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Review Article

Assessment of Utility Scale Wind Power Generation using the RETScreen: A Case Study of Wudil, Kano State, Nigeria

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Abstract
The growth of the power sector in Nigeria continues to be challenged by high rates of inefficiencies, epileptic supply, and a and a low rate of renewable energy investment, including wind power plants. However, there is a need to unbundle and free the energy market in a bid to generate and maintain a sustainable, secure, inexpensive, flexible in time, resourcefully supplied, and climate-friendly energy supply system. For effective achievement of energy expansion goals, the promotion of carbonless power technologies that help reduce greenhouse gas emissions is paramount. Hence, attention and huge investments in renewable energy technology (RET)-based power generation systems and related RET technologies are required. RETScreen Expert software helps to overcome the barriers to clean energy technology implementation, especially at the preliminary feasibility stage. The 9.0 version of the software added the ability to easily analyze the feasibility of wind power plant options in real-site conditions. This fast feature of the software enables the analysis of the real potential of the proposed 3000 KW wind farm. From the simulation executed, the technical and economic optimization of the proposed energy system has been achieved, and it has proven to be environmentally friendly.

Keywords: *Wind Power Plant, RETScreen Expert, Renewable Energy, Wind Energy.*

1.0. Introduction
The cost associated with electric energy derived from fossil and nuclear fuels, and with increases in environmental regulations, has led to constraints in the planning, use, and operation of electric utilities. Furthermore, global economic and political conditions that tend to make countries more dependent on their own energy resources have caused growing interest in the development and use of renewable energy [1]. In terms of their environmental advantages, renewables generate electricity with an insignificant contribution of carbon dioxide or other greenhouse gases (GHG) to the atmosphere, and they produce no pollutant discharge into water or soil [2]. Due to the rapid industrial and economic growth and increase in energy consumption, grid extension and replacement of old plants and the implementation of new power plants to cover the growth of electricity demand are the main objectives of developing a nation's electricity sector in the upcoming decade [3]. It is obvious that the implementation of any strategy towards adopting renewable energy will be an essential element of national plans for achieving sustainable development and protection of the environment via upgrading energy efficiency and replacing conventional polluting resources with renewable resources [1].

According to [4], wind energy resources have been playing a role as a replacement for conventional fossil fuels for electrical energy generation and are considered the wisest alternative fuel choice. Naturally, wind energy is clean, rich, and environmentally friendly. According to [5], wind energy has also become one of the fastest-growing renewable sources of energy in both the developed and developing worlds due to its many advantages. For instance, [5] stated that renewable energy from wind is used in the USA, Germany, Spain, Denmark, India, and China. The total installed capacity of wind power had significantly increased globally, from 6100 MW in 1996 to about 237,699 MW in 2011. [6] listed some African countries, such as Egypt, Morocco, and Tunisia, to have installed capacities of 550 MW, 291 MW, and 114 MW, respectively.

In Nigeria, there is a wind farm located in a small village called Rimi, 25 km south of Katsina City, with a generating capacity of 10 MW. It is being built in the area and is almost ready for commissioning. The project, first envisioned by the Katsina State Government, gained full support from the federal government through the Federal Ministry of Power (FMP) in 2007. The need to diversify Nigeria's energy needs, boost electricity generation, and have a constant power supply, adding to the vast wind resources in the northern part of the country, were the main drivers for governmental support for this pioneering project in Nigeria [5].

Just as the fossil fuel-based energy industry relies on exploration, discovery, and proven reserves of the available resources, the renewable energy sector depends upon the assessment of renewable resources for planning and selling their energy production technology [7]. For wind-based renewable energy technologies, the basic resource or fuel available is wind kinetic energy; hence, the assessment of wind resources is based upon the metrological data available [8].

Nigeria is endowed with large wind energy resources. Wind power, or wind energy utilization, is the use of wind kinetic energy to generate mechanical power through wind turbines to operate electric generators [9]. According to wind production indicators, an average wind speed of around 3.0 m/s is still sufficient to start wind energy production [10], [11].

Kano State suffers from a conventional energy shortage, which is attributed to the geographical nature of the region. Therefore, exploring other alternative sources of energy, such as wind energy, with a view to evaluating their potential for efficient energy utilization could help alleviate the power problems the region is facing [12]. Approximately 30% of the total population lives within Kano Metropolis, and 70% lives in rural areas. Coupled with being the commercial nerve center of the northern part of the country, an alternative energy resource must be exploited [12].

Several studies on the potentials of wind power in Nigeria and Kano were conducted by many researchers with different objectives and approaches, such as wind potential, wind speed capacity, and technoeconomic aspects, but none of the researchers included RETScreen in their assessments. The outcome of this research will be useful for investors, government agencies, and other organizations making decisions regarding wind energy investment in Kano.

2.0 Basic operation principle

The wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air, like a sail or propeller, can extract part of the energy and convert it into useful work. The spinning blades, attached to a hub and a low-speed shaft, turn along with the blades [13]. The rotating low-speed shaft is connected to a gearbox that connects to a high-speed shaft on the opposite side of the opposite side of the gearbox. This high-speed shaft connects to an electrical generator that converts the mechanical energy from the rotation of the blades into electrical energy [14].

Wind power can be converted into electricity or mechanical energy using wind turbines. The rotary machine used to convert air motion into electricity is referred to as a wind turbine. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. Mechanical power can also be utilized directly for specific tasks, such as pumping water [14] and [15].

The power in the wind is extracted by allowing it to blow past moving blades that exert torque on a rotor. The rotor turns the drive shaft, which turns an electric generator [16]. The amount of power transferred is dependent on the rotor size and the wind speed. The types of wind power plants based on capacity are oftentimes a large number of wind turbines that are built close together, which is referred to as a wind project or wind farm. A wind farm functions as a single power plant and sends electricity to the grid [17].

The feasibility of wind power plants is performed using RETScreen software through electric energy production analysis, financial analysis, and GHG emission analysis.

2.1. Wind Turbine characteristics

AAER wind turbines were used for the analysis. Each turbine had a rated power of 1000 KW, and three units of similar size and rating were combined to give the desired capacity of 3000 KW. The technical characteristics of each wind turbine are given in Table 1.

Table 1: Technical characteristics of AAER wind turbine

AAER	
Model	A-1000/S-50
Number of Rotor Blades	3
Hub height	70 m
Rotor Diameter	54 m
Swept Area	2,290 m^2
Capacity per unit	1000 Kw
Cut in wind speed	4m/s
Cut out wind speed	22m/s
Rated speed	22m/s

2.2. Software

RETScreen Expert is a software tool for analyzing clean energy projects based on Microsoft Excel developed by the CANMET Energy Diversification Research Laboratory of Canada. It is used to help decision-makers quickly determine whether a renewable energy, energy efficiency, or co-generation project is financially and technically viable [18]. It is powerful, free software.

RETScreen is used in this paper to perform energy production analysis and GHG emission analysis for a proposed wind off-grid power plant at the selected site. RETScreen software is capable of assessing RETs viability factors such as energy resources available at the project site, equipment performance, initial project costs, ‘‘base case’’ credits (e.g., diesel generators for remote sites), on-going and periodic project costs, avoided cost of energy, financing, taxes on equipment and income (or savings), environmental characteristics of energy displaced, environmental credits and/or subsidies, and the and the decision-maker's definition of cost-effectiveness [19].

The RETScreen software integrates a series of databases to help overcome the costs and difficulties associated with gathering meteorological data, product performance data, etc. Worldwide meteorological data has been incorporated directly into the RETScreen software. This meteorological database includes both ground-based meteorological data and NASA’s satellite-derived meteorological data sets. RETScreen Expert allows three main types of analysis for different types of installations [20]. The possible analyses are: comparison, feasibility, and performance. Each project analysis is done in 5 steps: establishment of the energy model, cost analysis, analysis of the emission rate of greenhouse gases, preparation of the financial summary, sensitivity analysis, and risk analysis [9].

2.3. Project Location Selection

The location was carefully selected based on the metrological data available in the RETScreen software. The power plant is located in Wudil Kano State, at latitude 11.8 ^{0}N and longitude 8.9 ^{0}E, as shown in Table 2 below.

Table 2: Geographical location of the proposed site

Location | Climate data

Location

	Unit	Climate data location	Facility location
Name		Nigeria - Wudil	Nigeria - Kano - Wudil
Latitude	°N	11.8	11.8
Longitude	°E	8.9	8.9
Climate zone		1A - Very hot - Humid	1A - Very hot - Humid
Elevation	m	531	0

Climate data

The location climate is shown below:

Table 3: Location climate data

Heating design temperature	16.3	
Cooling design temperature	34.7	
Earth temperature amplitude	17.2	

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	23.1	18.4%	1.16	5.55	95.1	3.4	25.6	0	405
February	24.9	16.4%	0.59	6.29	95.0	3.3	27.7	0	418
March	28.1	26.5%	0.97	6.65	94.8	3.6	31.2	0	561
April	28.2	51.1%	29.62	6.69	94.7	3.7	30.8	0	545
May	26.9	67.2%	94.71	6.37	94.8	3.5	28.6	0	524
June	25.1	78.1%	167.75	5.93	95.0	3.0	25.9	0	452
July	24.0	81.8%	255.15	5.45	95.1	2.8	24.6	0	434
August	23.9	81.4%	302.06	5.16	95.1	2.7	24.6	0	432
September	24.6	76.9%	192.58	5.53	95.0	2.4	25.3	0	438
October	25.8	56.6%	27.66	5.77	95.0	2.7	27.1	0	489
November	25.9	25.6%	0.56	5.65	95.0	3.1	27.8	0	477
December	23.6	20.1%	1.58	5.35	95.1	3.6	25.6	0	423
Annual	**25.3**	**50.2%**	**1,074.40**	**5.86**	**95.0**	**3.1**	**27.0**	**0**	**5,597**

The mean annual wind speed is 3.1 m/s which is strong and viable enough to set up wind power plant

3.0. Results and Discussion

These results are based on the energy production analysis and the GHG emission analysis. The data required to run RETScreen is listed in the relevant sections.

3.1 Electric energy production

The renewable energy analysis (wind energy) was done using RETScreen software. The program uses the monthly mean values of the wind speed to estimate the energy produced and the plant capacity factor. The electrical energy generated from the analysis is presented below.

Table 4: Energy generated by the Power Plant

Target

Summary

	Electricity exported to grid MWh	Electricity export revenue $	GHG emission reduction tCO_2
Proposed case	7,884	788,400	3,720

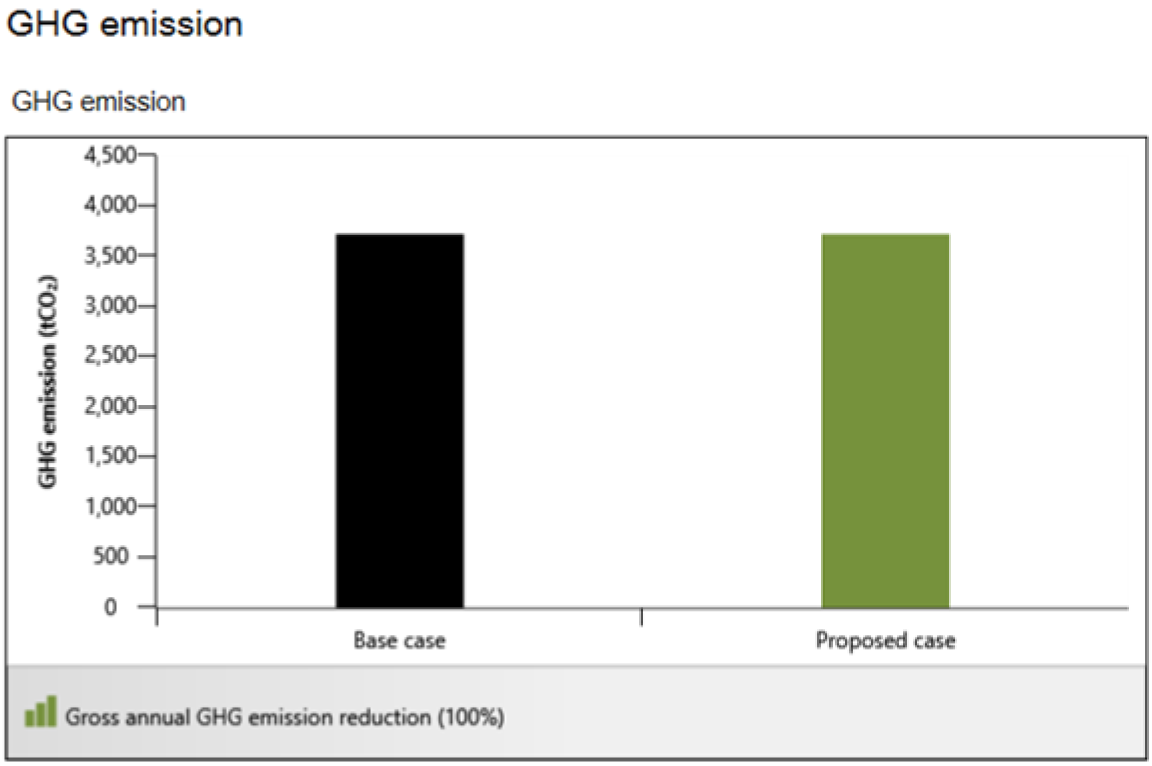
Propose site generates 7884MWh annually.

3.2 GHG emission analysis

The RETScreen is capable of estimating the amount of greenhouse gases (GHG) that could be avoided as a result of using renewable energy sources. The input required data are the fuel types used in the selected location, which is chosen to be ‘‘wind energy’’ in this case. The model estimated the GHG emission factor to be 0.472 tCO2/MWh. The ranges of variations of both the net GHG reductions in tCO2 and its equivalent cars and light trucks not used are shown in Table below. As shown in the table, a significant amount of GHG is reduced by installing wind turbine power plants as a replacement for conventional generation methods.

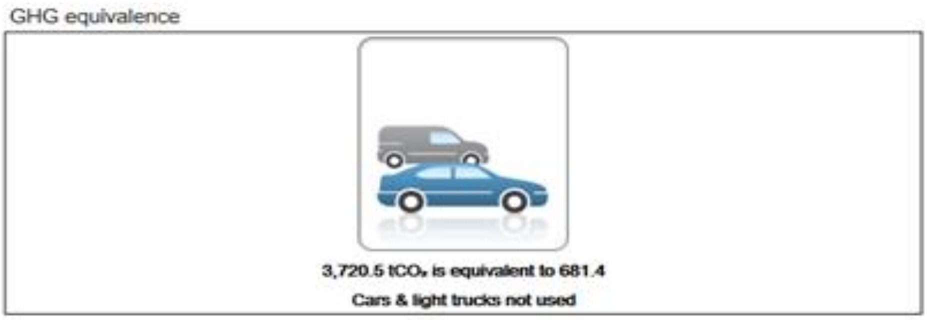
The analysis shows that the placement of the proposed 3000 KW wind off-grid power plant at Wudil offers good profitability, energy production, and GHG emission reduction compared to similar power plants using fossil fuels.

Table 5: Estimated GHG emission reduction



The installation of a wind power plant is carbon emission-free; hence, from the above figure, it was shown that a total of 3720.5t CO2 would be produced if fossil fuel were used to generate the same capacity of the power plant; however, by using a wind energy resource, the emission is 100% eliminated.

Table 6: Estimated number of cars and light trucks not used



GHG emission		
Base case	3,720.5	tCO_2
Proposed case	0	tCO_2
Gross annual GHG emission reduction	**3,720.5**	**tCO_2**

As wind energy is purely GHG emission-free, there is a 100% reduction in GHG emissions on the base case, which is equivalent to taking 681 cars and light trucks off the road.

4.0 Conclusion

This paper presented an extended analysis of a 3000 KW wind power off-grid power plant in Wudil in search of a replacement for the conventional power plant in place at the moment. In addition to the profitability of wind power plants in Wudil, the environmental impact of such projects is evaluated through GHG emission analysis, which shows that the use of wind power plants reduces large amounts of emissions to the environment or, equivalently, a large number of barrels of crude oil not consumed (which is also of economic value).

In response to energy needs and environmental concerns, electricity from wind generators is considered one of the future solutions. However, the variability and diffuse nature of wind power can be challenging for the operation of a power system. The advantage of using wind energy in electric energy production has by far outweighed these challenges. Therefore, it is recommended to start building large-scale wind power plant projects.

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