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Techno-Economic Analysis of Wind-Solar Hybrid Renewable Energy for Outdoor Lighting in Nigeria

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Abstract

Techno-economic analysis of wind–solar hybrid renewable energy generation system for outdoor lighting is presented in this study. The objective of this study is comparing the output efficiencies and recommends the best option for developing countries. The power generated would supply the energy requirements of the outdoor light where the system is installed. The system combines two green technologies; including small scale wind turbine and solar cell module. It is potable and can be installed on top of the conventional street lights and other outdoor lights in order to provide on-site renewable power to the lighting system. The technical and economic analysis was conducted by using the life cycle cost (*LCC*) method. The *LCC* technique is used to calculate the cost caused by the system during its entire life cycle and makes cash flows time-equivalent. The evaluations show that based only on cost, it is preferable to maintain standard street lamp over wind-solar hybrid street lamp because it will be less expensive to operate on an annual basis (N2, 138,364.8 versus N5, 187,379.6). This calculation however does not consider government incentive under green energy applications for installation cost and the tax reduction.

Keywords:
Renewable energy, Wind-solar hybrid energy system, Wind turbine, Life cycle cost, PV module

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Background to the Study

Cost of fossil fuels as well as environmental concern especially GHG emissions from conventional fossil fuel powered energy generating plants has forced a rethink about how we generate and use energy ("Eocene fossils," 1998). Fuel Diversification Policy (FDP) which was introduced in Nigeria since 1999 are aimed at reducing Nigeria's over-reliance on a specific fuel type (Jafar AH, 2008). The purpose of FDP is to achieve a more balanced electricity generation among various sources such as natural gas, oil, coal and hydropower. Based on the 2nd Nigeria Plan (2000-2020), the consumption of oil, gas and hydro had declined from respectively 4.2% to 0.2%, 77% to 55.9% and from 10% to 5.6%. These data shows Nigeria are in the effort to gradually change from the fuel sources dependency to other sources like hydropower, coal and other renewable energy sources (Exchange of ideas and information on the issue of Competitive Change in the Electric Power Industry. Topic: What are the issues involved in competition?, 1997).

Renewable energy such as wind energy and solar energy is receiving great attention due to the price fluctuation of fossil fuels in the international market as well as adverse environmental problems from the process of power generation from fossil fuels (Chong et al., 2013).There is the need for us to go for these available sustainable green technologies in most of our activities that require energy (Chong et al., 2011) claim that though there are drawbacks to wind and solar energy options are their unforeseeable nature and they rely on the climate changes. However, there are daily and seasonal complementary relationships between wind energy and solar energy. In addition, stable power output could be expected through the hybrid power system (Avila-Avila-Flores Medellin, 2014).

Objective of the Study

The objective of this study is comparing the output efficiencies and recommends the best option for developing countries. So, the problems can be partially overcome by integrating two or more resources in a proper combination to form a hybrid system, using the strengths of one source to overcome the weaknesses of the other.

System and Component

The sample area where the system will be set up and the economic analysis is to be carried out is the Faculty of Engineering Federal Polytechnic Damaturu. The outdoor lighting configuration is presented in **Figure 1.** Wind-Solar Hybrid Street Light Configuration.

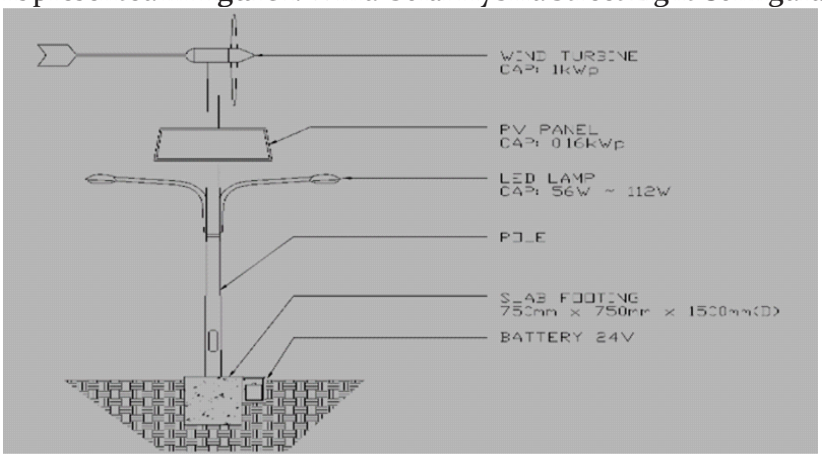

Figure 1. Wind-Solar Hybrid Street Light Configuration (Sullivan Lucas, 1998)

Table 1. System Components and Specifications.

No.	Components	Specifications	
1		LED lamp	56W – 112W
2		Wind turbine	
2.1		Rated power	1.0kWp
2.2		Rotor diameter	2.8m
2.3		Blades quantity	3 pieces
2.4		Blades material	FRP (Fiber Reinforced Plastic)
2.5		Rated speed	360RPM
2.6		Rated wind speed	8m/s
2.7		Weight	48kg
3		PV panel	
3.1		Rated power	0.16kWp
3.2		Size	1580mm x 808mm x 40mm(D)
3.3		Weight	15.5kg
4		Battery	DC 24V

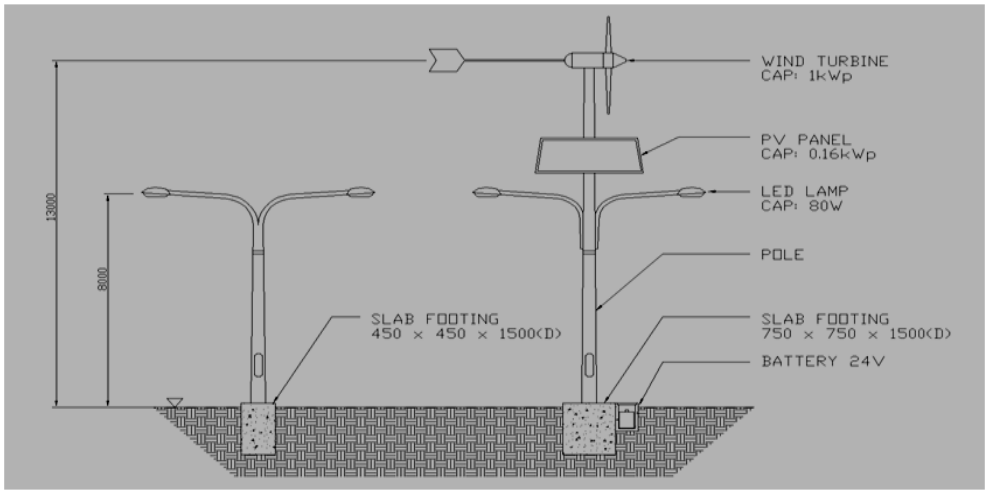

Figure 2: Comparison between Standard Street Lamp and Wind-Solar Hybrid Street Lamp (MacRae, 2002)

Study procedures

The experimental procedures of this study were carried based of comparison between the existing and setup activities in the faculty of engineering. Determination of various components of standard street lamp and wind solar hybrid street lamp were carried to ascertain the availability. Thus, followed by financial evaluation of the two parameters of subjects under consideration as can be seen in the subsequent section of the study.

Result and Discussion
Financial Evaluation

	Standard Street Lamp	**Wind-Solar Hybrid Street Lamp**
Slab footing	N 5,200.00	N13000.00
Pole	N 234000.00	N130000.00
LED lamp (2nos.)	N31,200.00	N31,200.00
Battery	-	N26000.00
PV panel	-	N41600.00
Wind turbine	-	N130000.00
Wiring works	N10,400.00	N20,800.00
Total	N280,800.00	N704,600.00

Annualized costs

Description	**Standard Street Lamp**	**Wind-Solar Hybrid Street Lamp**
Number of installation	50	50
Running hours	5 hours/day	5 hours/day
Installation / Initial Cost per lamp	N280,800.00	N704,600.00
Electricity Consumption	0.08 kWh	0.08 kWh
Equipment Lifespan	16[6]	15[7]
Average annual maintenance cost	N13000.00	N31,200.00
Electricity Tariff	N13.572 per kWh[8]	-
Interest rates	6%	6%

1. Wind-Solar Hybrid Street Lamp

Installation Cost: 50 X N704, 600 = N35, 230,000
Annual Operational Cost: None
Annual Maintenance Cost: N31, 200 x 50 pcs = N1, 560,000
Present value of an annuity PVA = Initial cost + operational cost x $\left[\frac{1-(1+i)^{-n}}{i}\right]$

= 677,500 + 30,000 x $\left[\frac{1-(1+0.06)^{-15}}{0.06}\right]$

=N50, 381,111.04
Annual Cost, A= PVA x $\frac{i}{1-(1+i)^{-n}}$

= N50381110 x $\frac{0.06}{1-(1+0.06)^{-15}}$

= N5,187,379.6

Installation Cost: 50 X N280800 = N14, 040, 000
Annual Operational Cost: 50 x 0.08 kWh x 5 hours x 365 x 13.572/kWh = N99, 075.6
Annual Maintenance Cost: N13000 x 50 = N650000
Present value of annuity PVA = Initial cost + operational cost x $\left[\frac{1-(1+i)^{-n}}{i}\right]$ (Waterhouse, 2000)

$= 270,000 + \left[\frac{1-(1+0.06)^{-16}}{0.06}\right] 0 + 12,500) x$
=N21, 610,082

Annual Cost, A $= PVA \times \frac{i}{1-(1+i)^{-n}}$

$= N21610082 \times \frac{0.06}{1-(1+0.06)^{-16}}$

= N2, 138364.8

Based only on cost, it is preferable to maintain standard street lamp over wind-solar hybrid street lamp because it will be less expensive to operate on an annual basis (N2, 138364.8 versus N5,187,379.6). This calculation however does not consider government incentive under green energy applications for installation cost and the tax reduction.

Return of Investment
Energy saving per month: 0.08 kWh x 5 hours x 365/12 x N13.572/kWh = 165.126
Initial cost difference: N677500 – N280800 = 396700
Return of investment: N423800 ÷ N166.4 = 2,547 months ≈ 212 years

Based on the return of investment above, the return in 212 years is unreasonable. Thus having a wind-solar hybrid street lamp is not worth it if it is working as a stand-alone system. Nevertheless, the results can be improved if the wind-solar hybrid street lamp is working as a grid system.

In a grid system, all additional energy gotten from the wind and solar system will be sold back to the government at a higher tariff rate. By assuming the feed in tariff rate remained constant throughout the year at N15.08 per kWh for wind[9] and N45.448 per KWh for solar[10], the revised return of investment will be:

Energy saving per month: 0.08 KWh x 5 hours x 365/12 x 13.572/kWh = 165.126
Wind energy sold per month: 1.0 KWp x 10 hours[11] x 365/12 x N15.08/kWh = N4586.8
Solar energy sold per month: 0.16 KWp x 4 hours[12] x 365/12 x 45.448/kWh = N884.7
Initial cost difference: N704600 – N280800 = 423800
Return of investment: N423800 ÷ (N166.4 + N4586.4 + N884) = 75 months ≈ 6 years, 3 months

Conclusion
From the results above, it can be concluded that having a grid wind-solar hybrid street lamp system is more worth it than having a standalone since the return of investment that is the payback period is only around 6years comparing to its life close to 15years.

Recommendation
This study base it findings on the long term solution to carter for present energy crisis rocking the world, hence it recommend urgent study in the area of biofuel, solar, and wind as alternative to sustain the environment in future. Thus, wind solar hybrid street lamp can be put trial in our various institutions at experimental scale for research purposes.

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