



HAL
open science

Designing reverse auctions for solar power as a potential energy access solution for the Nigeria power sector

Wale Arowolo

► To cite this version:

Wale Arowolo. Designing reverse auctions for solar power as a potential energy access solution for the Nigeria power sector. *Electricity Journal*, 2019, 32 (8), pp.106635. 10.1016/j.tej.2019.106635 . hal-03903679

HAL Id: hal-03903679

<https://hal.science/hal-03903679v1>

Submitted on 26 Sep 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Designing Reverse Auctions for Solar Power in Nigeria as a potential Energy Access Solution

Wale Arowolo¹

¹ Paris Sud University, RITM, Faculty of Economics, Law and Management, 54 Boulevard Desgranges, 92330, Sceaux, Paris Region, France.

Abstract

The Nigeria Power sector is on the precipice of financial and technical collapse. Recovering the financial deficit of over US\$3.1 Billion created within three years (ex-post reform), and the struggle to increase the grid power access above 4,000MW for about 190 Million people are some of the key burning issues in the sector. Given that about 80 million people do not have access to the grid in Nigeria, this paper proposes reverse auction market design for decentralized offgrid solar PV deployment as a potential solution for the Nigeria Power sector.

First, it reviews reverse auctions in developing countries, the key market design variables and the requirements for a successful solar auction plus storage technology design. Second, it argues that reverse auctions can be successfully run in Nigeria with well-designed market variables. Third, it provides the market design variables adaptable to the Nigeria case to achieve a successful auction run. Finally, it argues that these variables should be built on a foundation of a robust institutional and regulatory framework to be successful. This paper thus recommends designing reverse auctions for offgrid/minigrid solar PV plus storage technology as a potential solution to increase power access and attract investment considering the financial and grid constraints in the Nigeria Power sector. Furthermore, it recommends that grants for offgrid electrification with Solar Home Systems for rural areas should be further explored.

Keywords: Nigeria Power sector, Market Design, Solar Power Auction, Energy Policy

1. INTRODUCTION

The Nigeria Power sector is confounded with endemic economic, institutional, technical, financial and socio-political challenges that appear to have defiled many solutions (ex-post) market reform performed between 2010-2013. Nigeria currently has an available grid power hovering around 4,000MW (same range ex-ante reform) for about 190 Million people (seventh largest in the world). Less than 4,000 MW is dispatched on average (between January 2015 and March 2017) from the grid, with an average output generation capacity of 3,308 MW (PSRP, 2017). Three years ex-post reform, the sector has a financial deficit of over US\$ 3.1 Billion² in the value chain, putting it on the precipice of total collapse and requires approximately US\$7.5 Billion to stabilise in the next five years (PSRP, 2017).

The government is financially constrained (to a large extent) to provide the needed funds, and present/potential investors seem uninterested in the sector, considering the high risks of investment loss. According to a recent World Bank (2016) household survey, only 56% of Nigerians have access to the grid connection. Furthermore, an estimated 80% of those with connections use an alternative source of electricity supply, mostly diesel generation, due to reliability concerns (IEA, 2017). It is also estimated that the Nigerian economy is losing US\$ 29.3 Billion annually due to a lack of adequate power supply and is estimated to have lost US\$ 470 Billion in GDP since the year 2000 due to under-investment in power infrastructure (PSRIP, 2017). It is, therefore, critical to seek alternatives in decentralised power generation to increase electricity access in Nigeria.

The potential of renewable solar PV (for different cities, regions and geopolitical zones in Nigeria) have been studied and discussed in the literature (Giwa et al. 2017, Monyei et al. 2017; Akuru et al. 2017, Nwokocha et al. 2018, Ozoegwu et al. 2016, Aliyu et al. 2015, Ohunakin et al. 2014, Okoye et al. 2016, Mohammed et al. 2013, Mohamed and Petinrin 2014, Emodi and Boo 2015, Mas'ud et al, 2016, Aliyu A.K. et al 2018). Nigeria has good solar resource potentials (the annual average of total solar radiation varies from 12.6 MJ/m²/day (3.5kwhr/m²/day) in the coastal latitudes to about 25.2MJ/m²/day (7 kwhr/m²/day) in the far North (FGN, 2016), the technology is matured and available, speed of implementation in

² This US\$ 3.1 Billion was the accumulated deficit in the transitional electricity market between February 2015 and December 2016. There is also another deficit of 213 Billion Naira (US\$1.07 Billion at the exchange rate 163 Naira/1US\$ in December 2014) being the debts owed by the privatized PHCN to the generation and gas supply companies for the energy and gas supply prior to the privatization in 2013 and the market shortfall for the non-cost reflective tariffs MYTO 2.0 between November 2013 and January 2015. The Central bank of Nigeria availed a loan facility called the Nigeria Electricity Market Stabilisation Funds (NEMSF) for 10 years at 10% per annum to the DISCO and other market players to cater for the US\$1.07 Billion debt.

shorter time versus centralised generation, modular for local adaptations and green i.e. environmentally friendly (Arowolo and Perez, 2017). It is also noteworthy that the government has acknowledged these potential benefits of renewables solar in some recent policy documents (SE4ALL 2016, NREEEP 2015 and NREAP 2016). Furthermore, The Nigeria Regulator has also released a new minigrid regulation (NERC, 2016) to facilitate RE deployment through feed-in-tariffs and a business continuity regulation (NERC, 2017) to prevent market instability and to ensure security of supply and continuous operation of the sector. However, the policies and regulations appear to remain largely on paper while the fundamental problem of rescuing the sector from the precipice of financial and technical collapse remains unresolved.

Despite the potential of solar PV in minigrid/offgrid applications, the market is still in its infancy in Nigeria. According to a recent study by the World Bank, a solar minigrid with a cumulative capacity of 236kW serves about 9,100 people in Nigeria (ESMAP, 2017). Thus, given Nigeria's funding and grid constraint³ (maximum grid capacity of about 7,000MW) and about 80 million people in Nigeria's households without grid access (World Bank, 2016), this paper proposes reverse⁴ auctions market design for solar PV plus storage for offgrid electrification as a potential solution to increase electricity access, spur investments and create competition for the market. Under auctions, a RE buyer (governments or utilities) announces interest in buying a set amount of electricity from RE sources. RE sellers who meet predefined technical and financial criteria then submit price bids to the RE buyer, who typically selects the winning sellers based on the lowest bids (Shrimali et al. 2016). Auctions do not represent a RE policy *per se*; they are a mechanism that can be used to promote the development of renewable resources on a competitive basis (Maurer and Barroso, 2011).

This paper thus enriches the Nigeria Power sector debate in four distinct ways. First, it provides a summary of the latest policy documents to increase understanding of the current state of the Nigeria Power sector. Second, it makes the first contribution (to the best of our knowledge) on solar PV auction market design as a potential solution to increase power generation and access in Nigeria based on the current state of the sector. Third, it provides insight into the key auction market design variables as well as the foundational issues to address to run a successful auction in Nigeria. Finally, it argues that solar plus storage auction design (considering the grid and financial constraints) is a plausible path forward for Nigeria. Based

³ The Power grid in Nigeria is not fully developed. In 2017, the transmission network has a total installed capacity in operation is 7,223MW with a peak power generation wheeling capacity of 5,075MW (PSRP, 2017).

⁴ Please note that Reverse Auction (electricity producers/sellers bidding their product) is also called Auction in this paper

on the arguments and findings, it makes policy recommendations for stakeholders interested in and/or working on the Nigeria Power sector.

This paper is structured as follows: Section 2 gives an overview of the current state of the Nigeria power sector. Section 3 discusses the solar auction design for the Nigerian market. Section 4 is the conclusion and policy implications.

2. OVERVIEW OF THE CURRENT STATE OF THE NIGERIA POWER SECTOR

This section discusses the recent policy documents issued by the Nigerian government to address the financial, economic, technical and institutional challenges in the power sector as a springboard to provide an overview of the current state of the Nigerian power sector (ex-post reform).

- *Power Sector Recovery Plan (PSRP) 2017- 2021*

PSRP aims to recover the financial deficit in the sector and restore both technical and financial viability. It was developed by the Government/World Bank's team based on a forecast of 4,000MW (as the "Baseline Power Generation Level") in 2017 and increasing to 5,500MW by 2021 (PSRP, 2017). Furthermore, it aims to restore proper sector governance (through the appointment of qualified boards to the government agencies and of the qualified government representatives to the boards of the DISCOs), improve transparency through data-driven processes for decision making and encourage private sector investment.

Significant cash deficits have accumulated across the sector value chain between February 2015 and December 2016; the market shortfall (amount owed by Distribution companies to the rest of the market) is estimated at US\$1.5 billion, while the tariff shortfall (amount owed by consumers in aggregate to the power sector) is estimated at US\$1.4 billion. In addition, the Government Ministries, Departments and Agencies ("MDAs"), in aggregate, owe the electricity industry an estimated US\$206 million. This is a total deficit of over US\$ 3.1 Billion. PSRP estimates a financial intervention of US\$ 7.5Billion [US\$1.5 Billion annually over the next five years (2017-2021) until tariffs attain cost recovery levels] to fully fund historical and estimated future sector deficits while ensuring a minimum of 4,000MW is generated and distributed daily to ensure stability of the grid since partial or total grid collapse is also a frequent problem. As of the end of March 2017, there have been eleven (11) grid collapses since the start of the year compared to six (6) grid collapses for the full year 2016 (PSRP, 2017).

In a nutshell, PSRP hopes to resolve the financial and grid collapse challenges and to achieve a minimum power availability of 4,000 MW. PSRP relies on two sources of funding. It hopes the funding will come from the government budget and the sale of assets and MFIs (World Bank and AFDB) lending. Furthermore, it anticipates the risk of funds unavailability as and when needed, given the government's revenue shortfalls and existing expenditure commitments, inability to sell assets in a timely manner, and, even when the assets are sold, low sales proceed below the estimates.

These risks appear to have a high probability of occurrence. First, the Government is financially constrained, and the National Integrated Power Project (NIPP) assets have not been sold to date. Second, the World Bank seems unlikely to provide the US\$1.5 Billion (to eliminate sectoral cashflow deficits and loss reduction in distribution through improved metering - see Appendix 3) as the government finds it challenging to meet some lending conditions. Indeed, the World Bank's lending pre-conditions 'to do' list (please see Appendix 2) within a year to access the US\$1.5 Billion loan facility has already missed many deadlines as of date. Therefore, these two sources of finance appear undependable and unlikely to restore the much-needed financial and technical viability to the sector. Other proposed scenarios (tariff increase in July 2017, tariff increase in January 2018, tariff increase by 50% for all customer classes except small scale residential and commercial consumers in July 2017) were not implemented. The last working scenario is to increase tariff for all customer classes in July 2019 which implies the government needs to support the sector with US\$ 7.5 Billion. The government is currently supporting the sector through a loan facility of 702 Billion (US\$ 2.3 Billion from January 2017 to December 2018) to the Discos to pay 80% of the Gencos bills. Hiking tariffs have accompanying socio-political challenges (and a high probability of failure), as experience has shown in the last five years. It remains to be seen if it will be successful in July 2019 (a post-election period).

- *Renewable Feed-in-Tariff (REFIT) Regulation 2016*

The REFIT focuses on the grid connection of RE. The cap for REFIT is set at 2,000MW of RE power admissible into the grid (1,000 MW by the end of 2018 and 2,000 MW by the end of 2020) as the total grid capacity is anticipated to be within 10,000 MW to 20000 MW by 2020. The Market Operator or its successor is expected to purchase 50% of the RE electricity capacity limit, while the Distribution licensees shall take up the remaining 50% of the capacity. The seller's costs in this respect shall be pass-through to consumers via the tariffs, which shall be a weighted average of energy costs from renewable and fossil fuel sources. The additional power generation costs resulting from the REFIT will be covered through 'Burden sharing' by

electricity consumers in the interim, pending the setup of a special fund to cover the incremental cost.

Specifically for solar power, benchmark capacity is pegged at a minimum of 1MW and a maximum of 5MW applicable to the sites connected to the transmission grid or the distribution network. Lower capacity shall be procured by net-metering, and larger capacities shall be procured by competitive procurement after the coming into effect of the applicable regulations later.

It is noteworthy that REFIT has been designed considering the grid constraint. The transmission grid has a maximum installed capacity of 7,223 MW as of 2017 and managed to evacuate a record 5,074 MW on February 2, 2016 (PSRP, 2017). It appears that REFIT (with a maximum renewable allowance of 2,000 MW) cannot have a major impact on electrifying Nigeria, even if all the 2,000MW are built and connected to the grid by 2020. For the base year 2016, the FITs were pegged at US\$177/MWh (solar PV), US\$125.47/MWh (wind power), US\$154.72/MWh (small hydropower) and US\$154.71/MWh (biomass). The off-grid projects are included from the REFIT arrangement.

- *National Renewable Energy Action Plan (NREAP) 2015 - 2030*

The objective of the *NREAP* is to advance the development of renewable energies in Nigeria. Nigeria plans to achieve an electricity vision of 30,000MW by 2030 with at least 30% RE in the electricity mix (this is called the Electricity Vision 30:30:30). *NREAP* sets specific target of 2,000MW for grid connected solar PV by 2020 and 5,000MW by 2030. Total RE target of 5,325MW in 2020 and 13,800MW by 2030. For the off-grid RE system, the target is 187MW by 2020 and 5,545MW by 2030 through mini-grid and stand-alone systems.

Nigeria is now targeting 30,000MW by 2030 (revised downward from 40,000MW in Vision 2020) for an estimated population of 267 Million by 2030.

The specific action plans to promote grid connected RE are regulatory measures through planned FIT for medium scale renewable energy generation (1MW to 10MW) by independent Power Producers. In addition, the planned competitive procurement programmes to increase the generation of renewable electricity from 5MW and above for solar PV and from 10MW and above for wind, small and medium hydro-power (medium scale renewable electricity generation by energy companies). Other action plans are capacity building programmes through professional and technical courses on renewable energy and energy efficiency for both public and private institutions of the power sector.

For off-grid RE, the policies and measures include the planned provision of financial support (soft loan) with low interest rates for small-scale renewable energy generation companies. Furthermore, the planned provision of grants and subsidies of up to 30% of the initial costs of renewable energy utilisation facilities for communities, enterprises and individuals that embark on RE generation projects.

- *Sustainable Energy for All Action Agenda (SE4ALL-AA) 2016*

SE4ALL-AA draws from the targets set in the NREAP documents and sets out actions required to reach the national goals and objectives between 2015 and 2030.

The key actions are summarised as follows: i. Develop a National Energy Plan to manage energy ii. Secure multi-year investment budget to upgrade the grid capacity. iii. Promote efficient generation technologies. iv. Promote favourable policies and institutional arrangements for green mini-grids (GMG) and cogeneration systems. v. Conduct feasibility studies and develop bankable business plans for potential sites across the country. vi. Develop Rural Electrification and Access Plan to bring energy solutions to rural communities. vii. Develop solar power solutions for rural productive use. viii. Develop an Integrated Resource Plan to meet forecasted country annual peak power demand. viii. Build and invest in a robust national energy data management toolkit. x. Broaden human and institutional capacity and evolve a national nuclear technology acquisition master plan.

- *Economic Recovery Growth Plan (ERGP) 2017 - 2020*

The ERGP aims to increase power generation by optimising operational capacity, encouraging small-scale projects, pursuing long-term capacity, improving the commercial viability of generation and distribution companies and spurring investment in transmission infrastructure. The ERGP also aims to optimise the delivery of at least 10,000 MW of operational capacity by 2020 and to improve the energy mix, including through the greater use of RE (ERGP, 2017).

While these are good intentions, they undoubtedly require finance to realise. Unfortunately, the government is financially constrained to achieve these objectives. The government's approach is to embark on domestic and international borrowing for funding. However, it remains to be seen if the government borrowing plans will be successful.

- *National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015*

The objective is to ensure the development of the nation's energy resources, with diversified options to achieve national energy security and an efficient energy delivery system with an optimal energy resource mix. Furthermore, to guarantee adequate, reliable, affordable,

equitable and sustainable supply of RE at cost-reflective and appropriate costs in an environmentally friendly manner, to the sectors of the economy for national development.

The policies include creating an energy plan that includes renewable energy and energy efficiency as an integral part of national development plans. Coordinate and implement a comprehensive and integrated RE and energy efficiency (EE) policy into an integrated resource plan. Ensure coordination between the federal, state and local government levels for RE and energy efficiency matters. Specific policies for solar are, first, to harness solar energy resources and, second, to integrate them with other energy resources. Others are to promote the use of efficient solar energy conversion technologies, intensify efforts to increase the percentage of solar energy in the present energy mix and promote the development of energy storage technologies/complement solar power development with energy efficiency programs.

Table 1 below summarises the policy documents.

Policy Documents	Summary
<p>Power Sector Recovery Plan (PSRP) 2017-2021</p>	<p>It aims to recover the financial deficit in the sector and restore technical and financial viability.</p> <p>Ex-post reform sector's financial deficit is estimated at over US\$ 3.1 Billion between February 2015 and December 2016</p> <p>Estimated a financial intervention of US\$ 7.5Billion required from 2017 to 2021 to fund historical and estimated future sector deficits to ensure a minimum grid power availability of 4,000MW</p> <p>Proposes the government funding (budget allocation and sale of assets) and MFIs lending as possible sources of finance</p>
<p>Renewable Feed-in-Tariff (REFIT) Regulation 2016</p>	<p>Sets a cap of 2,000MW of RE for power admissible into the grid (1,000 MW by the end of 2018 and 2,000 MW by the end of 2020) considering the grid constraint.</p> <p>Excludes off-grid RE electrification projects.</p> <p>Incremental power generation costs resulting from the REFIT are to be borne by consumers pending the setup of a special fund.</p>
<p>National Renewable Energy Action Plan (NREAP) 2015-2030</p>	<p>Sets the Electricity Vision 30:30:30 (30,000MW generation with 30% RE in the mix by the year 2030.</p> <p>RE target of 5,325MW in 2020 and 13,800MW by 2030.</p> <p>Targets off-grid RE of 187MW in 2020 and 5,545MW in 2030 through mini-grid and stand-alone systems.</p> <p>Targets 2000MW for grid connected solar PV in 2020 and 5000MW by 2030</p>
<p>Sustainable Energy for All Action Agenda (SE4ALL-AA) 2016</p>	<p>Gives action plans to achieve the targets set in the NREAP documents. Keys actions are to:</p> <p>Develop National Energy, Rural Electrification and Integrated Resource Plans</p> <p>Secure investments and promote efficient generation technologies.</p> <p>Broaden human and institutional capacities.</p>

Economic Recovery Growth Plan (ERGP) 2017-2020	<p>Optimise the delivery of at least 10,000 MW of operational capacity by 2020</p> <p>Improve the energy mix, including through the greater use of RE.</p> <p>Improve the commercial viability of generation and distribution companies and spur investment in the transmission infrastructure.</p>
National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015	<p>Create specific energy plans to include RE and Energy Efficiency as an integral part of national development plans.</p> <p>Ensure the coordination between the federal, state and local government levels on RE and energy efficiency matters.</p>

While these policy documents are geared towards addressing the multi-faceted challenges in the Nigerian power sector, they also generally embrace renewable energy as a potential solution. However, financial constraint remains a major challenge to actualise their objectives. Therefore, the following section provides a possible path forward with solar PV auction to attract private investment and to create competition for the market.

3. RENEWABLE SOLAR AUCTIONS DESIGN “FOR THE MARKET”

Following failed attempts using systems of voluntary purchases of green electricity by consumers, as well as direct investment subsidies, demand-side strategic deployment policies have emerged as the preferred instrument in most countries. There are three public policy instruments with such common character: feed-in tariffs (FIT), bidding instruments (BI) and exchangeable quotas (EQ) (Finon and Perez, 2007).

FIT obliges electricity distributors to purchase electricity from any new RE plant in their service area and pay a minimum guaranteed tariff per kilowatt-hour fixed over a long period of time. BI selects by Auctions RE projects and obliges local electricity distributors to buy electricity from the successful plants by a long-term contract based on the bid price in the reference design. EQ introduces future obligatory targets for electricity suppliers to buy either green electricity directly from the RE producers or green certificates issued to RE producers, targets defined in terms of a percentage of their electricity deliveries (Finon and Perez, 2007).

In developed countries, the core rationale for introducing RE FITs was to create market certainty and simplify procurement processes to stimulate production and innovation in renewable energy technologies and markets, thus bringing prices down over time. However, in many developing countries, especially in Africa, the market for renewable energy technologies is much smaller, and this rationale does not apply (Eberhard, 2014). Furthermore, a quota system can only be implemented effectively where the electricity market is more mature: institutions are experienced, legal and regulatory frameworks and the process for

amending them are strong and predictable, competition practices and rules have been established, and players are both experienced and financially strong such as in countries with large, sophisticated utilities (Azuela and Barroso, 2011).

Hence, while FIT and EQ are instruments that have worked in developed countries, auction appears (in recent years) to provide a workable solution for many developing countries as evidenced by the increasing number of developing countries using it. RE auctions have gained popularity as an instrument to support RE deployment and have been adopted by more than 60 countries by early 2015, up from 6 in 2005. (IRENA and CEM, 2015).

Appendix 1 summarises the comparison of the three instruments based on the key decision-making criteria of investment risks, effectiveness/efficiency and complexity.

3.1 Overview of Renewable Auction

Auctions have proven to be an alternative to the traditional, administratively set FITs. They do not represent a RE policy *per se*, but they have been challenging the well-entrenched FITs that have been responsible for the installation of thousands of MW of renewable forms of energy in the world. In most cases involving electricity auctions, the sellers, such as generators, bid their products, as they are interested in selling the power contracts to large consumers or distribution companies, with the bidding process designed in part to select the lowest price (Maurer and Barroso, 2011).

In recent years, auctions have provided low and competitive prices for many countries. The lowest bids have mainly been for utility-scale solar PV, including in the United Arab Emirates (\$24/MWh), Chile (\$29/MWh), Dubai (\$30/MWh) etc. (IEA, 2016). In 2017, Saudi Arabia closed at US\$ 23/MWh for a 300 MW facility (IRENA, 2018). Auctions foster competition, push prices down in the entire supply chain, and therefore reduce end-user tariffs, making the whole process more sustainable (Maurer and Barroso, 2011). Well-designed auction schemes can kick-start a country's RE program. Organised auction processes tend to attract attention from international players and can be an interesting alternative for countries in which the energy market lacks a mature RE segment (Azuela et al., 2014).

The increasing interests in auction schemes are driven by their ability to achieve the deployment of renewable electricity in a well-planned, cost-efficient and transparent manner while also achieving several other objectives. The strengths of auctions lie in their i) flexibility, ii) potential for real price discovery, iii) ability to ensure greater certainty in price and quantity and iv) capability to guarantee commitments and transparency (IRENA and CEM, 2015). From

the policy-makers perspective, they are relatively easy to implement, and the government has control over the volume of RE contracted, ensuring the fulfilment of RE targets. Furthermore, competition between participants enables auctions to identify the lowest cost projects and minimise the cost to the government budgets (IEA, 2016).

The use of standard contracts in auctions results in a fair allocation of risk, and projects are more likely to move to financial close, construction and commercial operation (Eberhard et al., 2017). In most cases, participants bid certain strike prices that they need to make their project viable in a certain period (which is either pre-determined by the auction organiser or part of the bid) (Held et al., 2014). Auctions for RE are often conducted as multi-unit auctions in the form of static sealed bid auctions, either with pay-as-bid pricing or uniform pricing (Kreiss et al., 2017).

However, it is noteworthy that auction is not a perfectly efficient instrument. While auctions have proven to be strong mechanisms for ensuring market efficiency as well as economic efficiency, they have been criticised for their higher transaction costs, which could limit the entry of small/new players and result in cases of subpar performances in deployment rate (IRENA and CEM, 2015). Other possible risks or disadvantages of auctions in the literature include bidders' collusion, underbidding, project delay, etc. However, a careful design can minimise the disadvantages (although probably not eliminated) (Del Rio and Linares, 2014). Nevertheless, auctions have become the most preferred RE support mechanism in an increasing number of countries (IRENA and CEM, 2015).

3.2 Overview of Auction schemes in developing countries

The fact that auctions have worked in some developing countries with power problems like Nigeria makes it worthy of consideration in the Nigeria case. However, it is noteworthy that transfers of design solutions that have worked in a country are unlikely to produce the desired impact in another regulatory environment. Local adaptations and custom-made designs should be defined based on lessons and best practices learnt from other countries (Arowolo and Perez, 2017).

Brazil, China and India

Azuela et al, (2014) reviewed the performance of RE auctions experiences in Brazil, India, and China. These countries have been selected for the significant volume of RE deployed through auctions and experience accumulated over the last decade. They concluded that auctions appear as an effective way to stimulate competition among investors, provide price disclosure while eliciting the right amount of investment, and offered revenue stability via long-term

contracting. Furthermore, auctions offered stable guarantees to both investors and consumers in these countries. This two-sided benefit of the auction process is especially valuable when there is reason to believe that the environment may be technologically, economically, politically, or institutionally unstable (Azuela et al., 2014).

Auction mechanisms have been successful in bringing energy prices down, compared to the levelized cost benchmarks calculated based on “reasonable” assumptions, which are generally used to determine an auction’s cap price and price levels for FIT programs (Azuela et al., 2014). Furthermore, In India, Shrimali et al., (2016) found that auctions are almost always cost-effective, with savings of up to 58% from baseline FITs.

Sub-Saharan Africa (SSA)

South Africa is the pacesetter in auctions schemes in SSA. It executed four auction rounds between 2012 and 2015, which attracted US\$19 billion in private investment and led to wind power prices falling by 46% and solar PV by 71% in nominal terms (Eberhard and Kaberger, 2016). In 2016, Zambia’s World Bank supported scaling solar auction achieved low prices with lowest winning bid of US\$ 6.02cents/kWhr (AURES, 2017). The Zambian scaling solar programme has played a key role in advancing the rollout of renewable energy auctions in SSA. It has shown that countries in the region can procure renewable energy in a competitive, transparent manner at large scale, and at very low prices, despite what is considered a high-risk investment context (IRENA, 2018).

Furthermore, in April 2018, Senegal scaling solar program competitive auction to develop two utility-scale solar plants with a total capacity of 60MW was awarded to Engie/Meridiam with bids at just €3.80 cents/kWhr for the solar plant located in Kahone and €3.98 cents/kWhr for the solar plant located in Touba⁵. Uganda also completed auctions for small solar power generators in 2014. Notably, Uganda’s auction combined price competition with explicit “top-up” payments by donors and the offer of a World Bank partial risk guarantee (PRG) to reduce developers’ payment risk (Meyer et al., 2015). In addition, solar power auctions are currently ongoing in Ethiopia and Madagascar through the World Bank scaling solar program.

3.3 Design variables for solar PV auction in Nigeria

Design elements affect the participation of bidders in the auction by influencing the costs, risks, and expected benefits of participation (Lucas et al., 2017). Instrumental to the design of

⁵ Senegal Scaling Solar tender produces one of the lowest electricity costs in Africa
<https://ifcextapps.ifc.org/ifcext/pressroom/ifcpressroom.nsf/0/4CB4EFF92BB608CE8525826B004CAECD?OpenDocument>

auctions are stringent bidding requirements (financial, environmental, grid connection, *etc.*) and strong compliance rules (penalties, bid bonds, project completion guarantees, *etc.*) that reduce the risks of underbidding, project delays and project failure (IRENA, 2013).

Building upon the framework of Azuela et al. (2014), this section provides the key design variables and discusses how to design solar PV auction in the Nigeria case as follows:

- *Supply and demand specification*: This element determines who can effectively participate in the auction and how much product will be contracted. On the supply side, the auction mechanism may restrict bids to particular types of technologies or sites (Azuela et al., 2014).

As a starting point for Nigeria, the capacity to be contracted should be determined based on reliable power demand projections, load profile computations and locational information from Geographical Information Systems (GIS) and energy system simulation tools. With this approach, the Nigerian government can provide reliable data on the procurement capacity needed at specified locations. Thereafter, the participants should be screened with the key pre-qualification criteria of developing country project delivery experience and adequate financial resources.

Furthermore, Nigeria's auction should be technology specific (i.e. solar PV) for off grid/mini-grid electrification. The literature [Ajayi (2010), Ohunakin (2011), Ayodele et al. (2016), Oyedepo et al. (2012) etc.] on wind potential assessment with the data from the Nigeria Meteorological Agency (NIMET) shows that the wind regime in Nigeria goes from "Low" in the south (annual average of 3m/s at 10m), to "Medium" in the North, peaking only in the northwest at 7.5m/s (Brimmo, 2017). However, Brimmo (2017) argued that NIMET's wind speed measurements are greater and inconsistent with those available from satellites and wind forecast models. Given these limitations of wind power coupled with the present lack of cost competitiveness of other renewable technologies, Nigeria's auction should be focused on solar PV.

Winner selection process: Typically, the winner of the auction is determined simply by the least-cost bid – however, it is not uncommon to incorporate other decision criteria, introducing a compound "index" that ranks the candidates. Another element to be defined is whether the auction includes a (disclosed or undisclosed) price cap and how bidders' ultimate remuneration will be determined based on their bids (Azuela et al., 2014).

In the Nigeria case, while the least cost bids per specified sites should be a criterion for determining the winners. Other criteria should be introduced to select the winning bids. First, local resource development is critical to enable indigenous capacity building in installation, operation and maintenance, manufacturing and research and development. Besides the economic impact, it will provide sustainability and enhance the socio-political acceptability of the solutions. Furthermore, sealed bid auction (pay-as-bid) with undisclosed price caps should be appropriate for the Nigeria solar auction as it is less complex than the multi-round descending clock auctions or the hybrid model. It will also reduce transaction costs and minimise the possibilities of bidder's collusion. Under sealed-bid auctions, project developers simultaneously submit their bids with an undisclosed offer of the price at which the electricity would be sold (Del Rio, 2017). Considering the current institutional capacities in Nigeria, it is critical to minimise the complexity and transaction costs.

Product characteristics: Typically, the product offered to the winners is a long-term power purchase agreement (PPA), with some important components being contract duration, escalation/indexation clauses, and liabilities of the contract parties. The enforceability of the contract terms, including the choice of the contract counterparty and the mechanism for collecting payments from consumers and/or taxpayers, can have a direct influence on the generators' financial risk (Azuela et al., 2014).

In the Nigeria case, contract duration should be linked to the asset lifetime (20-25 years) to give the investors sufficient time to recoup their investments over the asset lifecycle. Escalation clauses should be indexed to the macroeconomic variables to manage uncertainties. Furthermore, local content obligations, liabilities, insurance and liquidated damages of the contracting parties should be as explicit as possible, and the PPA should address security measures to protect assets (particularly) in the restive regions of Nigeria.

Furthermore, invoicing and payment collection mechanisms should be technology-enabled (to manage theft) to be effective. Besides, (delayed) payment risks should be properly addressed in the PPA as it could become a sticky point for investors. If the developer does not receive timely payments from the buyer, the developer will find it challenging to make interest and principal payments on the bank loan that financed the project (Meyer et al., 2015). Therefore, the PPA should provide sovereign guarantees (support from multilateral financial institutions should be helpful) to manage payment defaults/delays and macroeconomic risks. Lessons learnt from Zambia show that the auction procedure should be combined with policies and instruments which directly reduce the financing costs and participation risks to have appropriate competition levels and low bid prices (AURES, 2017).

Requirements and penalties: These helps to ensure that the winners' obligations will be fulfilled. Some of the standard practices include pre-requisites to register projects to participate in an auction, bid bonds (to be executed in case bidders' obligations are not met), completion bonds (to be executed if project milestones of the auction winners are not met), and the possibility of contract termination after a predetermined period of delay (Azuela et al., 2014).

The inclusion of requirements and penalties is sine qua non for a successful solar auction in Nigeria. Their purpose is to assure technical and financial competence of bidders to achieve successful project delivery (on schedule) and should neither deter investors nor stifle competition. Therefore, penalties and bonds should be implemented in the project lifecycle from initiation to delivery. However, penalties and bonds should be reasonably agreeable to the investors. The design of the requirements and penalties should be based in part on the procurement capacities and the site specific geo-technical information.

Strategy and coordination: Because auctions offer full disclosure of projects that will be built ahead of time, multiple attempts have been made in order to best coordinate these renewable capacity additions with the expansion of the transmission grid and the generation system as a whole (Azuela et al., 2014).

In the Nigeria case, it is important to coordinate the solar auctions with the existing distribution and transmission grid network in the centralised generation and ultimately with the national infrastructure development plans. This coordination will help to clearly address decision-making at the intersection of the auctioned projects and the existing centralised power generation. The lack of holistic plans in this regard could create future challenge(s). This created problems in India where the threat of central grid extension became a gateway barrier preventing mini-grid development (Comello et al, 2017).

3.4 Foundation of a successful Auction design for Nigeria

Moving from auction theory to real-life implementation is not an easy task. This holds true particularly when auctions are implemented in markets that are not fully functional, or where institutions are not strong enough to support any formal competitive electricity auction procurement schemes (Maurer and Barroso, 2011). For Nigeria to successfully execute a solar PV auction, the design has to be carefully executed and the foundational issue that may lead to failure addressed.

Building upon the framework of Maurer and Barroso (2011), the next section addresses the foundational principles and further discusses how to achieve a successful solar PV auction in

the Nigeria case. This centres on the Robustness of the Institutions and Regulatory Framework, Regulatory Stability, Transparency and Fairness and Auditing the Process.

Robustness of the Institutions and Regulatory Framework

Designing and implementing any type of formal auction system requires a candid assessment of the robustness of the institutions and the regulatory framework in each country or state (Maurer and Barroso, 2011).

In the Nigeria case, the regulatory framework is weak as the regulator constantly struggles with the implementation of regulations and policies. Some key unresolved challenges for many years include achieving cost-reflective tariffs (current tariff recovers an estimated 30% of the value chain cost, a situation partly responsible for the current state of the sector), grossly unmetered customers, etc. Indeed, these are worrying concerns for the investors and the change of the leadership of the Regulator in the year 2017 does not appear to have done much to allay investors' fears.

Thus, a good foundation to design and implement solar PV auction in Nigeria will rely as a springboard on the obvious improvement in the performance of the sector Regulator. Key achievements such as achieving cost-reflective tariffs, closing the metering gap and enforcing contracts and regulations in the value chain should constitute a strong selling point to attract and renew investors' waned interest in the Nigeria Power sector and the accompanying solar PV auction. This foundation is, therefore, indispensable considering the sectoral status quo. Furthermore, experience has shown that even in countries where the legal framework is solid, the enforcement of PPAs resulting from auctions depends on the existence of cost-reflective tariffs and commercial discipline. Where cost-reflective tariffs are not the practice, or non-payment is perceived as high risk, auctions for new generations tend to fail or require government support, thus increasing government-contingent liabilities (Maurer and Barroso, 2011).

Regulatory Stability

Regulatory stability is a key element in attracting investors to participate in competitive auctions. One of the greatest worries of current and potential investors with regard to auctions is related to regulatory stability and the fact that, in some cases, the auction rules are constantly changing -sometimes even during the bidding process itself (Maurer and Barroso, 2011).

In the Nigeria case, frequent change(s) in policies and incessant political interference/change of leadership could stifle the ability of the Regulator/institutions and lead to policy uncertainty

and investors high risk perceptions. As a starting point, a renewable solar PV design for Nigeria should fully have the buy-in of all the stakeholders; binding changes should only be implemented in jointly agreed circumstances. Moving the goalpost in the middle of the game should be strongly discouraged and clearly spelt out prior to the commencement of the auction to allay investors' uncertainty fears.

Transparency/Fairness and Auditing the Process

Other necessary conditions for the success of an auction process include its transparency, as well as investors' perception of the fairness of the process (Maurer and Barroso, 2011).

In 2016, transparency International ranked Nigeria 136th worldwide (TICPI, 2016)⁶. Investors watch out for these ratings and make decisions on them. Hence, these should be noted prior to the commencement of the solar PV auction in Nigeria, and serious efforts should be geared in this direction. Furthermore, streamlined administrative procedures, with communication and transparency provided equally to all bidders, are essential to the success of an auction scheme (IRENA, 2013). This should be carefully addressed and appropriately planned, and rules should be clear to the potential participants. In addition, the auditing process should be explicit to all participants to gain investors' confidence.

3.5 Solar Power Auction plus Storage Design for Nigeria

Adding energy storage is a way to increase the value (and, of course, the cost) of distributed renewables. Energy storage enables a higher share of renewable electricity produced to be consumed onsite by reserving the final supply of electricity to the times when it is needed (IEA, 2016). Battery storage can be deployed almost anywhere and on a small scale. In certain contexts, battery storage is already cost-effective, e.g. in certain off-grid systems, where it competes with diesel generation (IEA, 2016).

Furthermore, in rural India, Comello et al (2017) using LCOE also found that mini-grids based on solar PV plus storage are more economical than incumbent energy services (kerosene or diesel based) available to the households without central grid connection. Furthermore, studies analysing the economics of stand-alone PV power system have shown that the life cycle cost of PV energy is lower than the cost of energy from diesel or petrol generators and that the solar PV system is economically feasible in remote and rural areas where the monthly average solar irradiation range is 3-6 kWh/m² (Zhang, 2014).

⁶ Transparency International is the global civil society organization leading the fight against corruption.

Considering the grid constraint [max. capacity of 7,223MW in 2017 (PSRP, 2017)], a carefully designed solar PV plus storage auction focused on offgrid/minigrad electrification should contribute meaningfully to increasing power access in Nigeria. Furthermore, the stored energy makes power available during times of the day (especially night) without sunshine and could potentially provide high-quality power supply. Hence, the variables of the solar minigrad auctions should be designed plus storage.

In addition, grid-scale battery costs have declined by more than two-thirds in eight years, and costs are expected to continue to fall at a rapid pace, aided by battery deployment in the automotive and consumer electronics industries (IEA, 2016). Large increases in manufacturing scale, improvements in storage capacity and density and reductions in material costs are working to push down the costs of batteries and other storage technologies (IEA, 2016). Moreover, the World Bank (in September 2018) announced the “Accelerating Battery Storage for Development” program (to commit US\$ 1 Billion and to mobilise an additional US\$4 billion) to accelerate investments in battery storage to expand energy access in developing countries. It refers to it as the “game changer” for developing countries. The program aims to finance and de-risk investments in utility-scale solar parks with battery storage and off-grid systems, including mini-grids. This also shows that solar PV plus storage is a workable design, as battery costs should continue to decline in the coming years.⁷

This auction design approach is already gaining momentum in some developing countries. For instance, in 2016, India called for its first tender for solar energy (300 MW of projects) that mandated the inclusion of a storage component (REN 21, 2017). Suriname also held a tender for a solar PV project that included battery storage. Furthermore, solar PV developer SkyPower (Canada) announced an agreement to bid for up to 750 MW of solar-plus-storage capacity in India’s upcoming tenders (REN 21, 2017). In Africa, Madagascar has also commenced the first 25MW solar PV plus storage auction under the World Bank scaling solar project. Thus, the solar PV plus storage auction is a workable solution for Nigeria to explore to significantly improve electricity access. Table 2 below summarises the findings.

⁷Press release of the World Bank’s accelerating battery storage for development program http://www.worldbank.org/en/news/press-release/2018/09/26/world-bank-group-commits-1-billion-for-battery-storage-to-ramp-up-renewable-energy-globally?cid=ECR_LI_worldbank_EN_EXT

SOLAR POWER AUCTIONS DESIGN “FOR THE NIGERIA MARKET”	
3.1 Overview of Renewable Auction	<ul style="list-style-type: none"> • Auction is a solid mechanism to ensure market and economic efficiency. • Auction provides low and competitive prices, reduces tariffs to end-users and achieves deployment of renewable electricity in a cost-efficient and transparent manner. • Auction is not perfectly efficient. Key failure risks are bidders’ collusion, underbidding etc and must be carefully designed bearing the risks in mind.
3.2 Overview of auctions in developing countries	<ul style="list-style-type: none"> • Auction is in vogue in developing countries to procure power on a competitive basis. • Studies on Brazil, China, India and some Sub-Sahara African countries show that auctions can be effective (achieve low prices, attract investment and spur competition) if well-designed
3.3 Design variables for solar power auction in Nigeria	<ul style="list-style-type: none"> • <i>Supply and demand specification (project-specific requirements)</i> ✓ Obtain Power demand projections, load profiles and locational information from GIS and energy simulation tools ✓ Screen participants with key pre-qualification criteria of developing country solar power project delivery experience and adequate financial resources ✓ Focus on Solar Power auction • <i>Winner selection process</i> ✓ Take the lowest cost bid with strong local content development plans ✓ Use sealed bid auction (pay-as-bid) with undisclosed price cap • <i>Product characteristics</i> ✓ Put in place sovereign guarantees (supported by MFIs) to hedge risks ✓ Use technology to facilitate invoicing and payments to manage theft ✓ Write PPA clauses in clear terms ✓ Index escalation clauses to macroeconomic variables ✓ Align PPA to asset lifetime • <i>Requirements and penalties</i> ✓ Put in place from initiation to project delivery ✓ Ensure they are reasonably agreeable to participants • <i>Strategy and Coordination</i> ✓ Align auction projects with existing centralised power system ✓ Meticulously design the auction from the outset to prevent failure.
3.4 Foundation of a successful Solar Power auction design for Nigeria	<ul style="list-style-type: none"> • Strengthen the regulatory and institutional framework to attract investors to the solar auction by addressing the core issues of cost-reflective tariffs, metering gaps and institutional capacity development. • Ensure regulatory stability to allay investors' uncertainty fears • Avoid frequent change(s) in policies and incessant political interference • Assure stable leadership of the Regulator/institutions to avoid policy uncertainty and investors high risk perceptions. • Ensure the buy-in of all stakeholders • Implement changes to the process in jointly agreed circumstances only • Ensure that meticulous planning and rules of engagement are clear to potential participants.
3.5 Solar Power auction plus storage design for Nigeria	<ul style="list-style-type: none"> • Considering the grid constraint in Nigeria (max. capacity of 7,223MW) and good solar irradiance, a well-designed auction for solar power plus storage for off-grid/minigrad electrification will contribute meaningfully to improve power access and attract private investments to Nigeria. • Solar PV auction plus storage will help to achieve high quality power supply (cost effectively) for off-grid/minigrad electrification in Nigeria. • Solar PV plus storage is cost effective in off-grid systems (SHS and minigrad), where it competes with diesel generation. • Declining solar PV and battery costs will facilitate the competitiveness of this solution • Solar Auction could potentially solve simultaneously the two problems of power access and affordability in Nigeria.

4. CONCLUSION AND POLICY IMPLICATIONS

The Nigerian government has recently put in place new policy documents to address the multi-faceted issues confounding the power sector. The core issues of recovering the financial deficit worth several billions of US dollars due to the lack of cost-reflective tariffs and the challenge to increase electricity access (while stabilising on-grid power access above 4,000MW) remain the hot topics in 2017 and 2018. These financial and technical issues have put the sector on the precipice of total collapse, and it appears the policy documents will remain, at best, on paper if unresolved. The sector thus appears to be at a dead end as the government is financially constrained, MFIs have seemingly stringent lending conditions, and investors are risk averse to stake their funds in the sector.

This paper presented an overview of the current state of the sector using the recent policy documents guiding decision-making as a springboard. Thereafter, it reviewed the literature on RE for the Nigeria Power sector and found knowledge gap in solar PV auction market design. To bridge this gap, it reviewed the state-of-the-art on renewable auction market design for solar PV in developing countries, the key auction design variables, foundations of a successful auction and solar auction design plus storage to draw relevant and adaptable lessons for the Nigeria Power sector case. Below are the policy recommendations:

- *Market Design for solar PV plus storage auction*

Considering the financial and technical challenges bedevilling centralised power generation in Nigeria. Renewable solar auction plus storage technology in offgrid/minigrad solution (due to the grid constraint) provides a path forward to increase power access and attract investments to the sector. However, the solar PV auction must be well-designed on a strengthened regulatory and institutional framework as a springboard to allay investor's fears.

Furthermore, the solar auction key design variables (supply and demand specification, winner selection process, product characteristics, requirements and penalties and strategy and coordination) should be carefully adapted with an in-depth understanding of the Nigeria situation to attract bidders and to manage auction risks such as high transaction costs, underbidding, collusion, delays and project completion/deployment.

- *Use of Grants for off-grid electrification with Solar Home Systems (SHS) in rural areas*

Since a major challenge confounding the Nigeria power sector is the paucity of funds, grants from multilateral and bilateral institutions such as the International Climate Fund (ICF), Global Environment Facility (GEF) Trust Fund, etc and philanthropic organisations for small-scale projects should be further harnessed and channelled to provide SHS for very remote and poor

neighbourhoods in Nigeria. The release of such grants should also be accompanied by the training of the locals in the installation and, operation and maintenance of the SHS to ensure sustainability.

Early-stage grant financing plays a crucial role in building enterprise-level institutional capacity and during the scale-up stage of SHS, as evidenced by the case of Mera Gao Power in India (IRENA, 2016). Another case in point is in Kenya, where (SHS account for 80% of installed solar capacity). Many international donor organisations have been active in supporting the development of the private SHS market through various programmes (Hansen et al., 2015). Bangladesh has also deployed more than 4 million SHS as of June 2016, providing electricity to more than 18 million people (IRENA, 2016). However, it should be noted that any successful rural electrification programme also requires complementary infrastructure development and the existence of an effective implementing agency (Bhattacharyya and Palit, 2016).

References

- Akuru U.B, Onukwube I.E, Okoro O.I, Obe E.S. (2017), Towards 100% renewable energy in Nigeria. *Renewable and Sustainable Energy Reviews* 71 (2017) 943–953
- Aliyu A.S., Dada J.O, Adam I.K. (2015), Current status and future renewable energy prospects in Nigeria. *Renewable and Sustainable Energy Reviews* 48 (2015) 336–346
- Aliyu A.K., Modu B., Tan C.W (2018), A review of renewable energy development in Africa: A focus in South Africa, Egypt and Nigeria *Renewable and Sustainable Energy Reviews* 81 (2018) 2502–2518
- Ajayi O.O. (2010), The potential for wind energy in Nigeria. *Wind Engineering* 34 (2010) 303-311
- Arowolo W., and Perez Y. (2017), Market Reform in the Nigeria Power sector: A review of issues and potential solutions. (Under Review) *Energy Policy Journal*, 2017.
- Ayodele T.R, Ogunjuyigbe A.S.O., Amusan T.O. (2016), Wind power utilisation assessment and economic analysis of wind turbines across fifteen locations in the six geographical zones of Nigeria. *Journal of Cleaner Production* 129 (2016) 341 -349
- AURES (2017), Auction for renewables support in Zambia: Instruments and lessons learnt. Auctions for Renewable Energy Support (AURES), EU Horizon 2020 Program, Report D4.4-ZM, July 2017
- Azuela G.E and Barroso L.A (2011), Policy Instruments to Promote the Development of Renewable Energy: Emerging Experience in Selected Developing Countries. The World Bank, Washington, DC
- Azuela G.E., Barroso L., Khanna A., Wang X., Wu Y., Cunha G. (2014), Performance of Renewable Energy Auctions: Experience in Brazil, China and India. Policy Research Working Paper 7062. Energy and Extractive global practice, World Bank Group, 2014.
- Bhattacharyya S.C. and Palit D., (2016), Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required? *Energy Policy* 94 (2016) 166-178
- Brimmo A.T, Sodiq A., Sofela S., Kolo I., (2017), Sustainable energy development in Nigeria: Wind, hydropower, geothermal and nuclear (Vol. 1), *Renewable and Sustainable Energy Reviews* 74(2017) 474-490
- Comello S.D, Reichelstein S.J., Sahoo A., Schmidt T.S. (2017), Enabling Mini-grid Development in Rural India. *World Development* Vol. 93 pp. 94-107, 2017.
- Del Rio P. (2017), Designing auctions for renewable electricity support. Best practices from around the world. *Energy for Sustainable Development* 41 (2017) 1–13

- Del Rio P. and Linares P. (2014), Back to the future? Rethinking auctions for renewable electricity support. *Renewable and Sustainable Energy Reviews* 35 (2014) 42–56
- Eberhard A. (2014), Feed-in tariffs or auctions? Procuring renewable energy supply in South Africa. *Energy RE: Renewable Energy Supplement - June 2014 - Page 36*
- Eberhard A., Gratwick K., Morella E., Antmann P. (2017), Independent Power Projects in Sub-Saharan Africa: Investment trends and policy lessons. *Energy Policy* 108 (2017) 390–424
- Eberhard A. and Kaberger T. (2016), Renewable energy auctions in South Africa outshine feed-in tariffs. *Energy Science and Engineering* 2016; 4(3): 190–193
- Emodi N.V, and Boo K-J (2015), Sustainable energy development in Nigeria: Current status and policy options. *Renewable and Sustainable Energy Reviews* 51(2015) 356–381
- ERGP (2017), Economic Recovery and Growth Plan 2017-2020, Ministry of Budget and National Planning, Federal Republic of Nigeria, 2017.
- ESMAP (2017), Minigrids In Nigeria: A case study of a promising market. Conference Edition, Energy Sector Management Assistance Programme (ESMAP), The World Bank, November 2017.
- FGN (2016), The Nigeria Power sector investment opportunities and guidelines, Ministry of Power, Federal Republic of Nigeria (Draft), June 2016.
- Finon D., and Perez Y., (2007), The social efficiency of instruments of promotion of renewable energies: A transaction-cost perspective. *Ecological Economics* 62 (2007) 77–92.
- Giwa A., Alabi A., Yusuf A., Olukan T. (2017), A comprehensive review on biomass and solar energy for sustainable energy generation in Nigeria. *Renewable and Sustainable Energy Review* 69 (2017) 620–641
- Hansen U. E., Pedersen, M. B., Nygaard, I. (2015), Review of solar PV policies, interventions and diffusion in East Africa. *Renewable and Sustainable Energy Reviews* 46 (2015) 236-248
- Held A., Ragwitz M., Gephart M., Klessmann C., Visser E. (2014), Best practice design features for RES-E support schemes and best practice methodologies to determine remuneration levels. DIA-CORE Project, Work Package 5, Intelligence Energy Europe Program, 2014.
- IEA (2016), World Energy Outlook / Special Focus on Renewable Energy, International Energy Agency, Paris, France.
- IEA (2017), Energy Access Outlook – From Poverty to Prosperity, World Energy Outlook Special Report, International Energy Agency, Paris, France.
- IRENA (2018), Renewable energy auctions: Cases from sub-Saharan Africa, International Renewable Energy Agency, Abu Dhabi.

IRENA (2013), Renewable Energy Auctions in developing countries. International Renewable Energy Agency, Abu Dhabi, 2013.

IRENA and CEM (2015), Renewable Energy Auctions – A Guide to Design. International Renewable Energy Agency, Abu Dhabi, 2015.

IRENA (2016), Policies and regulations for private sector renewable energy mini-grids. International Renewable Energy Agency, Abu Dhabi, 2016.

Kreiss J., Ehrhart K-M, Haufe M-C (2017), Appropriate design of auctions for renewable energy support: Pre-qualifications and penalties. *Energy Policy* 101 (2017) 512–520

Lucas, H., del Rio, Pablo and Sokona, S (2017) 'Design and Assessment of Renewable Electricity Auctions in Sub-Saharan Africa', in Pueyo, A. and Bawakyillenuo, S (Eds) *Green Power for Africa: Overcoming the Main Constraints*, Brighton: IDS

Mas'ud A.A., Wirba, A.V., Sukki F.M, Albarracin R., Munir, A.B., Bani N.A. (2016), A review on the recent progress made on solar photovoltaic in selected countries of sub-Saharan Africa. *Renewable and Sustainable Energy Reviews* 62 (2016) 441–452

Maurer L.T.A and Barroso L.A (2011), *Electricity Auctions: An overview of efficient practices*, A World Bank study, World Bank, 2011.

Meyer R., Tenenbaum B., Hosler R., (2015), *Promoting Solar Energy through Auctions: The Case of Uganda*. Live wire knowledge note series; no. 2015/49. Washington, D.C. World Bank Group.

Mohammed Y.S, Mustafa M.W., Bashir N., Mokhtar A.S., (2013), Renewable energy resources for distributed power generation in Nigeria: A review of the potential. *Renewable and Sustainable Energy Reviews* 22 (2013) 257–268

Mohamed S. and Petinrin J.O. (2014), Renewable energy potentials in Nigeria: Meeting rural energy needs. *Renewable and Sustainable Energy Reviews* 29 (2014) 72–84

Monyei C.G, Adewumi A.O, Obolo M.O., Sajou B. (2018), Nigeria's energy poverty: Insights and implications for smart policies and framework towards a smart Nigeria electricity network. *Renewable and Sustainable Energy Reviews*. Elsevier, vol. 81(P1), pages 1582-1601

NERC (2016), *Regulations for Mini-Grids*. Nigerian Electricity Regulatory Commission 2016

NERC (2017), *Business Continuity Regulation*. Nigerian Electricity Regulatory Commission 2017

NREEEP (2015), *National Renewable Energy and Energy Efficiency Policy*. Approved by the Federal Executive Council for the Electricity Sector, Ministry of Power, Nigeria.

NREAP (2016) *National Renewable Energy Action Plans 2015- 2030*. Approved by the National Council of Power, July 2016

Nwokocha C.O, Okoro U.K, Usuh C.I. (2018), Photovoltaics in Nigeria e Awareness, attitude and expected benefit based on a qualitative survey across regions. *Renewable Energy* 116 (2018) 176-182

Ohunakin S. O (2011), Wind resource evaluation in six selected high-altitude locations in Nigeria. *Renewable Energy* 2011; 36:3273–81.

Ohunakin S.O., Adaramola M.S., Oyewola O.M, Fagbele R.O. (2014), Solar energy applications and development in Nigeria: Drivers and barriers. *Renewable and Sustainable Energy Reviews* 32 (2014) 294–301

Okoye C.O, Taylan O., Baker D.K., (2016), Solar energy potentials in strategically located cities in Nigeria: Review, resource assessment and PV system design. *Renewable and Sustainable Energy Reviews* 55 (2016) 550–566

Oyedepo S.O. (2012), Analysis of wind speed data and wind energy potential in three selected locations in south-east Nigeria. *Int. J. Energy Environ Eng* 2012;3(1):1–11.

Ozoegwu C.G, Mgbamene C.A, Ozor P.A., (2017), The status of solar energy integration and policy in Nigeria. *Renewable and Sustainable Energy Reviews* 70 (2017) 457–471

PSRP (2017), Draft Power Sector Recovery Program: 2017-2021, Federal Republic of Nigeria. April, 2017.

PSRIP (2017), Power Sector Recovery Implementation Program, Federal Ministry of Power, Nigeria, May 2017.

REN21 (2017), Renewables Global Status Report 2017, Renewable Energy Policy Network for the 21st century, REN21 Secretariat, Paris.

REN21 (2016), Renewables Global Status Report 2016, Renewable Energy Policy Network for the 21st century, REN21 Secretariat, Paris.

REFIT (2016), Regulations on Feed-In Tariff for Renewable Energy sourced electricity in Nigeria, Nigerian Electricity Regulatory Commission, 2016.

SE4ALL (2016), Sustainable Energy for All Action Agenda. Approved by the National Council of Power, July 2016.

Shrimali G., Konda C., Farooquee A.A. (2016), Designing Renewable Energy Auctions for India: Managing Risks to maximize deployment and cost effectiveness. *Renewable Energy* 97 (2016) 656-670

TICPI (2016), Transparency International Corruption Perception Index 2016. Assessed on August 29, 2017 at [http://www.ey.com/Publication/vwLUAssets/EY-Transparency-International-Corruption-Perceptions-Index-2016/\\$FILE/EY-Transparency-International-Corruption-Perceptions-Index-2016.pdf](http://www.ey.com/Publication/vwLUAssets/EY-Transparency-International-Corruption-Perceptions-Index-2016/$FILE/EY-Transparency-International-Corruption-Perceptions-Index-2016.pdf)

World Bank (2016), Who Uses Electricity in Sub-Saharan Africa? Findings from Household Surveys Policy Research Working Paper 7889, Energy and Extractives Global Practice Group, August 2016.

Zhang F. (2014), Can solar panels leapfrog power grids? The World Bank experience 1992–2009. *Renewable and Sustainable Energy Reviews* 38 (2014) 811–820

APPENDIX 1

Investment Risks	Effectiveness/Efficiency	Complexity
Feed in Tariff		
<ul style="list-style-type: none"> • Low price, volume and balancing risks • In spot market transactions, balancing risk may arise (this risk can be minimized introducing a “per area” mechanism) • Designed to create stable investment environment (although successive FITP design adjustments may decrease investors’ confidence) • Predictable revenue streams • Help increase debt financing 	<ul style="list-style-type: none"> • Effectiveness in terms of market growth is high (subject to compliance with RPO) • Sophisticated FIT design can reduce inframarginal rents • Allows for strategic support of different types of RE • No incentive for cost reductions (entire supply chain) • Overall cost of FITP may be high (depends on FITP design and market conditions) 	<p>In general, complexity is low but depends on the type of FIT (tradeoffs between simplicity and complexity)</p> <ul style="list-style-type: none"> • Depending on design complexity, calibration may require a complex administrative process
RPS - REC		
<ul style="list-style-type: none"> • Moderate to high price risk (value of REC depends on market dynamics) • Moderate to high volume risks (once targets are met, suppliers do not have an incentive to purchase RE generation) • Balancing risk may be high (depends on market rules and support mechanisms) • Less predictable revenue streams require higher IRRs • Participation in bids may entail high transaction costs • More difficult to secure financing 	<ul style="list-style-type: none"> • Effectiveness in terms of market growth depends on actual compliance with quotas (market share) • Market based instrument, fosters competition among RE suppliers (least-cost RE introduced first) • Favors mature technologies 	<ul style="list-style-type: none"> • REC market design and the periodic setting of targets/quotas may be complex • REC market requires high institutional and administrative capacity
Competitive Procurement (Auctions)		
<ul style="list-style-type: none"> • Moderate to high price risk (depends on contract design, market rules) • Stop-and-go nature creates uncertainty • Less predictable revenue streams require higher IRRs • Awarded contracts provide predictable revenue streams • Participation in bids may entail high transaction costs • More difficult to secure financing 	<ul style="list-style-type: none"> • If competition is effectively fostered, delivers low prices (entire supply chain) • Allows for strategic support of different types of RE • High deployment risk (project delays or no implementation at all due to difficulties in financial closure, administrative or licensing barriers, weak rule of law or weak enforcement of contracts or project completion guarantees) 	<p>Design of auction mechanism may be complex (depends on type of market and market conditions)</p> <ul style="list-style-type: none"> • Requires high institutional and administrative capacity • Requires robust rule of law, enforcement of contracts • Regulatory stability is crucial (stable auction rules) • Requires proper design of project completion guarantees and penalties for delays and underperformance.

Table 1 Source: Azuela and Barroso (2011), Design and Performance of Policy Instruments to Promote the Development of Renewable Energy: Emerging Experience in Selected Developing Countries

N.B: Renewable Portfolio Standard (RPS) and Renewable Energy Certificate (REC) are quota mechanisms- also referred to as Exchangeable Quota (EQ) in this paper

Appendix 2

The WORLD BANK GROUP CONDITIONS for the Nigeria government to qualify for facility

The list below highlights the tasks FGN has to fulfill in order to qualify for the \$2.5 Billion:

1. FEC approval of the Power Sector Recovery Implementation Program (PSRIP)
2. Sources of funding identified for the PSRP
3. Appointment of Boards (Nigeria Bulk Electricity Trading Plc (NBET), Transmission Company of Nigeria (TCN), Nigeria Electricity Liability Management Company (NELMCO), Niger Delta Power Holding Company (NDPHC), Rural Electrification Agency (REA), Bureau of Public Enterprises (BPE)
4. Appoint BPE professional Directors on Distribution Company (DISCO) Boards
5. Policy statement issued by Federal Ministry of Power, Works and Housing (FMoPWH) on cost reflective tariff/ subsidy path endorsed by Federal Ministry of Finance (FMoF).
6. Update Multi-Year Tariff Order (MYTO) methodology consistent with policy
7. Carry out tariff review (per MYTO review schedule)
8. Budget containing provision for Ministries, Department and Agencies (MDA) debt approved
9. Announce the operational mechanism for subsidy
10. Institutional arrangements in place for oversight, implementation and monitoring of the PSRIP
11. Issue the gas pipeline vandalism prevention strategy
12. Implement (approved actions) to reduce gas pipeline vandalism
13. Review and confirmation of gas and transmission infrastructure investment required for PSRIP
14. Conduct legal review of sector contracts including Performance Agreements, Vesting Contracts and PPAs to facilitate hitch-free contract activation
15. Review of BPE/NERC of Disco investment/performance improvement plans
16. Market Operator submits generation adequacy report to Nigeria Electricity Regulatory Commission (NERC)
17. Review of timing of projects in preparation and issue policy for competitive procurement
18. Issue communications strategy for PSRIP and begin implementation

Extracted from the POWER SECTOR RECOVERY IMPLEMENTATION PROGRAM DOCUMENT

Appendix 3

S/N	Item	Description	WBG funding	Status January 2019
1	Performance-based loan for financial support to eliminate sector cashflow deficits	Performance-based loan for financial support to NBET to ensure GENCOs and gas suppliers are paid 100%, notwithstanding any shortfalls from DISCO	US\$ 1 Billion	Yet to be approved
2	Loss reduction in distribution, including metering	Initial deployment to be focused on maximum demand customers. The metering scheme will be tied to clearly defined performance targets for the DISCOs supported by data and information received during an audit exercise	US\$ 500 Million	Yet to be approved
3	Support to the Transmission Company of Nigeria (TCN)	Financing Program for TCN priority program Rehabilitation and reinforcement of existing transmission substations and lines.	US\$ 486 Million	Approved February 2018.
4	Rural Electrification Initiatives	Solar minigrid projects, social solar electrification projects -school, hospitals and Rural Electrification Fund.	US\$ 350 Million	Approved June 2018. Hopes to generate a total of 126 MW.
5	Guarantees	Independent Power Producers guarantees (IBRD)	US\$ 305 Million	Approved.
		Total	US\$ 2,641 Billion	

Source: PSRIP (2017) and Author's Analysis