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Whistleblowing on photovoltaic operations in Nigeria: panacea for sustainable development

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Abstract

Background: There is no gainsaying about the importance of energy to the growth, development and socioeconomic well-being of any society. Photovoltaics (PV) have been identified not only as a means of meeting the energy needs of the Nigerian population but also as a tool in its national development. In this study, we reviewed the policy efforts of Nigeria in improving the renewable energy spread and the PV operations and utilization across the country.

Results: The technical audit of PV operations in Nigeria is evaluated using questionnaires administered in the 27 Local Government Areas in Imo State, as a case study. The component items in the latent variable scales of the audit have been tested for internal consistency using the Cronbach's alpha. The good variable scale "Appropriateness for energy need" indicated a dissenting perception, whereas the acceptable variable scales "Adequacy in energy efficiency" and "Sustainability of PV project" indicated significant confidence in their perceptions. The perception in the energy need, which is associated with the limitations in PV utilization, is perceived as wrongdoings.

Conclusions: The whistleblowing policy is advocated as a germane measure to reduce or stop these wrongdoings and improve PV utilization and spread in Nigeria.

Keywords: Photovoltaic, Renewable energy, Whistleblowing, Sustainable development, Nigeria

Background

Renewable energy is prescribed as the viable option in attaining the sustainable development goal of ensuring global access to affordable, reliable, sustainable and modern energy by mid-twenty-first century (SDG 2016). The earth's surface receives 1.4×10^5 TW of solar power, but 3.6×10^4 TW is usable, which is converted to electricity by concentrating solar thermal or photovoltaic (PV) technologies (Quaschning 2004; Hosenuzzaman et al. 2015). With about 10% of the world population without access to electricity having 30% of them in rural areas, it is anticipated that the decreasing cost of PV will boost investments in PV power plants owing to its ability to meet the growing energy demand yet reducing energy inputs to climate change, especially in reducing CO_2 emissions (Asumadu-Sarkodie and Owusu 2016; Ren et al. 2020). There have been about 60% of the world electricity generated by fossil fuels as of 2016, whereas 1.3% of global electricity is PV generated with about one-third of that capacity installed in China (Alsabbagh 2019). Until recently, the most popular application of this PV electricity has been in household electrification and water pumping driven by electric motors (Benlarbi et al. 2004; Dike et al. 2012; Singh 2019). Further declining price in PV coupled with the higher conversion efficiency suggests it will be the lowest cost option for future electricity supply, projected to account for 35% of the global electricity generation capacity by 2040 (Green 2016). This is evident as more PV power plants are installed globally, with indications that the PV module lifetime may be longer than the alleged 25 years hence improving the Levelized Cost of Energy (Breyer and Gerlach 2012). Indeed, energy needs will exacerbate as global urbanization is expected to increase, with Africa and Asia projecting at 56% by 2020, whereas China, India and Nigeria account for 37% of the projection (Ebhota and Jen 2019).

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In Nigeria, PV utilization has significantly increased due to the population growth and the associated energy needs, whereas the country's energy consumption index has also significantly increased (Nwokocha et al. 2018). However, with the increasing population, several settlements are remotely located from the national grid (Tijani et al. 2014). It has been shown that the rural settlements, which represent 70% of the population, require 2324.5 Wh/day or 850.8 kWh/year by each household for electrification (Adeoti et al. 2001; Ugwoke et al. 2020). Remedy to this challenge is not readily at the sight as the country has 12.5 GW of installed electric power capacity, whereas less than one-third is operational as of 2015 and only about 15% is finally distributed to end-users (ERGP 2017). Nevertheless, there exist enormous potentials for PV power penetration as Fig. 1 shows the global solar radiation (Gh) on the optimally inclined plane across the country (Nwokocha et al. 2018). The effect of the insufficiently available energy on Nigeria socioeconomic status cannot be overemphasized. This has prompted most local business organizations to subscribe to the hybrid system, which comprises PV coupled to battery and generator, to sustain operations and profitability (Oparaku 2003; Adesanya and Pearce 2019). Noteworthy is that variability of PV power poses a challenge to its grid operation and utilization (Ming et al. 2017; Huang et al. 2018; Ebhota and Jen 2019).

The inadequate information about the technology, trust issues, lack of trained and technical skilled labour, public awareness and acceptance, adulterations, and absence of governing bodies and legislation are challenges in the penetration of PV technology (Mukai et al. 2011; Jones and Olsson 2017; Nwokocha et al. 2018; Alsabbagh 2019). Also, there exist challenges of the huge up-front capital cost for purchase and installation as well as the maintenance requirements (Dale and Benson 2013; Alsabbagh 2019). Gaps in grid parity, solar cell efficiency, smart grids security, resiliency and reliability, which may arise in the long-term from faults in transportation, installation and operations, still subsist (Breyer and Gerlach 2012; Smith et al. 2014; Tsanakas et al. 2016; Olowu et al. 2018). There is a complex and energy-intensive manufacturing process in producing the PV modules from silicon (Green 2016). The growing need for PV technologies has

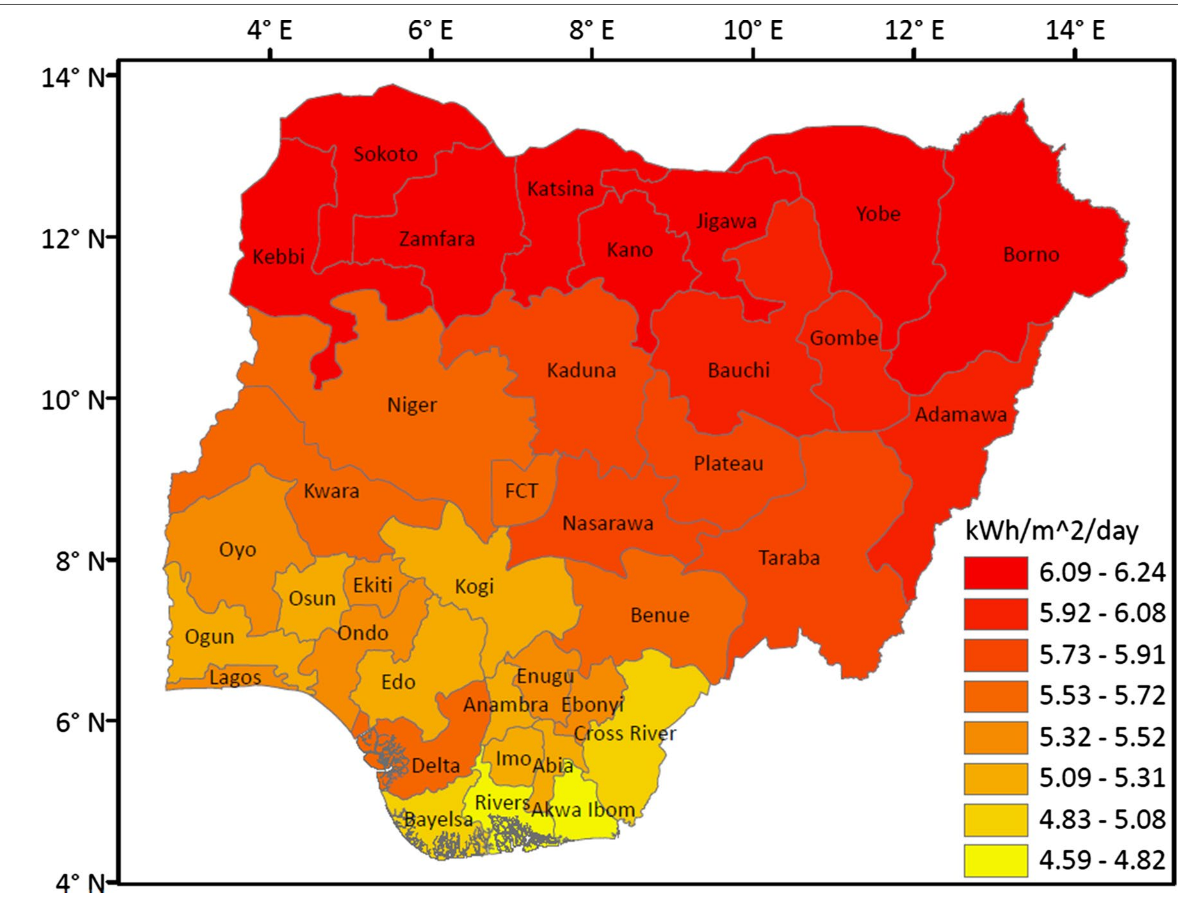

Fig. 1 Map of Nigeria indicating the global solar radiation (Gh) on the optimally inclined plane across the states (Nwokocha et al. 2018)

increased demand for the mining industry with the attendant political, economic and environmental risks, especially in giving such metals a greater value, for instance, platinum, cobalt, lithium, vanadium and rare earth (Vikstrom 2020). Hence, there is the need for a reliable environmental licensing process (Hoffmann et al. 2019). On the other hand, competition for land in PV installation poses a grave threat to food production systems (Jones and Olsson 2017).

In this study, we aim to evaluate the operations of PV in Nigeria and the shortcomings, whereas we proffer whistleblowing policy as a viable measure to attaining its sustainable development. The remaining of this paper has been outlined as follows: second section presents Nigeria efforts towards PV penetration as an optional energy grid, evaluation and technical audit of PV operation in Nigeria is presented in third section, whistleblowing as the panacea to improving PV operations in Nigeria is presented in fourth section, and final section is Conclusion.

Nigeria efforts towards PV penetration as an optional energy grid

From the onset of Nigeria electricity generation in 1896 up till the last two decades, there has been no national existing model for financing and business ventures in that sector as obtained elsewhere (Ogueke et al. 2014; Adesanya and Pearce 2019). The National Integrated Power projects mandated to solely generate and supply grid electricity had been marked with corruption allegations (Diemuodeke and Oko 2013). Then, the national energy policy, the Electric Power Sector Reform act of 2005, births the framework for private sector participation in electricity generation, transmission and distribution (Enongene et al. 2019). The policy established a national energy generation target of 31% from all renewable energy sources by 2030 with solar PV delivering 76.36% of that for the States and Local Government Areas' (NREAP 2016; Enongene et al. 2019; Khodayar et al 2019). The intention is for Nigeria to produce 30,000 MW of electric power by 2030 with 30% sourced from renewable energy termed "Electricity Vision 30:30:30" (NREAP 2016). But when compared with its ECOWAS peers, the 2030 targets seem quite remote (NREAP 2016).

There have been advancements in the large commercially available PV markets for off-grid PV rural electrification in developing countries (Breyer and Gerlach 2012). Hence, there have been efforts to source Green Equity Funds for the Nigeria national renewable energy targets (NREAP 2016). Indeed, diverse national energy and electricity reforms and policies expected to enhance the country's energy outlook have being implemented (Adesanya and Pearce 2019).

The Rural Electrification Strategy and Implementation Plan for the implementation of the Rural Electrification Agency, produced in 2016, is to expand the national access to electricity as swiftly as achievable in a cost resourceful approach. The Renewable Electricity Policy Guidelines of 2006 specifies the expansion plans for the renewable electricity mix up to 2016. The National Renewable Energy Master Plan of 2006, which was revised in 2012, provides a comprehensive structure for achieving the development and exploitation of renewable energy to 75% accessibility by 2025. The National Renewable Energy and Energy Efficiency Policy of 2015 is to promote the renewable and energy efficiency capacity of the country by 2020 and limiting potential conflicts in the future. The Renewable Energy Feed-in Traffic Regulations of 2015 aims at supporting the national renewable target through private sector participation. The National Renewable Energy Action Plan from 2015 to 2030, developed to achieve the national target under the ECOWAS Renewable Energy Policy, portrays the nation's method of development and expansion to attain the regional 23% and 31% renewable energy target in 2020 and 2030, respectively. The Nigerian Bulk Electricity Trading Plc was established as the solely licensed issuer of Power Purchase Agreements, which in 2016 has already signed Memoranda of Understanding with solar energy firms to install and operate solar power stations in the country (Table 1).

Eventually, the success in these measures has brought about the proliferation of individual and non-individual off-grid solar PV projects that are either operational or in developmental stages at different locations throughout the country. But these PV projects are not exempted from the limitations and challenges that have been enumerated above. This has been evident in the persistent failures in most small and high profile PV projects as well as in the abandoned PV projects littered at various locations (Dike et al. 2017; Nwokocha et al. 2018).

Methods

Technical audit of PV operation in Nigeria

A technical audit was carried out on the public PV power projects sited at the administrative headquarters in the 27 Local Government Areas of Imo State, as the reference case. Imo State is one of the administrative federating States of Nigeria, whereas its choice was based on its proximity and the availability of resources. Data were obtained from questionnaires administered to 20 respondents that were simple randomly selected by lottery method. The sample population was drawn from the strata of 10 males and 10 females, respectively that comprised of 5 older adults and 5 younger adults, respectively. The response rate of 100% was attained using a

Table 1 Proposed solar power plants based on Nigerian Bulk Electricity Trading Plc signed Power Purchase Agreements (SWE 2016; Vanguard 2016; Bloomberg 2017; Nation 2017)

S/N	Location/ State	Capacity (MW)	Solar Project Partner
1	Adamawa	500	LTI ReEnergy/ Nigus
2	Bauchi	100	Nigeria Solar Capital Partners
3	Borno	100	General Electric
4	Enugu	100	GreenWish Partner
5	Federal Capital Territory (FCT)	100	LR Aaron Power
6	Jigawa	50	GreenWish Partner
7	Jigawa	80	Nova Scotia/CDIL/Scatec Solar
8	Jigawa	50	Oriental Renewable Solutions
9	Kaduna	50	GreenWish Partner
10	Kaduna	50	En Africa
11	Kaduna	50	Quaint Abiba Power
12	Kaduna	100	Anjeed Innova Group
13	Kano	100	Dangote/Black Rhino Group
14	Katsina	75	Pan Africa Solar
15	Katsina	100	Nova Solar 5 Farm
16	Kebbi	100	General Electric
17	Kogi	100	Middle Band Solar One
18	Nasarawa	50	Afrinergia Power
19	Nasarawa	100	Motir Dusable
20	Nasarawa	100	General Electric
21	Niger	100	General Electric
22	Plateau	70	CT Cosmos
23	Sokoto	100	KVK Power
24	Taraba	100	General Electric
Total capacity		2425	

drop-off/pick-up survey method, thus summing a total of 540 respondents (Olson-Hazboun et al. 2016). The component items from the questionnaire were designed to address the latent variables outlined in Table 2, which demonstrates the perception of the population to the PV projects.

Data analysis

The items of each latent variable (Table 2) were tested for reliability in their internal consistency using the Cronbach's alpha method (Taber 2018). The interrelationship among the percentage agreement in responses to the items and across the 27 locations, for each respective variable scale, is evaluated using the single-factor analysis of variance (ANOVA) (Nwokocha et al. 2018).

Results

The reliability test score indicates that the items in the variable "Appropriateness for energy need" has good consistency among themselves and with the overall instrument. The variables "Adequacy in energy efficiency" and "Sustainability of PV project" have acceptable consistency among themselves and with the overall instrument, respectively. In the variable "Appropriateness for energy need", the p-value indicates that there were dissenting perceptions (Table 3). This is likely as there has been a significantly increasing demand for electric energy due to modernization and urbanization (Chineke et al. 2010). Also, the failure of the PV powered street lights and water borehole systems create doubts of PV meeting the actual non-metered home energy needs. The poor spread of the projects is also indicative of this perception. Another concern is the amount of land area that would be required to meet these energy needs.

The p-value on "Adequacy in energy efficiency" indicates the confidence in the functional PV projects' performances (Table 4). This is evident as the projects function effortlessly and efficiently, lighting the streets at night and providing clean water from the water pumps. They do not see any refuelling for this to go on, and the infrastructures do not need frequent servicing. Similarly, the p-value on "Sustainability of PV project" indicates the confidence in the sustenance of the PV projects for a longer period (Table 5). This is derived from the duration

Table 2 Latent variable scales in the PV projects Technical audit with their respective reliability and component items

Latent variable scales	Cronbach's alpha (reliability test)	Component items
Appropriateness for energy need	0.82	1. Solar project is initiated at the appropriate time. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 2. Location of the solar project is appropriate and feasible. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 3. Area coverage of the solar project is appropriate. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 4. Solar project serves the purpose for which it is provided. (4-point Likert scale from "Strongly agree" to "Strongly disagree")
Adequacy in energy efficiency	0.74	1. Energy output of the solar project satisfies the purpose for installation. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 2. Solar project functions efficiently and when it fails repairs come immediately. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 3. Solar project performance is the same with conventional energy powered options. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 4. Experts should mount and maintain such solar projects. (4-point Likert scale from "Strongly agree" to "Strongly disagree")
Sustainability of PV project	0.70	1. There is adequate security provided for the solar project. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 2. There have been varying discomforts associated with the installed solar project. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 3. Solar project is expected to have a long life span. (4-point Likert scale from "Strongly agree" to "Strongly disagree") 4. More installations of such solar project are encouraged. (4-point Likert scale from "Strongly agree" to "Strongly disagree")

Table 3 Single-factor ANOVA on the percentage agreement of the items in the variable scale "Appropriateness for energy need" with $\alpha = 0.05$

Source of variation	SS	*df*	MS	F	P-value	F crit
Between groups	9328.24	26	358.7785	2.2849	0.0026	1.6327
Within groups	12,718.75	81	157.0216			
Total	22,046.99	107				

Table 4 Single-factor ANOVA on the percentage agreement of the items in the variable scale "Adequacy in energy efficiency" with $\alpha = 0.05$

Source of variation	SS	*df*	MS	F	P-value	F crit
Between groups	3004.17	26	115.5449	0.9209	0.5794	1.6327
Within groups	10,162.50	81	125.4630			
Total	13,166.67	107				

Table 5 Single-factor ANOVA on the percentage agreement of the items in the variable scale "Sustainability of PV project" with $\alpha = 0.05$

Source of variation	SS	*df*	MS	F	P-value	F crit
Between groups	3241.67	26	124.6795	0.7302	0.8158	1.6327
Within groups	13,831.25	81	170.7562			
Total	17,072.92	107				

of completion and operation of the PV projects. Also is the safety of the functional projects from destruction and vandalism within their localities. There is also the performance improvement in some of the PV projects and in their quality.

Discussion

Certainly, investors, the government and even the citizens incur potential costs and losses when PV installations go wrong or wrongdoings are perceived in its operations. These wrongdoings may be involuntary in some cases. Whistleblowing is imperative to reduce these kinds of costs or losses. Such wrongdoings, as enumerated in the previous section, will be defined by the whistleblowers who are motivated by incentives, pressure, opportunity or rationalization, and may respond differently to the situations; however, with the rationale for it to be stopped or corrected (Latan et al. 2019; Smaili and Arroyo 2019). It is vital to see the whistleblower being a concerned citizen or of strong moral character rather than erroneously as a disgruntled or vindictive individual or group (Watts and Buckley 2017; Smaili and Arroyo 2019).

Since the wrongdoings vary, it is expected that the motivations for whistleblowing should vary too, but the fundamental motive should be to improve the deployment of PV to improve energy availability and accessibility in Nigeria for sustainable development. The issue then becomes what brings about these kinds of wrongdoings, when, how and why they do occur (Near and Miceli 2016)?

Indeed, the whistleblowing in the PV operations should be in encouraging and prioritizing grid parity in per unit energy cost, for its sustainability (Zheng and Kammen 2014). In the funding gaps, there should be financial support policies such as a third-party financing option for both residential and commercial projects (Alsabbagh 2019; dos Santos Carstens and da Cunha 2019). For the shortage of skilled professionals, the training and retraining of technicians and artisans being issued verifiable certifications are vital (Mukai et al. 2011; Akinyele et al. 2019; dos Santos Carstens and da Cunha 2019). In the PV technologies deployed, incorporating recent trends rather than obsolete technologies should be prioritized such as the use of recent conversion efficient generation of PV cells, the use of bifacial PV modules, incorporating Phase Change Materials in projects to enhance cell efficiency of PV modules and incorporating solar trackers in the PV installations (Smith et al. 2014; Njoku 2016; Hussin et al. 2017; Liang et al. 2018; Akinyele et al. 2019; dos Santos Carstens and da Cunha 2019).

With regard to the cost and availability of components, local manufacturing should be supported for components mined locally bearing in mind the global technology trend and local environmental regulations to optimize PV operations (Hoffmann et al. 2019; Vikstrom 2020). For location spread and area coverage, off-grid technologies with scales of households to community should be encouraged and prioritized, with incentives such as feed-in taxes and tax credits, especially as PV project lead time is the shortest for any power generation technology (Hancevic et al. 2017; Jones and Olsson 2017; Ohunakin et al. 2018; Khodayar et al. 2019). In the scarcity of land for the PV projects, the use of rooftops should be encouraged and prioritized instead of agricultural land (Jones and Olsson 2017; Enongene et al. 2019). And in the city layout of the PV locations, incorporating the aesthetic perception of PV technologies in the architectural and urban planning should be supported (Sánchez-Pantoja et al. 2018). For utility energy losses, the incorporation of smart inverters to monitor, react to and adjust their output should be prioritized (Obi and Bass 2016). For the quality and standards of PV materials, penalties such as imprisonment and fines should be imposed on adulterators (Nwokocha et al. 2018).

However, there are challenges of whistleblowing such as harassment and retaliation against the whistleblower, the strength of evidence against the wrongdoing and how supportive the responsible agencies are (Yang and Yang 2019). Hence, the Nigerian government or policymakers should assign a department, agency or commission that strengthens punishments for PV operations wrongdoers and make whistleblowing an important channel to the PV energy penetration and sustainability. Public participation should form an indispensable part of whistleblowing especially with the comparative cost and anonymity offered by the rapid development of the Internet and smartphones (Watts and Buckley 2017).

Conclusions

The energy poverty in Nigeria has adversely affected the country's desire to attain sustainable development goals and improve the socio-economic status of its citizens. Notwithstanding the numerous renewable energy policy efforts in Nigeria, there is yet to be the desired renewable energy coverage and utilization across the country. The PV energy has been identified to be a more suitable means of attaining the energy spread and in a shorter time span. However, PV operations have their attendant limitations, which could be intentional or unintentional. The technical audit of the PV projects operation in Nigeria using the internally consistent latent variable scales reveals a dissenting perception of its appropriateness to their energy needs. However, the PV projects energy efficiency and their sustainability show significant acceptance in the audit.

The perception of the energy need is associated with the limitations in PV energy utilization. Whistleblowing is advocated as a panacea to improving the operations of PV energy in Nigeria, whereas the indicators to the perceived wrongdoings in the PV utilization will be reduced or stopped if the policy is adequately supported.

Abbreviations
ANOVA: Analysis of variance; ECOWAS: Economic Community of West African States; Gh: Global solar radiation; PV: Photovoltaics; TW: Tera Watt.

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Authors' contributions
UKO and TCC carried out the research conception and design, data acquisition, analysis and interpretation of data. Both authors drafted the manuscript. All authors discussed the results and commented on the manuscript. All authors read and approved the final manuscript.

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Availability of data and material
All the data generated or analysed during the study are included in this published article.

Declarations

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Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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