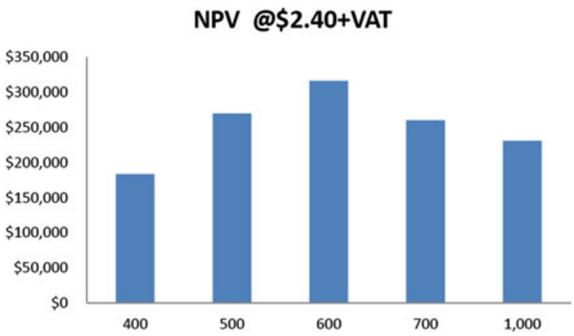

Fig. 5 NPV of various solar PV project sizes considered

The difference between the power produced by the solar system and that purchased from KPLC is the power saved and valued at $0.225 per kWh. At certain times, there would be excess power from the solar and it would be exported to KPLC. Exported power is valued at a maximum of $0.12 per kWh.

4.4 Project Financing and Economics

To finance the project, the University secured credit availed by a local bank, Co-operative Bank of Kenya, under a credit line provided by the AFD Green Line of Credit at 4.1 % yearly interest rate over a 10 year period, with one year moratorium on the principal. Prior to the project, the University monthly spending on electricity varied from KES 1.5 million (US $17,000) to KES 2.5 million (US $28,700) per month as shown below, and averaging an annual amount of KES 24 million (US $280,000) (Fig. 6).

Assuming a basic system cost of $2.40 per watt plus VAT, as well as current energy prices of $0.225 per kWh, and a feed-in tariff of $0.12 per kWh, the ratio of captive use to export is 3:1, the expected financial returns from the project are as shown below (Fig. 7):

The project is expected to turn to turn cash positive within the second year as savings from purchases from the grid and exports outweigh the cost of imports. Payback period is estimated at 7 years (Fig. 8).

5 Conclusions

5.1 Green Initiatives are Good for the Bottom Line

The 600 kW project at Strathmore University demonstrates that the sustainable initiatives in institutions of higher learning can result in reduced operational costs. However, critical factors such as cost of capital need to be evaluated (Fig. 9).

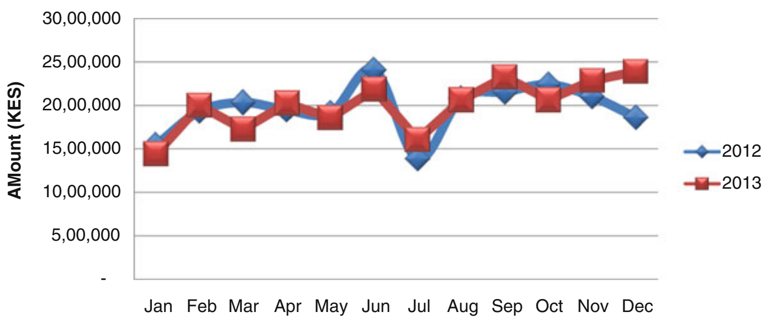

Fig. 6 Monthly expenditure on electricity at Strathmore University for 2012 and 2013

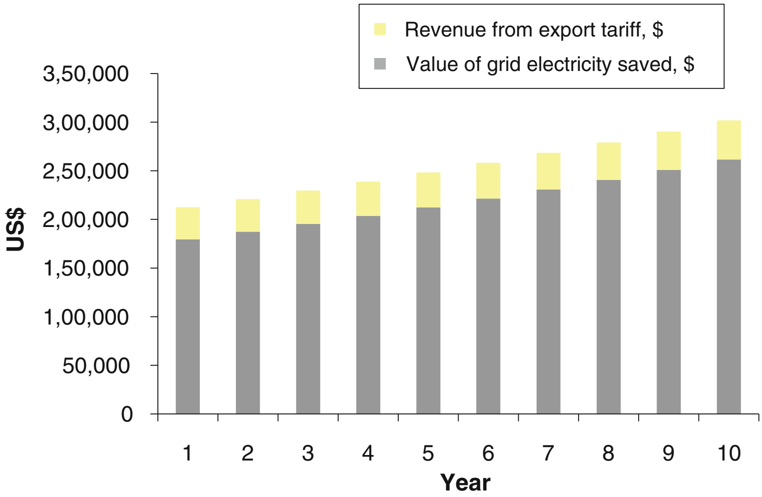

Fig. 7 Projected combined revenue and savings (first 10 years of the Solar PV project)

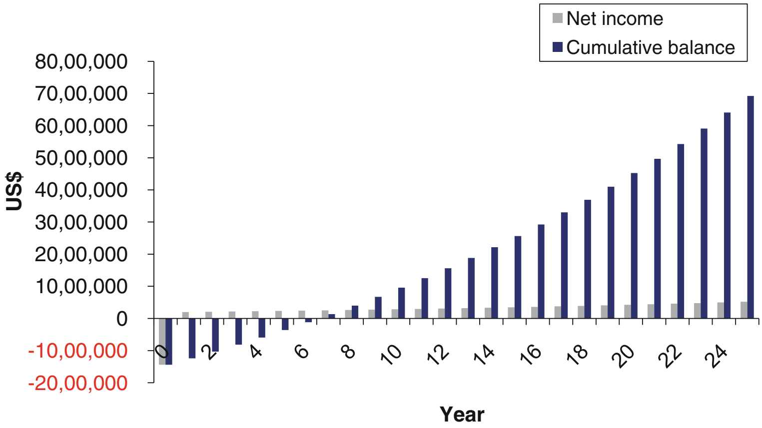

Fig. 8 Cumulative project balance and net income for 25 years

The Weighted Average Cost of Capital (WACC) is as important a factor in determining the Levelized Cost of Electricity (LCOE) from Solar PV as solar radiation (Ondrazcek et al. 2013).

The fact that Strathmore University could access relatively cheap financing at 4.1 % yearly interest rate compared to a market rates in Kenya in excess of 10 %, made the project commercially viable without any subsidies. As a result, the sustainability initiative not only results in reduced carbon emission, but also lowers the cost of energy to the University (lower solar PV LCOE compared to costs of electricity).

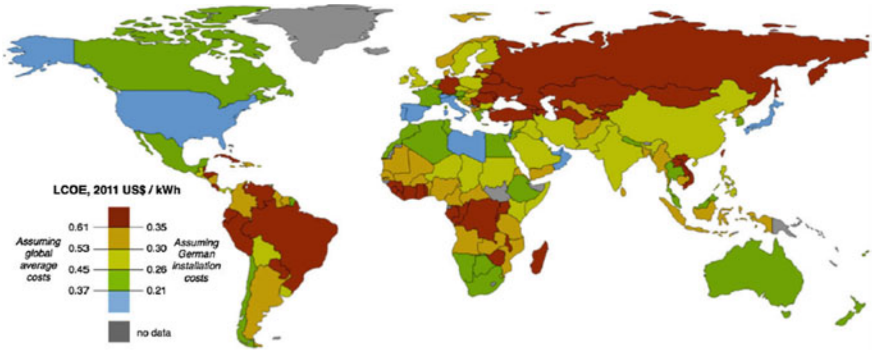

Fig. 9 Global map of LCOE, based on weighted average national GHI nationally-specific WACC

5.2 Regulatory Environment

Undertaking sustainability initiatives at tertiary level institutions requires an enabling policy environment. In the case of Strathmore University, the solar PV project has encountered numerous challenges that have delayed the implementation of the project. The cyclic annual nature of solar production, combined with University operating hours requires that the supply of excess electricity production be sent to the National Grid, for later use when the load exceeds the available generation capacity or the sun energy is not available. However, a net-metering policy is non-existent in Kenya at the moment while the existing FiT regime was not suitable to the University needs of using captive power on site. Further, changes to the VAT bill resulted in additional costs to the project which severely impacted its financial viability.

5.3 Measuring Progress

Lack of data concerning energy consumption and carbon emissions patterns results in lack of clarity on priority areas to focus on. For example, Davis (2014) highlights that keeping close tabs on energy usage is a valuable practice that leads to significant energy savings. Analysis of data from many areas of operations for instance, refrigeration and air conditioning, commuting and waste provides an understanding into the factors influencing emissions from higher institutions of learning. In this regard, Strathmore University intends to develop a metric to measure the impact of a number of sustainable initiatives at operational level in the institution and utilize the metric as an indicator to gauge their progress towards achieving a more sustainable system.

5.4 Sustainability Initiative as a Change Agent

Strathmore University has over 5,000 students on its campus. Through the project, the University aims at creating awareness amongst its student population by explaining to them the incorporated sustainability initiatives brought into the built environment. Through the Strathmore Energy Research Centre, the University intends to conduct seminars to educate the students on the application of technologies such as solar PV. It is envisaged that these students will then become agents of change in their homes or work places in the topic of sustainability. Further, senior management from other tertiary institutions will be invited to open days to tour our green facilities and get familiar with details behind the 600 kW project.

The project will also serve as a hands-on training for solar technicians from various vocational training institutions in the region. Grid-connected solar PV is a relatively new area in Kenya with a shortage of qualified technicians.

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Author Biography

Professor Izael Pereira Da Silva is a Renewable Energy specialist with over 15 years of experience in research and academic leadership. Professor Da Silva is an Associate Professor at Strathmore University and the Deputy Vice Chancellor Academic Affairs. Under his mandate lays the creation of the Strathmore Energy Research Centre—SERC in partnership with GIZ in which he is the director. SERC offers various activities including training, research and consultancy in energy related topics. Previously he founded and directed CREEC—Centre for Research in Energy and Energy Conservation in Makerere University, Kampala, Uganda. He left CREEC in 2010 and joined Strathmore. CREEC is very much relevant for Uganda and currently runs a good number of renewable energy projects sponsored by the World Bank, GIZ, ADA (Austria Development Agency), UNIDO, Ministry of Energy and Mineral Development, Uganda National Council for Science and Technology, Sida/SAREC, NORAD, Global Alliance for Clean Cook stoves, etc. Professor Da Silva has a PhD in Power Systems Engineering from the University of Sao Paulo (Brazil). Professor Da Silva has been working with Government Ministries, Development Agencies such as the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the Swedish International Development Cooperation Agency (SIDA), the World Bank, etc. His research interests are: Renewable Sources of Energy and Efficient Use of Energy, Renewable Energy Policy, Rural Electrification and Sustainable Development. He is also a Certified Energy Manager with the Association of Energy Engineers in the United States of America.