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IMPACTING NIGERIA'S ELECTRICITY DEFICIT: A CASE STUDY REVIEW OF ENABLING SOLAR PV POLICIES

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ABSTRACT: *This paper examines Nigeria's dismal performance in electricity power generation and supply; it conducts a case study review is done of enabling Solar PV policies as a complementary alternative to effectively mitigating the effects of this challenge. Besides envisaging dire socio-economic implications in the event of a total national grid overhaul without alternative back-ups, this paper proffers the harnessing of the nation's abundant solar energy sources as a leapfrogging strategy. In its analysis and discussion of the reviewed case studies, this paper posits that solar energy has the capacity to boost Nigeria's electricity power generation and supply towards reducing current high levels of energy poverty. In backing its hypothesis, this paper conducts a case study review of two countries - United States of America and China - that have efficiently exploited their solar energy resources through deliberately conceptualised, designed and implemented policies, and in so doing facilitating a diversified, reliable and sustainable power generation and supply process. The paper concludes with recommendations put together based on inferences drawn from the case study reviews, as well as imputations made from an overarching analysis and discussion of these enabling policies.*

KEYWORDS: Solar PV, Enabling Policies, Renewable Energy Technology (RETs), Electricity, Deficit, United States of America (US), China.

INTRODUCTION

Energy plays a central role in all nations' socio-economy. It also serves as a key component in boosting all indices of growth including transportation, improved standard of living, job creation, education, agriculture and healthcare, [**1**]. Just about 40% of Nigeria's estimated 200 million population have access to electricity supply, **[2].** With the National Grid limited in coverage and mostly focused in the urban areas, a preponderant number of Nigerians in the rural areas are without grid-access and electricity. Additionally, the urban areas, despite being under the National Grid coverage, still suffer insufficient electricity supply owing to the poor state of the grid's power generation infrastructure, as well as its distribution and transmission lines. Accordingly, this dismal electricity supply has had negative effects on the development potentials and growth of the Nigerian economy. With a surging population, energy (electricity) demand is bound to increase tremendously, hence the need for urgent steps to be taken to harness alternative solutions that are sustainable and environmentally friendly. The global trend in today's power sector development, remains a gravitation towards clean-renewable energy. Renewable Energy if properly harnessed, has the capacity to ensure stable electricity supply that would not only boost the satisfaction of domestic needs, but also manufacturing and industrial sector needs for national growth and

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development, **[3]**. Diversification into renewable energy sources will also facilitate the attainment of key Sustainable Development Goal's (SDG) such as cutting down carbon emissions, reduction in negative climate change effects, and other related hazards. SDG 7, one of the 17 Sustainable Development Goals established by the United Nations General Assembly (UNGA) in 2015, aims to ensure access to affordable, reliable, and sustainable energy for all by the year 2030,**[4].** SDG 7 has five outcome targets namely - 'promote access to research, technology and investments in clean energy'; 'increase global percentage of renewable energy'; 'ensure universal access to modern energy'; 'double the improvement in energy efficiency'; and 'expand and upgrade energy services for developing countries' - all of these which tally with this papers objectives.

Nigeria is endowed with abundant renewable energy sources such as solar, hydro, biomass and wind, which if harnessed, has the capacity to boost electricity power generation and supply, consequently reducing national energy poverty and its debilitating effects across critical sectors of the economy.Solar Renewable Energy is the most viable of the renewable alternatives in the Nigeria socio-economic, geographical and technological context. In the socio-economic context, solar energy resources are more accessible and affordable to a wider range of Nigerians when compared to other renewables. Similarly, in the geographical context, Nigeria is located on a high radiation belt; while in the technological context, Nigeria stands to benefit from global advances in solar photovoltaic technology, drop in material and component prices, and tech-sophistication competent for mainstream power generation.

Solar energy is harnessed by deploying either of two Renewable Energy Technological systems (RETs), namely, the Solar Photovoltaic Systems (PV) or the Concentrated Solar Power (CSP) also known as the Concentrated Solar Thermal. In terms of scope, this paper focuses on Solar PV.
The Solar PV system is made up of panels placed directly either on rooftops, or on the ground in solar farms, or on floating barges on a large sea expanse - all designed to convert sunlight directly to electric power. With an average abundant daily sunshine of 5.535KWh/m2 across Nigeria, 6000 Megawatts can be generated from Solar PV Panels placed on a 3000 km radius of empty sun scorched land, **[5]**. Also, 6000 Megawatts alone represents half of the nation's potential electricity generation capacity, **[6]**. Nigeria, therefore, no doubt has abundant supply of solar energy and sits atop a position of natural-resource strength.

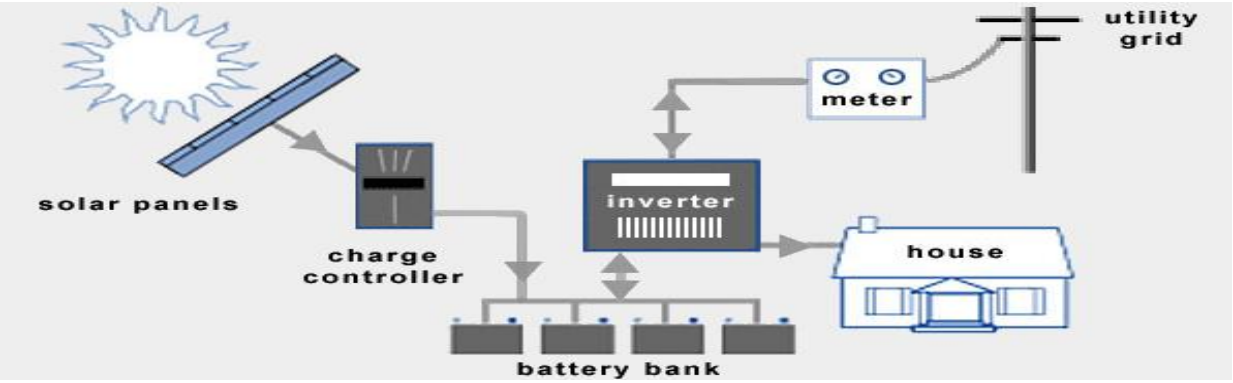

Figure 1 - Solar PV System, **[7]**

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Bangladesh, just like Nigeria is located on a high solar radiation belt with a high population density of 163 million as well as an increasing energy demand and consumption rate. **[8],** submit that Bangladesh exploited this strength, tackling their electricity challenge by initiating a Solar Homes National Electrification Strategy which saw over 4 million homes installed with independent solar PV rooftop power systems. This they submit will support and complement the Bangladeshi national grid by over 220MW by the end of 2021. It is therefore incumbent on Nigeria to explore in-depth policy options for harnessing enablers and tackling barriers affecting the emerging Nigeria Solar PV sector. At the heart of any effort aimed at exploiting renewable energy as an alternative solution to the national electricity challenge, are policies deliberately designed to address all underlying or prerequisite factors, **[9]**. These policies if implemented, will ensure the removal of barriers like bureaucratic bottle necks/red tape, create awareness and sensitization, hence securing a holistic buy-in and product/service patronage across all stakeholder category, **[10]**.

Nigeria is located on a high solar radiation belt, and abundant in solar energy with an average solar irradiation of 2011kWh/m2 per year, **[11]**. Experts conservatively estimate that Solar PV panels placed strategically on just 1% of the large expanse of empty land area that make up most of Northern Nigeria, has the capacity to harness, produce and distribute 207,000 GWh per year. This amount of electric power is equivalent to about 4.6 million barrels of oil per day, **[11].** As earlier stated, Solar PV has over time, developed into a 'mature technology' competent for mainstream electricity generation and distribution. The cost of Photovoltaics has also declined owing to advances in technology and increase in the scale of manufacturing, sophistication levels and demand. The Global PV market is fast growing at about forty times the installed capacity it was ten years ago. According to the International Energy Agency (IEA), Solar PV is currently responsible for contributing at least 1% of electricity generation worldwide. The IEA envisages that solar power will be the world's largest source of electricity by 2050, **[12]**.

Problem Statement

Nigeria needs more than 10 times it current electricity capacity to fully cover and guarantee power supply to its estimated 200 million population. Despite an installed capacity of 13000 megawatts (MW), power generation hovers around 5000 megawatts (MW), [**13**]. With one of the lowest per capita power consumption rates across the world, **[14]**, submits that irregular power supply is the second major challenge affecting over 80% of Nigeria's businesses, after access to finance. Citing World Bank estimates, the author(s) posit that investing in solar powered plants has the capacity to increase electricity availability to about 80 millions Nigeria currently with access to very little to none. According to **[15]**, fuel-powered generators, collectively, provide eight times more power than the national grid in Nigeria, gulping an estimated $14bn a year in purchase and running expenses. **[15],** posit that such a huge amount could be spent more efficiently on more sustainable and clean energy outcomes.

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Addressing Nigeria's electricity challenge will require an extensive overhaul and rehabilitation of the National Grid, especially its faulty power generation architecture which comprise its transmission and distribution lines. The technical, financial, logistics and time implications of such an overhaul will present consequences like increased power outages and downtimes - exacerbating the already deplorable situation. Anticipatory diversification and utilisation of renewable energy sources remains a viable alternative that will help the economy leapfrog these power outages and downtimes as well as other fallouts from a far-reaching overhaul. It is therefore imperative that a process is put in place to harness and optimise these solar energy sources through both on-grid and off-grid solutions. This approach has been adopted by many countries across the globe as they proactively invest into a sustainable, reliable, cleaner and greener energy future.

Demand for solar energy continues to increase as most end users buy into this shift. Falling prices of solar PV technology and the improved capacity of same to capture and retain increasingly more energy, as well as net metering options that enable the feed-back of excess energy into the grid, has made this RET even the more appealing and attractive.

As at 2018, China and the United States of America remained the two leading markets in terms of annual solar PV deployment, both with an annual deployment of 44 GW-DC and 11 GW-DC, respectively, **[16]**. Both countries have remained at the fore front of production and deployment through 2019 to 2020. A case study review of these two countries and their enabling policies remain key to proffering effective recommendations and implementation strategies that would serve as lessons to Nigeria's power challenge.

CASE STUDY REVIEW

United States of America

The desire to substantially reduce Greenhouse gas (GHG) emissions as well as identify more sustainable, environmentally friendly and longer term sources of energy, is among the chief drivers of renewable energy policy formulation and implementation in the United States, **[17]**. Additionally, the nation's increasing reluctance to rely on foreign nations – especially unstable regional states - for oil and gas, is another.

Some of the earliest research in Solar PV technology was conducted in the United States, culminating in the creation of the first silicon solar cell in America. Today, the country has one of the largest Solar PV markets in the world and employs over 242,000 people while generating tens of billions of dollars in economic value. According to the U.S. Office of Energy Efficiency and Renewable Energy, the U.S is abundant in solar energy sources with staggering potential. The Office submit that placing PV panels on 22,000 square miles of the country's total land area, is enough to harness and distribute sufficient electricity power supply to the entire U.S, **[18]**.

Comparative success has been recorded in the US Solar PV market, when placed side by side other western, Asian and Middle Eastern contemporaries. More American states, for example Nevada, Vermont, California, Hawaii and a host of others, have gone above and beyond the 10% limit in

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their respective total electricity generation mix. The industry growth, currently put at 40% promises to continue on the back of increasing solar construction projects - all due to deliberately designed and implemented policies, **[19]**.

Solar PV installations in the country, continues to increase both in the residential and utility-scale markets. In 2018, solar alone generated about 1.5% of U.S. electricity. Same year, solar installations represented 22% of all new electricity generation capacity in America (second to natural gas at 58%), with 2 million residential PV systems installed and covering at least 1.7% of overall households in the country. In 2019, the U.S. emerged the second largest Solar PV market going by annual and cumulative installations. 13.4 GW alone of Solar PV was installed in the same year with a cumulative installation of 74.84 GW, **[19]**. Also, in the year 2019, the percentage of electricity generated by fossil fuels in the U.S dropped from 70% in 2010 to 62% while renewable power generation increased from 10% to 18% within the same period. These progressive growths were majorly driven mainly by enabling Solar PV government policies like Solar Investment Tax Credits which is easily one of the most successful US Federal Government policies encouraging solar power generation, distribution and supply in the country, **[16]**. Accordingly, solar power is more accessible and affordable today in the United States owing to deliberate Federal and State Government policies, designed to incentivize and encourage investments in RETs.

The U.S. Federal and State Governments, provide incentives to subsidise and support the purchase and installation of RET by its citizens. Besides, Government puts in place certain requirements that demand a percentage of electric power sales must come from renewable energy sources. Investment in renewables Research and Development, by the U.S. Department of Energy in collaboration with academics and private tech organisations, also serves to proliferate or further increase RET alternatives as well as available options, hence increasing availability but driving down price, **[20]**.

The United States solar energy development policy decision made at the Federal level sets the context for what happens at the state, local and community levels. It helps guide the two latter levels in deciding strategies that are most effective as it applies to their respective jurisdictions. Accordingly, the American Federal Government has designed and implemented key policies and regulations to help fast track and enhance the deployment of solar energy across states and communities. Additionally, the Government has also invested into key data and research necessary to assist local governments and communities in developing their own specific programs, **[20]**.

The Solar Investment Tax Credit (SITC) - is a U.S. Federal tax incentive designed and enacted into law under the Energy Policy Act 2005, to facilitate and streamline the deployment of solar energy across the country. It has proven to be one of the most important federal policy mechanisms designed to support the growth of solar energy in America. It has also been attributed to causing a 10,000% growth in the US solar industry from 2006 till date. The SITC works such that the tax credit is claimed against the tax liability of solar energy project investors, be they commercial, residential or utility scale. For example, if a homeowner were to purchase a residential solar PV system, the tax credit will be claimed against his or her personal income tax. For commercial or

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utility-scale solar projects, the credit is claimed by the investor or business that owns the system. In terms of amount, SITC is calculated based on the investment capital required to build and complete the energy project. Consequently, the tax credit inadvertently provides for a 'dollar for dollar' reduction in the personal or business income taxes both would otherwise have paid to the Government, **[20], [21]**.

Figure 3: Cost before and after ITC, **[21]**.

The Public Utilities Regulatory Act (PURPA) - is a government policy which has played a critical role in expanding the rate of expansion of solar energy - especially solar PV - across the United States. PURPA is a 1978 Act enacted as a policy intervention in response to the country's energy crisis at the time, to promote the conservation of electricity, improve energy efficiency as well as ensure equitable electricity rates. It continues to deliver on its mandate by ensuring that both residential and commercial utilities purchase power from renewable energy producers - tagged 'qualifying facilities'. Although a federal law, discretionary implementation of PURPA was left to states to implement as they deemed fit, especially with specific regard for the varying availability of renewable energy resources across the respective states. Consequently, while this advantage/benefit was optimised in states with abundant sustainable energy resources, little in terms of implementation was done in states with little resources due to low availability and demand. The Act requires electricity utilities to purchase electric energy from qualifying facilities at a rate that does not exceed the incremental cost to the electric utility, **[20], [21]**.

The Solar Energy Technologies Office (SETO) - funds innovations in solar technologies by supporting proactive research and development to enhance the capacity, performance and reliability of solar technologies. SETO has been designed to achieve its mandate/goals through targeted funding mechanisms that engender improvements in the efficiency of the PV system; enhance grid performance and capacity; reductions in cost of non-hardware installations/set up;

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and subsidy permissions, inspection and training costs. In so doing, obstacles to solar energy development and implementation are greatly reduced, **[20], [21]**.

Beyond federal policies, state governments have also designed and implemented their own respective policies that promote the growth of solar energy and its enabling technology within their immediate constituencies.

The Renewable Electricity Standard (RES) - as state level policy, it requires utilities/electricity suppliers to source a percentage of their energy from sustainable or renewable energy sources such as solar, wind and biomass. This is usually measured as a percentage of the total energy or as a quantity of energy produced in MWh. To meet RES requirements, utilities either develop or generate from renewable energy sources or purchase from third parties. Over twenty nine (29) states, have adopted the RES as an alternative electrification policy, **[20], [21]**.

Net Metering (NM) - is a policy designed specifically to compensate for excess electricity fed into the grid by utility customers from their solar PV systems. It works in such a way that electricity produced by the system is used directly while the excess is conserved in batteries and the remaining sent back into the grid. NM as a process works to provide financial credit to customers who feed back the grid from the excesses generated from their solar PV systems. It is calculated or determined based on the value of electricity not used. In practical terms, billing for NM is calculated thus; the amount of electricity moved out of the grid is netted against that fed back into the grid. If the amount moved out is in excess of that fed in, the customer is billed for the net electricity consumed; while if that fed in is more than that moved out, the customer receives a credit which could be used in offsetting future bill payments. NM has proven a very important tool in helping consumers make savings off their distributed solar investments. As of 2019, forty (40) American states including Washington DC have mandatory NM policies as well as varying state-centric consumer compensation packages, **[20], [21]**.

Peoples' Republic of China

China's solar PV industry has developed rapidly, becoming the largest global PV manufacturer since 2009, as well as shipping over 20,000 MW worth of solar panels over the past 5 years alone, (2015 - 2020). Increasing demand from the world market between 2006 and 2008, served as a push in furthering the growth and expansion of the Chinese PV industry to that of a global competitor. The global financial crisis of 2008, however, greatly affected China's foreign market and exports as her major European and North American clientele embarked on aggressive foreign-import spending cuts in preference for looking inwards and building their own domestic PV manufacturing capabilities and industries. In response, China reduced its dependency on the foreign exports by supporting the growth of its own domestic industry which it had erstwhile ignored. The Government, recognising the need to support this critical industry, introduced a series of policy backed incentives to drive growth, namely - the national Feed in Tariff scheme (FiT) and direct subsidies for solar PV installations amongst others. As a result of these steps, China's domestic solar PV market witnessed steady growth with its cumulative installed capacity going up from 140 MW in 2008 to 300 MW in 2009, 800 MW in 2010 and a massive leap to 3300 MW in

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2011. Particularly, the introduction of FiT in 2011 served as a catalyst in boosting the PV market with installation reaching a record high 2.5 GW. It is pertinent to note that this 2.5 GW represented 9.12% of the world total that same year, **[22]**.

Solar PV development and growth in China is closely tied to the government's deliberately conceptualised and designed policies; like, the 2006 Renewable Energy Law, the late 1990s and early 2000 Brightness and Township Electrification Programme, 2009 Rooftop Subsidy Programme and Golden Sun Development Programme, the 2009 Solar PV Concession Programme, the 2011 National Feed in Tariff (FiT) program, the 2012 Five Year Plan for Renewable Energy Development programme, and the 2012 Free Connection Service Policy, **[22]**. These policies have proven critical to China's Solar PV growth development plan and remains a well laid foundation for the tremendous boost in its Solar PV manufacturing capacity, energy generation, transmission and supply that is currently being witnessed nationally across the Peoples Republic.

The Renewable Energy Law - came into effect in January, 2006 but was amended in 2009. Comprising five key mechanisms, it represents the first national framework for the promotion of renewable energy development in China. The five (5) key mechanisms established by this law are; the national target for the development of renewable energy in China with the objective of ensuring favourable market scales; a mandatory connection and purchase policy by which grid companies are compelled to engage purchase agreements with renewable energy generators to purchase electricity generated as well as providing grid connections services; an on-grid electricity price incentive for all electricity generated from renewables which pays renewable electricity generators a fixed additional amount for each Kilowatt-hour (kWh) of electricity generated; cost sharing mechanism whereby the cost of Renewable Energy generation and grid connections is divided among power utility companies and end users; and the Renewable Energy Development Special Fund which affords or offer additional financial support for research and development for renewables and other relevant pilot projects to ensure rural utilization of renewables, **[22], [23], [24].**

The Brightness and Township Electrification Programme - served as a major driving force for solar PV market expansion in China between the late 1990s and the early 2000s. The aim of the brightness programme was to provide power to over 23 million Chinese without any form of access to electricity in the mostly remote areas of rural China at the time. The Township Electrification Programme (TEP), itself, was designed to meet the domestic needs of residents and public utilities in un-electrified townships in the border regions of Western China. Initiated by China's National Development and Reform Commission (NDRC), 688 towns were targeted for electrification with the construction of 20 MW total installed capacity solar PV power stations. It is noteworthy that the TEP represents the first time the Chinese national government deployed stand alone RETs to address the electricity demands of remote areas outside the national grid coverage. The programme signified a transition from pilots and experiments in the use of RETs to actual implementation and electrification projects that meet the needs of the people, **[22], [24]**.

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The 2009 Rooftop Subsidy and Golden Sun Demonstration Programmes - were both initiated in response to China's trade frictions with Europe and America, for which the Chinese Government sort to boost its domestic solar PV market. In March 2009, the Government's Ministries of Finance, and, Housing and Urban-Rural Development, both pulled together to implement the Solar Roofs program which was designed to provide upfront subsidies for residential and commercial user installations, as well as a 50% subsidy or discount of the bidding price for all critical-component parts suppliers. In July of the same year 2009, the Government's National Energy Administration, and the Ministry of Science and Technology, initiated another subsidy program nationwide - the Golden Sun Demonstration Program - which was designed to support more than 500 MW in solar PV projects, and attained this milestone within two to three years. This program in fully demonstrating China's full determination in incentivising solar PV uptake and adoption, subsidised the total cost of both on-grid and off-grid systems by 50% and 70% respectively. By 2012, both programs put together, having progressed through various phases, had a total capacity of 3423.2 MW, **[22], [25]**.

The Solar PV Concession Program - was initiated by the Chinese Government between 2009 and 2010. It went a long way to increase nationwide enthusiasm, confidence and demand for solar PV systems, as well as triggering a domestic market surge. Under this initiative, public tenders and concessions were offered to prospective bidders. This arrangement saw to the design of 13 solar PV power plants with an aggregate capacity of 280MW. As an additional incentive, the successful bidders were granted the exclusive right to operate these plants for 25 years at an on-grid price. The cumulative effect of these competitive measures and their implementation saw to significant reduction in solar PV electricity price, **[22], [25]**.

The National Feed-in Tariff (FiT) scheme - was introduced by the China National Development and Reform Commission in July 2011, in an effort to boost/incentivise the development of the country's solar power industry, as well as increase the share of solar power in its energy portfolio. The FiT scheme is a direct response to concerns raised by Chinese solar project developers and lenders who had lost out in the aftermath of Europe and U.S. cutting subsidies and reducing their patronage of the Chinese market. The FiT simply put, compensates the developer or end consumer for the excess electricity generated by the solar PV system but not used. It works such that a fee is paid under a net tariff arrangement for any solar energy that is fed into the grid from the PV system. This measure has further encouraged investments, with developers and lenders being incentivised hence boosting overall market confidence in solar PV, **[22]**.

The Five Year Plan for Renewable Energy Development - also regarded as the '12th plan', was conceived by the Chinese government to promote varying forms of solar power development projects that will see to the construction of large on-grid PV stations and other power generation projects in provinces and autonomous regions which have abundant natural solar energy resources and unutilised large expanse of land to place panels and mini-grids, **[22], [27], [28], [29].**

The Free Connection Service Policy - was established pursuant to the '12th plan' and in response to the Chinese government's call seeking local patronage and support for its domestic solar PV

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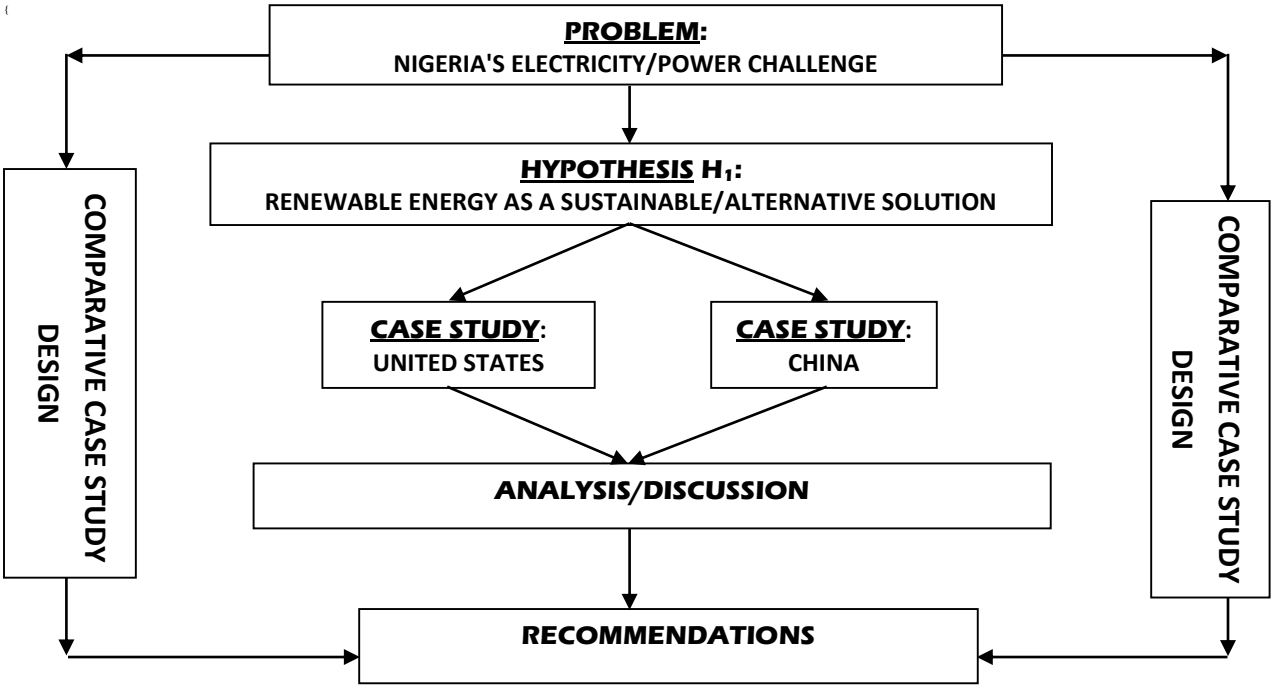
industry in the aftermath of investment pullout by Europe and the U.S. The concept behind this strategy entailed the State Grid Corporation of China (SGCC), providing free connection services, equipment testing, and integration plan development services, among others to incentivise solar PV electricity producers located close to customers, **[22], [29]**.

METHODOLOGY

Research methodology, is, 'a systematic and orderly approach taken towards the collection and analysis of data so that information can be obtained from those data', **[30].** The methodology adopted is chosen because it proves to be the best alternative in aiding the realisation of objectives, and adequately providing the most effective means through which the paper's hypothesis are tested and verified as figuratively illustrated below.



This research design is adopted to investigate, "what is happening, gain new insights, assess phenomena, ask questions and clarify understanding of a problem" – **[31]**. Through literature and case study reviews, this paper investigates how select countries (U.S and China) have successfully diversified, harnessed and implemented solar PV energy solutions using select policies and implementation strategies. In so doing the paper has verified 'what is happening' in the solar PV sector in these countries, 'gained new insights' from the solar PV capacity installation strategies adopted by these countries, while equally 'clarifying understanding' around the peculiarities of Nigeria's power challenge vis-avis that of the countries under study. Secondary data for this research were obtained through a review of journal papers and articles.

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ANALYSIS/DISCUSSION

Enabling policies are central and fundamental in guiding any process that guarantees the successful implementation of reforms, and attainment of targeted outcomes as envisaged. In this case, impacting Nigeria's electricity deficit and the consequent challenge it poses to the economy, can only be addressed through the mechanism of carefully conceptualised, designed and implemented policies that serve as guiding frameworks. These frameworks drive the achievement of rational outcomes which simply put, is the robust generation and equitable distribution of electric power that sufficiently caters for the domestic (residential), commercial (industrial), infrastructural and other socio-economic needs of the Nigerian state.

A case study review of enabling solar PV policies - designed and implemented by US/China - which proved instrumental to the progress both countries are making in grid/off-grid power generation, is therefore justifiable especially if juxtaposed with the view to evaluating, analysing and recommending them as viable policy-framework solutions to the peculiar Nigerian challenge. The US, driven by the desire to substantially reduce GHG and tap into more sustainable clean energy sources, has in the course of this drive, formulated practical policies that serve to enable and incentivise a systemic and infrastructural roll-out in America. China, on its part, was originally driven by its governments perception of solar PV manufacture and expertise export as a major income earner and an economic/tech leverage on the global stage. It is evident, that as global electricity demand increases, governments are diversifying, hence designing and implementing enabling policies to scale up and optimise the use of RETs as viable alternatives.

This case study review of both US and China reveals would-be potential barriers to solar PV deployment in the Nigerian scenario such as market uncertainty driven by inconsistent policy signals from federal and state governments; bottlenecks created by regulatory and permitting processes that are time consuming and restrictive; grid integration challenges; poor orientation and sensitization hence poor awareness and buy-in by potential consumers; perceived high cost of RETs; lack of supportive subsidies and affordable financing; and the lack of competent capacity and technically skilled manpower needed to facilitate system design and fabrication of solar pv technology, as well as requisite know-how for RET installation, operation, service and maintenance.

A synthesis of both case studies has thrown forward the following enabling solar PV policies. These synergy of policies deployed by both countries, have culminated in the development of solar PV technology for alternative electricity production, as well as securing full stakeholder buy-in. Accordingly, on analysis and discussion, these enabling policies are recommended to aid in achieving far reaching interventions towards mitigating Nigeria's electricity challenge amidst its distinct peculiarities. It is also within this wider context, that a preponderant number of policy makers, worldwide, are seeking to learn from successful deployment and implementation approaches across the globe.

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Accordingly, and within the context of enabling US/China polices reviewed, the Nigerian government can draw from these in developing sustainable energy policies that would diversify electricity generation and supply, improve energy security as well as expand energy access.

The **Renewable Electricity Standards (RES)** can be implemented as a Nigerian policy with a regulatory mandate requiring a specific amount of electricity either sold or generated, must come from Solar PV technology. Also known as 'solar set-asides', this strategy will ensure competitive targets that drive an upscale in solar investments, infrastructure and energy generated and supplied there-of. The RES also incorporates a compliance and cost control mechanism that would balance the cost and benefits of compliance, ensuring that the consumer and local economy suffers no disadvantage as a result of such a mandatory regulation. Part of the RES policy will comprise a renewable energy credit system that would foster an energy generation and accountability framework that is accurate and efficient, which is very crucial for a fledgling Nigerian market. A Nigeria-specific RES should require that electricity providers generate a workable percentage of energy from Solar PV, as well as a levy fines on them for non-compliance on a monthly, quarterly or annual basis. A **Feed-in Tariff** represents another viable policy that would enable an increase in the deployment of RET in the Nigeria. It boosts investor confidence and provides a high level of market certainty for producers/developers. Simply put, fixed electricity prices would be paid to solar PV electricity producers for each unit produced and injected into the electricity grid. The payment of the FIT is guaranteed for a certain period of time usually 15 to 20 years. **Net Metering (NM)** can also be initiated as a tariff based policy that would help determine the value of excess electricity returned to the grid in favour of compensating the consumer. Implemented in the Nigerian scenario, the consumer's private or commercial power production via their Solar PV system(s) would be subtracted from their power usage from the grid, the difference will be reconciled by both parties either in credit or in deficit depending on amount of electricity produced or consumed as they case may be respectively. A well designed and implemented net-metering policy supported by simplified interconnection standards would prove effective in supporting this aspect of Nigeria's envisaged distributed solar electricity market. NM in Nigeria, has the prospects and capacity to incentivise and drive more buy-in, public support and investment into Solar PV as a viable electricity alternative, in that consumers can own small scale renewable energy technologies with which they can produce electricity both for their domestic/commercial use as well as get paid for excess feedback to the grid. NM policy would inadvertently create a value stream that is supportive of and boosts the economy in the medium and long term.

A Nigerian-state policy designed after the **US PURPA Act** would serve to improve energy efficiency, electricity conservation as well as ensure equitable electricity rates. Such an Act of parliament on becoming a policy would require that residential, commercial and government utilities purchase electricity from renewable energy developers aiding in no small way in facilitating the nation's overall solar deployment, patronage as well as sending out consistent short, medium and long term policy signals on where the government stands. The **Solar Investment Tax Credit Policy** has proven very popular in the US, and has been credited for being a major plank in supporting America's ongoing transition to a renewable energy economy, so much so that

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the US Congress has extended its expiry date multiple times from its inception as part of the Energy Policy Act of 2005 till date. SITC can be designed in the Nigerian context to facilitate and incentivise the deployment of solar energy and technology across the country. The Federal Government on consultation with prospective energy producers and the private sector, can fix a percentage on which the total cost of system purchase and installation (commercial and residential), can be deducted, hence a 'naira for naira' benefit in the income taxes a private individual or commercial developer would otherwise have paid the federal government. As a back up to this, Custom duty waivers can be introduced at the ports to encourage and fast track importation of RETs into the country with minimal bottleneck and government bureaucracy.

From the China and US case study reviews, it is clear sustainable energy projects need legal authority to connect to the grid; hence interconnection standards will ensure RETs meet fixed technical requirements and connection specification as a pre-requisite to grid interconnection. An enabling **interconnection standards** policy would primarily help framework in detail the conditions under which Solar PV power developers in Nigeria can connect to the national grid. This is very important in ensuring grid reliability vis a vis its critical support in boosting the distributed solar electricity market. For an interconnection standards policy to be effective in Nigeria, it will have to ensure standardised and uniform interconnection across board, as well as appropriate capacity limits. To further incentivise this process, the Government can adopt a similar model to the Chinese Free Connection Service policy whereby developers are offered free grid inter-connection services, equipment installation and testing, and integration plan development services.

The **Brightness and Township Electrification Programme** remains a policy that served as a bedrock for massive solar PV expansion in China with the goal of providing electricity to over 23 million Chinese without any form of connection to the grid at the time. A Nigeria-centric policy fashioned after this, can be designed through a strategy that deploys stand-alone RETs like roof-top solar panels, and installed capacity solar power stations to remote areas without grid connection. The **Rooftop Subsidy Programme** is a good complementary and support policy to the former, in that government subsidised RETs will serve as an incentive that would fast-track consumer buy-in and large-scale nationwide uptake especially in areas without grid connection. This paper acknowledges the incumbent Nigerian Federal Government's similar efforts in this regard which was recently announced by Vice President Yemi Osinbajo as a solar power project designed to electrify 5 million homes, give 25 million Nigerians access to clean energy by 2030, as well as create 250,000 jobs in the process, **[32]**. However, rolling out such an ambitious project cannot be done in isolation, it has to be guided and frame-worked through the instrumentality of enabling policies that would serve primarily as a foundation for takeoff, and as a supportive, institutionalised and workable system for project implementation, operational efficiency, and service delivery.

A national solar energy research and development (R&D) office similar to the **US SETO**, should be established in Nigeria and dedicated to oversee research into solar technologies and other related

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renewable energy innovations. This would put the country on the path of RET manufacturing, operational and maintenance capacity, as well as engendering the technical know-how for local manpower skill acquisition and performance in this regard. This has proven a huge local boost and global economic leverage for China.

Policy Recommendations

1. Federal Ministry of Power should partner the National Assembly and Private Sector in designing and developing a regulatory Renewable Energy Standard (RES) or Renewable Energy Law that mandates all stakeholders to source a fixed amount of electricity from Solar PV RETs (Grid and Offgrid). Policy mandate should be overseen and enforced by the Nigerian Electricity Regulatory Commission (NERC) and Nigerian Bulk Electricity Trading (NBET), for maximum compliance and output.

2.Federal Government through the Federal Ministries of Power; Science, Technology and Innovation; and Education should partner in designing and developing a robust curriculum and manpower training capacity for the development of local technical skills and know-how required to effectively manage, operate and maintain solar RETs. This will aid in blocking the increasing gap and shortage of qualified personnel. Trained manpower with requisite capacity is a core pre-requisite for a successful advocacy and rollout nationwide.

3.The Federal Government through the Federal Ministries of Power, and Finance, should partner the private sector in developing a viable national solar Feed-in Tariff scheme. An enabling national FiT policy for the Nigerian Solar PV industry engenders a mechanism that amongst other things - helps accelerate investment in Solar PV RETs through long term contract to developers/producers that offers them cost-based compensation, price certainty and guaranteed purchase of their electricity by electric utilities nationwide. It is a 'win-win' for both government and investor, and helps resolve the cost barrier involved in introducing Solar PV into the market. Accordingly, Federal Government should ensure a Net Metering policy that effectively complements the FiT as well as ensures a commensurate benefit to the developer/producer.

4.Federal Government through the Federal Ministry of Power, and Finance, should partner prospective private sector investors, solar PV energy producers and other key sector practitioners in designing a Nigeria-centric Solar Investment Tax Credit Policy that would facilitate large scale deployment of RETs through the instrumentality of deductible tax credits. FG, through the Federal Ministry of Finance and Nigeria Custom Service (NCS) should also design and implement a five year duty waiver (in the first instance), for all Solar PV RETs import into the country.

5.Federal Government should formulate an interconnection standards policy that would guide the entire process through which Nigerian solar PV electricity producers can connect the national grid in a standardised and uniform manner across board, and within appropriate capacity limits. To further incentivise the process, FG can implement a free connection service policy for a five year period, whereby producers are offered free grid inter-connection, equipment installation/testing, and integration plan development services, respectively. The Rural Electrification Agency (REA), Transmission Company of Nigeria (TCN), Electricity Distribution Companies (DisCos) and Generation Companies (GenCos) should be tasked with the mandate to partner its delivery.

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6.Federal Government, through the Federal Ministry of Finance and Central Bank of Nigeria (CBN), to partner financial sector (Banks and Micro-finance Institutions), in developing finance models and subsidy arrangements that would allow low to medium income earners to access RETs at affordable rates or through staggered payment plans. Government policy involvement in this regard will help get rid of unfavourable finance/collateral requirements usually set by banks to the detriment of prospective investors/consumers.

7.Federal Government should prioritise the establishment of RET finance schemes e.g. establishing a National Fund for Solar PV projects can provide a mechanism through which fossil fuels can be taxed and the proceeds used in developing the renewable energy industry, funding its electrification projects and its enabling private and public sector agencies. Proceeds can also be channeled into funding policies similar to the Chinese Brightness and Township Electrification and Rooftop Subsidy Program, which target the mass installation of standalone rooftop panels. Successful implementation of this policy makes a case or justification for successfully approaching major bilateral and multilateral donors for further access of developmental funding.

8.Federal Government through the Federal Ministry of Information and Culture (FMIC), and the National Orientation Agency (NOA) should immediately commence extensive public enlightenment and sensitisation campaigns on Solar PV and its benefits as an alternative and sustainable source of energy, especially in the rural out-of-grid areas.

9.Federal Government through the Federal Ministries of Power; Education; and Science Technology and Innovation, should make robust budgetary provisions for Solar PV Research and Development so as to fund further innovations in capacity enhancement, performance and reliability of solar RETs.

CONCLUSION

Nigeria's energy policy for the past ten years has always harped on the need and importance of a renewable energy and energy efficiency policy (REEEP); however the country is yet to move towards implementing a centric policy which encapsulates tied mandates, regulatory enforcements, allocated responsibilities, real-time targets and realistic implementation time-lines. Consequently, key partners in the supposed implementation and realisation of Nigeria's REEEP are not fully equipped, neither fully accountable to what should be a measured and coordinated policy implementation. Policy articulation and design with an enabling framework, is a key step in moving forward, however, a case-study of workable policies to strengthen conceptualisation and implementation is a core and important strategic step.

The challenge posed by Nigeria's electricity deficit can be mitigated if measures that impact at its very root are effectively implemented. These measures, presented as enabling policies are core foundational catalysts that would guide and drive these strategies. Consequently, the evaluation of policies that have proven workable and successful in the US and China is justifiable if these policies can be properly situated and applied in the Nigerian context. Enabling Solar PV policies

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must be sufficient and substantial enough to elicit demand, as well as influence market transformation; they must be clearly defined and unambiguous to encourage a broad range of key investors and market participants to easily assess risk, evaluate finance options and make informed investment decisions. Policy stability is key to fostering sustained growth in the immediate Solar PV market and must endure for a long time-tenure to attract large-scale investment and development. Policy must ensure sound technical, administration and regulatory standards for grid and off-grid connections of Solar RETs.

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