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

Wale Arowolo¹

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 200 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 SSA and 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 to 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, Reverse Auction, Energy Policy

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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. Only 3,571MW was generated in September 2018 from the grid (NERC, 2019) for about 200 million people. Three years ex-post reform, the sector had 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 stabilize 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. It is also estimated that the Nigeria economy is losing US\$ 29.3 billion annually due to lack of adequate power supply and is estimated to have lost US\$ 470 billion in GDP since year 2000 due to underinvestment in power infrastructure (PSRIP, 2017). It is therefore critical to seek alternatives in decentralized power generation to increase electricity access in Nigeria.

The potentials 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. 2018, 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 (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, the speed of implementation is in a shorter time versus centralized generation, it is modular for local adaptations and green (Arowolo and Perez, 2017). It is also noteworthy that these potential benefits of renewables solar have been acknowledged by the government 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

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.

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 for the World Bank, a cumulative capacity of 236kW solar minigrid serving about 9,100 people exist 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 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.

This paper thus enriches the Nigeria Power sector debate in three distinct ways. First, it makes the first contribution (to the best of my 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. Second, 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. Third, it argues that solar plus storage auction design (considering the grid and financial constraints) is a plausible path forward for Nigeria. Based 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 policy documents in the Nigeria power sector. Section 3 discusses the solar auction design for the Nigeria market. Section 4 is the conclusion and policy implications.

2. OVERVIEW OF POLICY DOCUMENTS IN THE NIGERIA POWER SECTOR

This section discusses the recent policy documents 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 Nigeria Power sector (ex-post reform).

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

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

PSRP aims to recover the financial deficit in the sector and to 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). 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.

Presently, the last workable scenario in the PSRP 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 supported the sector through a loan facility of 702 billion naira (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 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 grid connection of RE. The cap for REFIT is set at 2,000MW of RE power admissible into the grid (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 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.

For the base year 2016, the FITs were pegged at US\$177/MWh (for 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 excluded 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 (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 off-grid RE system, the target is 187MW by 2020 and 5,545MW by 2030 through mini-grid and stand-alone systems.

For off-grid RE, the policies and measures include the planned provision of financial support (soft loan) with low interest rate 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 utilization 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 summarized 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 etc

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

The ERGP aims to increase power generation by optimizing operational capacity, encouraging small-scale projects, and pursuing long-term capacity, improve commercial viability of generation and distribution companies and spur investment in transmission infrastructure. The ERGP also aims to optimize 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).

- *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 to include 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 etc.

Table 1 is the summary of the policy documents.

While these policy documents are geared towards addressing the multi-faceted challenges in the Nigeria power sector, they also generally embrace renewable energy as a potential

solution. However, financial constraint remains a major challenge to actualize their objectives. Therefore, the next 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 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 issues to RE producers, targets being 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, 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. In 2018, auction continues to gain global relevance, as more than 67 countries (most of them developing) are using these competitive procurement mechanisms to contract renewable power (IRENA, 2018).

3.1 Overview of Renewable Auction

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 tariffs to the end-users, making the whole process more sustainable (Maurer and Barroso, 2011).

The increasing interests in auction schemes are driven by their ability to achieve deployment of renewable electricity in a well-planned, cost-efficient and transparent manner while also achieving several other objectives (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 fulfillment of RE targets (IEA, 2016).

The use of standard contracts in auctions result in a fair allocation of risk and projects are more likely to move to financial close, construction and commercial operation (Eberhard 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 includes bidders' collusion, underbidding, project delay etc. However, the disadvantages can be minimized (although probably not eliminated) through a careful design (Del Rio and Linares, 2014).

3.2 Overview of Auction schemes in SSA

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 tailor-made designs should be defined based on lessons and best practices learnt from other countries (Arowolo and Perez, 2017).

Sub-Sahara Africa (SSA)

South Africa is the pacesetter in auctions schemes in SSA. It executed four auctions round 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, the 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. 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 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 Nigeria government can provide reliable data on needed procurement capacity 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.

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>

Furthermore, the Nigeria's auction should be technology specific (i.e solar PV) for offgrid/minigrd 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. In view of these limitations of wind power coupled with the present lack of cost competitiveness of other renewable technologies, the 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. Beside the economic impact, it will provide sustainability and enhance 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 minimize 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 minimize the complexity and transaction costs.

Product characteristics: Typically, the product offered to the winners is a long-term power purchase agreement (PPA) – 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 the investors. If the developer does not receive timely payments from the buyer, the developer will find it difficult 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/delay 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 put in place in the project lifecycle from initiation to delivery. However, penalties and bonds should be reasonably agreeable to the investors. The design of the requirement and penalties should be based in part on the procurement capacities and the site specific geo-technical information.

Strategy and coordination: Because auctions offer a 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 of 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 centralized 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 centralized 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 centers 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 appears 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.

Thus, a good foundation to design and implement solar PV auction in Nigeria will rely as a springboard on the improvement in the performance of the sector Regulator. Key achievements such as achieving cost reflective tariffs, closing the metering gap and the enforcement of 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 in 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 generation tend to fail or require the government support, thus increasing the government-contingent liabilities (Maurer and Barroso, 2011).

Regulatory Stability

Regulatory stability is a key element to attract 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 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 the confidence of the investors.

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

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 at 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).

Considering the grid constraint [max. capacity of 7,223MW in 2017 (PSRP, 2017)], a carefully designed solar PV plus storage auction focused on offgrid/minigrid 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. Moreover, Arowolo et al. (2019) performed solar PV plus storage techno-economic analysis for the Nigeria case and posited that it is not impossible to expect a well-designed solar plus storage auction to produce prices in the range of US\$0.09-US\$0.12/kWh in Nigeria. This cost will be at the low end of the current grid tariffs and can potentially achieve high quality power supply with some demand side management. Hence, the variables of the solar minigrid auctions should be designed plus storage.

In addition, the 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 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 mobilize 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, off-grid systems – including

mini-grids etc. 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 is the summary of the findings.

4. CONCLUSION AND POLICY IMPLICATIONS

The Nigeria 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 and the challenge to increase the electricity access (while stabilizing 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 in a dead end as the government is financially constrained, MFIs have seemingly stringent lending conditions and investors are risk averse to stake their funds into 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 SSA, 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:

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

- *Market Design for solar PV plus storage auction*

Considering the financial and technical challenges bedevilling centralized power generation in Nigeria. Renewable solar auction plus storage technology in offgrid/minigrid 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 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 with 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). A lot of international donor organizations 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).

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Table 1: Summary of the policy documents.

Policy Documents	Summary
<p>Power Sector Recovery Plan (PSRP) 2017-2021</p>	<p>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>
<p>Economic Recovery Growth Plan (ERGP) 2017-2020</p>	<p>Optimize 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>
<p>National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015</p>	<p>Create the 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>

Table 2 is the summary of the findings.

SOLAR POWER AUCTIONS DESIGN “FOR THE NIGERIA MARKET”	
3.1 Overview of Renewable Auction	<ul style="list-style-type: none"> • Auction is a strong mechanism to ensure market and economic efficiency. • Auction provides low and competitive prices, reduce tariffs to end-users and achieve deployment of renewable electricity in 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 auction 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 centralized 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 meticulous planning and rules of engagement should be clear to the 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.

	<ul style="list-style-type: none">• 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.
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