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HIGH-IMPACT OPTIONS FOR A RENEWABLE ENERGY CLEAN ENVIRONMENT AND HEALTHY NIGERIAN ECONOMY

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ABSTRACT

High-impact renewable energy is the most rapidly expanding energy source globally. Despite its subordinate status in Nigeria relative to conventional energy sectors, our principal trading partners and numerous prominent multinationals are allocating hundreds of millions of dollars towards high-impact renewable energy in anticipation of forthcoming transformations in global energy markets. As Nigeria deliberates on strategies to combat climate change, the nation's high-impact renewable energy sectors aim to guarantee that Nigerians have access to all available options. Consequently, they have united to develop alternatives for a pristine environment and a robust Nigerian economy. This study acknowledges the absence of a singular answer to climate change and delineates a crucial array of actions that, in conjunction with additional strategies, would enable Nigeria to attain its long-term economic and environmental objectives.

This study emphasises the opportunities linked to Nigeria's substantial renewable energy resources. These are renewable resources that are renewed by the Earth's natural cycles and exert little effects on the environment and human health. They encompass wind, solar, geothermal energy, run-of-river hydroelectricity, and sustainable biomass fuels. These resources can substitute fossil fuels in various domains, including power generation and space and water heating. Fuel cells, while not a renewable resource alone, represent a promising technology that, when integrated with renewable sources, can provide diverse and impactful electricity. The paper also delineates prospects linked to the augmented utilisation of passive renewable energy and energy efficiency in structures.

This paper further delineates three principal strategies for Nigeria to establish a high-impact

renewable energy sector and their prospective contributions to mitigating the nation's greenhouse gas emissions. They are specifically a) fostering the establishment of a high-impact renewable electricity market (4.1 Mt), b) promoting the utilisation of consumer-oriented renewable energy technologies, and c) advocating for enhanced passive renewable energy and efficiency measures. A set of complimentary measurements was established for each of these possibilities. The initiatives outlined in this paper if well and promptly executed will diminish future costs associated with addressing climate change by enhancing Nigeria's capacity to mitigate and prevent emissions proactively.

1. INTRODUCTION

Solar energy can be directly harnessed through several devices. Solar thermal technologies transform solar energy into thermal energy for the purpose of heating water and air. Applications encompass solar water heating systems and solar walls for extensive space heating. The expenses associated with most solar thermal solutions are readily recouped by fuel savings over their operational lifespan. Photovoltaics (PV) transform solar energy into electrical power. Photovoltaic technology yields operational cost reductions in numerous on-grid and off-grid applications. In recent years, the global yearly growth rate for photovoltaic sales has exceeded 25%. Passive solar employs architectural strategies to harness and retain solar energy for temperature control in residential and commercial structures.

Wind energy is the most rapidly expanding energy source globally and has experienced cost reductions exceeding 50% in the past decade. Wind turbines harness wind energy and convert it into electricity. They are available in various sizes, and numerous European manufacturers are currently producing individual wind turbines sufficiently large to supply electricity for over 500 houses.

Earth energy refers to solar energy that is absorbed by the Earth and stored a few meters beneath the surface. This free energy can be harnessed and enhanced to beneficial temperatures with a ground-source heat pump. This heat can subsequently be supplied as hot air or water for home or commercial space heating. The procedure can likewise be inverted for air-conditioning. In numerous instances, the expenses associated with geothermal energy systems are readily recouped through fuel savings over the technology's lifespan.

Run-of-river hydroelectricity employs a turbine to produce electricity from naturally flowing water, without the construction of a dam for water storage expressly intended for power generation. Run-of-river hydro power is economically viable in the long term and can generate substantial electricity when situated near the electricity demand. Micro and mini-hydro technologies, utilising free-flowing water, are frequently cost-effective for small-scale generating in rural or distant areas.

Biomass fuels are derived from diverse agricultural crops, wood, and agricultural byproducts. Ethanol exemplifies a biomass fuel that is frequently utilised as a petrol additive. Most vehicles may utilise gasoline with a significantly higher ethanol concentration without compromising performance, whilst diminishing hazardous emissions.

This study emphasises the prospects linked to Nigeria's substantial renewable energy resources. These are renewable resources that are renewed by the earth's natural cycles and exert little effects on the environment and human health. They encompass wind, solar, geothermal energy, run-of-river hydroelectricity, and sustainable biomass fuels. These resources can substitute fossil fuels in various domains, including power generation and space and water heating. Fuel

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This paper further delineates three principal strategies for Nigeria to establish a high-impact renewable energy sector and their prospective contributions to mitigating the nation's greenhouse gas emissions. They are specifically a) fostering the establishment of a high-impact renewable electricity market (4.1 Mt), b) promoting the utilisation of consumer-oriented renewable energy technologies, and c) advocating for enhanced passive renewable energy and efficiency measures. A set of complimentary measurements was established for each of these possibilities.

2. LITERATURE REVIEW

In recent years, the 'energy question' has increasingly taken precedence over other choices, strategies, and policies related to human survival and progress. Contemporary societies heavily rely on dependable, cost-effective, and sustainable energy sources. Energy is a needed input for the majority of production processes and economic activities, as well as a fundamental aspect of daily life. Enhanced access to contemporary energy services is essential for social and economic advancement (Oyedepo, 2014a).

Currently, the bulk of global energy supplies are sourced from fossil fuels (including natural gas, oil, and coal), resulting in the ongoing depletion of these resources and causing detrimental environmental effects. Numerous individuals are apprehensive about these issues and seek to urgently mitigate the symptoms; nonetheless, not all comprehend the fundamental causes and, therefore, fail to recognise that both technology and social transformations are necessary. It is now universally recognised that renewable energy capacity must be augmented by harnessing its vast potential (Lorenzini et al., 2010). Therefore, the advancement and implementation of clean, renewable energy is essential for the economic and environmental welfare of any nation. Renewable energy is crucial for fulfilling future energy requirements and attaining sustainability. Nonetheless, its proliferation and implementation have been sluggish over the past decade due to diminished fossil fuel prices and obstacles within the energy industry. Stringent methodologies are essential to expedite the advancement and application of renewable energy, hence enhancing its role in the existing energy supply compositions (Nnaji et al., 2010).

The necessity for emerging nations to improve their renewable energy initiatives will create economic prospects for trade-oriented cities. The utilisation of renewable energy in developing nations such as Nigeria is now somewhat restricted, despite the belief in its considerable potential (Oyedepo, 2012a).

Owing to numerous financial and technical limitations, renewable energy remains underutilised in Nigeria. Nigeria remains significantly reliant on fossil fuels. The adverse effects on the environment and the economic strain resulting from the inefficient utilisation of fossil fuels must be mitigated by the implementation of suitable technology, national energy policies, and management strategies. Nevertheless, social and economic growth, together with poverty alleviation, are the paramount concerns of Nigeria. Renewable energy (RE) sources could fulfil the energy demands necessary for the urgent socioeconomic development of this country. Therefore, to advance renewable energy technologies (RETs) in Nigeria, more efficient and adaptive policies are necessary to address the immediate demands of the populace.

An energy-poor country is characterised by its residents' inability to access electricity sufficient to fulfil fundamental need, like lighting and cooking. A significant portion of the population in developing nations, such as Nigeria, is adversely impacted by their minimal energy usage, while others rely on polluting fuels or invest excessive time procuring fuel to satisfy their fundamental necessities (Emodi and Boo, 2015). The Energy Poverty Action Initiative of the World Economic Forum (IEA, 2007) states, "Access to energy is essential for enhancing quality of life and is a critical requirement for economic development." Inadequate access to electricity in Nigeria evidently results in heightened poverty, subpar economic performance, restricted employment opportunities, and challenging possibilities for institutional development. The rapid population expansion signifies that the nation's energy need will persistently escalate, akin to the substantial rise in energy demand prompted by the worldwide population surge and industrial revolution of the 20th century (Mohammeda, 2013). The energy crisis in Nigeria has significantly impacted public electricity consumers. This scenario has unequivocally forced most households in both rural and urban areas of the country to heavily rely on combustible renewable energy sources, particularly for domestic heating and cooking. Fuelwood and charcoal are prevalent energy sources frequently utilised in Nigeria. Universally accessible energy services, characterised by renewable resources that are sufficient, economical, dependable, high-quality, safe, and environmentally friendly, are essential for sustainable development and poverty alleviation in the nation.

The primary aims of this study are to: (i) evaluate energy resources in Nigeria and the current state of the power sector; (ii) examine the potential and utilisation of renewable energy sources (solar, wind, small hydro, and biomass) in Nigeria; (iii) analyse the factors hindering the development of renewable energy technologies in Nigeria; and (iv) assess the roles of decentralised renewable energy systems in achieving sustainable energy in Nigeria. Electricity, being a vital resource for contemporary society, is crucial for future societal growth. This commodity must be delivered consistently to meet everyday demands. The performance and efficiency of the power generation industry are crucial for ensuring a quality and reliable electricity supply. Uninterrupted access to high-quality energy infrastructure is crucial for enduring economic growth and development. The insufficient supply of power might hinder the development of industries, small enterprises, hospitals, and the installation of other infrastructure facilities in both urban and rural areas (Oyedepo et al., 2012).

The power sector is a fundamental component of global economic development; its advancement relies on aligning quality with energy services, since this is the sole method to provide a foundation for stable and robust economic growth. The Ministry of Economy (2002) asserts that the power sector is a vital component of a country's economic activity, serving as a dynamic factor and possessing unquestionable strategic significance for other sectors of the economy. Consequently, the provision of power under ideal conditions of security, quality, and cost must remain an unwavering priority in the formulation of a nation's energy policy.

One method to address the increasing energy demand in a developing nation such as Nigeria is to establish an appropriate and sustainable power generation system. Nigeria's electricity sector is facing significant issues due to outdated equipment, insufficient generation and transmission capacities, and elevated aggregate technical and commercial losses. These difficulties arise from years of neglect, mismanagement, and insufficient finance. The issues intensified due to a substantial surge in electricity demand stemming from economic and demographic expansion.

The electrical grid is inconsistent and inadequate to satisfy increasing demand, leading to recurrent load-shedding and other disruptions. This has also restricted the bulk of Nigerians' access to clean and modern energy services. Furthermore, the erratic nature of the country's electrical supply has led to extensive self-generation of power from alternative sources in Nigeria; the affluent predominantly depend on generators, resulting in a 75% rise in the consumption of petroleum products in 2012 (Udoudoh and Umoren, 2015).

Approximately 62% of Nigerians depend on wood fuel for their energy requirements due to insufficient power, leading to significant deforestation in the nation (Babanyara and Saleh, 2010; Eleri et al, 2012; Zubairu et al., 2015). The reliance on firewood presents a significant indoor pollution risk and resulted in about 79,000 fatalities in Nigeria due to smoke inhalation in 2011 (Eleri and Onuvae, 2011). A 2013 research by the World Health Organisation indicated that smoke inhalation from firewood used by women resulted in 98,000 fatalities (Emodi and Boo, 2015).

In the past decade, the Nigerian power sector has pursued optimal strategies to enhance power availability in the nation. In 2005, the federal government initiated a series of extensive programs for electricity reform. The National Electric Power Authority (NEPA), the exclusive electricity provider, was succeeded by the Power Holding Company of Nigeria (PHCN), which was divided into six generation companies (GenCos), eleven distribution companies (DisCos), and the Transmission Company of Nigeria (TCN) (Wijeratne and Omontuemhen, 2016). The National Assembly enacted the Electric Power Sector Reform Act in 2005, leading to the inauguration of the Nigerian Electricity Regulatory Commission (NERC) on November 1, 2005, tasked exclusively with regulating power sector activities, including tariff structures (Okafor, 2017). The Rural Electrification Agency (REA), an autonomous entity, was established to monitor advancements and ensure transparency in the power sector. Initiatives were implemented to diversify the power sector through agreements for investments in hydropower, nuclear energy, and various renewable energy sources. In 2010, a Roadmap for Power Sector Reform was established, privatising the generating and distribution businesses, although the transmission of power remained under state ownership. The Nigeria Bulk Electricity Trading Plc (NBET) was established to engage in the procurement and resale of electric power and ancillary services from independent power producers and successor generation firms (Idemudia and Nordstrom, 2016).

The primary aim of the power sector reform is to establish an electricity supply business in Nigeria that adequately fulfils the requirements of its population in the twenty-first century. Others want to modernise and enhance electricity access while fostering national, economic, and social growth (ECN, 2014). Regrettably, despite the commitment of both public and private sectors to enhance the power ecosystem through investment, heightened competitiveness, and deregulation since the initiation of the reform process in 2010, there has been no substantial advancement in the power sector. The fundamental issue of inadequate power persists unresolved, with minimal prospects for improvement, while prices continue to escalate. Nigeria's electricity infrastructure capabilities still have a considerable distance to cover to match those of other growing economies. The primary emphasis must be on eliminating or at least mitigating the principal obstacles to the generation, transmission, and distribution of power across the nation.

3. THREE PRINCIPAL OPTIONS RECOGNISED BY NIGERIA'S HIGH-IMPACT RENEWABLE ENERGY SECTOR

Three principal choices identified by Nigeria's high-impact renewable energy sector and their potential contributions to mitigating the nation's greenhouse gas emissions are as follows. A series of complimentary measures has been formulated for each of these alternatives.

3.1 Fostering the Advancement of a High-Impact Renewable Electricity Market (4.1 Mt)

a) Consumer information regarding power items (enabling measure);
b) Market-wide incentives for high-impact generation (consumer credit, production credit, Renewable Portfolio Standards);
c) Acquisition of green power (0.4 Mt);
d) Elimination of tax impediments to renewable energy generation (1.4 Mt);

3.2 Facilitate the Adoption of Consumer-Oriented Renewable Technologies

a) Net metering (0.1 Mt);
b) Consumer credit for rural renewable electricity generation (0.5 Mt);
c) Partnership between municipalities and the federal government for 50,000 solar rooftops (0.4 Mt);
d) Expedited funding for on-site renewable energy and water heating (2.0 Mt);
e) Minimum biomass fuel content in petrol (3.1 million tonnes).

3.3 Promote Enhanced Utilisation of Passive Renewable Energy and Energy Efficiency (3.2 Mt)

a) Low-cost loan for R-2000 residences (0.5 Mt);
b) Low-interest loans or tax incentives for household energy-efficient retrofits (1.4 Mt).

Significant insights can be gleaned from industries that include renewable energy sources into their operational frameworks. The subsequent are essential lessons that others may derive:

a) The current technology can substantially aid Nigeria in fulfilling its carbon reduction obligations. Although focused R&D expenditure is essential for certain technologies, the immediate emphasis should be on cultivating and advancing the markets for clean technologies that are currently exhibiting significant market share gains in other nations.
b) The strategies for addressing climate change may yield a net economic advantage for Nigeria. Numerous measures delineated in this document are classified as "no-regrets" solutions, indicating that ancillary advantages such as job creation and diminished healthcare expenditures warrant their execution irrespective of their capacity to mitigate GHG emissions.
c) The sooner Nigeria adopts strategies to address climate change, the more advantageous the outcomes for its citizens.

4. THE IMMINENT ENERGY REVOLUTION

The world is poised for an energy revolution. Shell International's evaluation of worldwide trends suggests that substantial market transformations will transpire in the energy sector during the forthcoming decades. Both Shell and BP-Amoco have declared their intention to invest hundreds of millions of dollars to position themselves for a market where they anticipate renewable energy would account for 5%-10% of the global energy supply by 2020 and 50% by 2050.

In an article entitled "The Future of Energy," The Economist posits that the swift reduction in renewable energy costs may compel the formidable $1 trillion per annum fossil fuel industry to recede early in the next century. 2 The report states that wind energy is nearing price parity

with fossil fuels, with costs approximately 50% of their 1990 levels. In contrast, the paper predicts a dismal future for nuclear and large hydro energy, despite the fact that governments in most industrialised nations continue to allocate a disproportionately larger share of their energy research and development funds to nuclear compared to renewables.

Although several stakeholders in Nigeria's fossil-fuel sector caution that the necessary actions to combat climate change may result in economic catastrophe, numerous others contend that these steps will generate opportunities. Michael Porter and Claas van der Linde assert in their essay "Green and Competitive" in the Harvard Business Review that pollution results from inefficiency, and well-crafted environmental legislation can stimulate innovation and reduce costs. Three The authors assert that "managers must begin to perceive environmental enhancement as an economic opportunity" and that "resisting innovation will result in a decline in competitiveness in the contemporary global economy."

These arguments pertain not alone to corporations, but also to nations. Countries such as the U.S., Britain, Japan, and Germany are either in the midst of enacting or have already enacted robust regulatory measures to promote the growth of domestic renewable energy markets. Nigeria, however, has made what could be charitably termed as "incremental progress" in its preparations for the impending energy revolution.

Nigerians face a decision to make. We can capitalise on the impending energy revolution and establish early-mover advantages in both our economy and environment. Alternatively, we may persist in permitting our economic liabilities and social costs to escalate, subsequently importing climate change solutions at a significantly elevated cost in the future.

5. THE HEALTH BENEFITS OF RENEWABLE ENERGY

The fossil fuel emissions that most significantly affect human health include nitrogen oxides (NO_x), sulphur dioxide (SO_2), and particulate matter (PM). Recent studies reveal that roughly 1 in 13 non-traumatic fatalities in Nigerian cities is attributable to air pollution resulting from fossil fuel combustion. Four This incurs substantial expenses for Nigerians and the Nigerian healthcare system.

Renewable energy sources can deliver cleaner electricity, mitigating climate change and offering more affordable energy to all. However, are you aware that renewable energy also offers considerable health advantages? The World Health Organisation (WHO) reports that around 99% of the global population inhales air daily that fails to comply with WHO air quality criteria, hence jeopardising their health. Renewable energy sources such as wind and solar can enhance air quality and mitigate health hazards for the global population. Mitigating greenhouse gas emissions benefits not just the environment but also human health. Renewable energy benefits contribute to enhanced health through improved air quality and diminished sickness risk. What are the advantages of renewable energy? We examine the potential of renewable energy sources to enhance public health by mitigating pollution. Recent studies indicate that approximately 1 out of every 13 non-traumatic deaths occurring in Nigerian cities can be attributed to air pollution from the burning of fossil fuels.4

5.1 Diminished Risk of Respiratory Ailments

The combustion of fossil fuels significantly contributes to health-related concerns due to the emission of detrimental gases such as nitrogen oxide, sulphur dioxide, and carbon dioxide. These gases can induce respiratory ailments such as asthma and may aggravate these conditions, resulting in hospitalisation. Utilising renewable energy sources in lieu of fossil fuels

diminishes the emission of these gases into the atmosphere, potentially mitigating respiratory ailments and reducing the risk of exacerbating the conditions of individuals already afflicted. Enhancing indoor air quality is achievable by retrofitting your residence to increase efficiency and establish a cleaner domestic atmosphere.

5.2 Reduced Incidence of Myocardial Infarctions and Cardiovascular Disorders

Besides respiratory ailments, the combustion of fossil fuels, such as coal, exacerbates other health concerns, including heightened risk of myocardial infarction and cardiovascular disorders. A significant advantage of renewable resources is enhanced air quality and a reduction in environmental contaminants, which may mitigate the incidence of cardiovascular diseases in the populace.

5.3 Reduced Health Care Expenditures

The health problems linked to fossil fuels significantly burden the Nigerian economy. In 2011, Dr. Paul Epstein, Associate Director of the Centre for Health and the Global Environment at Harvard Medical School, published a report in the Annals of the New York Academy of Sciences estimating the health impacts of fossil fuels to be between $345.3 billion and $543.3 billion. Shifting from fossil fuel combustion to renewable energy sources might yield substantial financial savings for the nation and enhance public health outcomes. In addition to significant economic advantages, renewable energy offers personal financial enhancements through incentives such as solar tax credits and rebates.

5.4 Enhanced Air Purity and Improved Air Quality

Improved air quality in our surroundings correlates with enhanced health. Subpar air quality leads to respiratory disorders, cardiovascular diseases, neurological complications, cancer, and diminished life expectancy. A primary advantage of clean energy is the enhancement of air quality, which diminishes the likelihood of health issues.

5.5 Reduced Contamination in Water Supply

Fossil fuels not only contaminate the atmosphere but also use and degrade substantial quantities of the water supply, hence restricting resources available for potable water and essential sectors such as agriculture. One advantage of wind energy and other renewable sources, such as solar, is their minimal water requirement for operation, which may alleviate water scarcity concerns and enhance water quality.

5.6 Enhanced Quality of Life

Although decreasing fossil fuel consumption would not eradicate current health conditions, it can enhance the quality of life for individuals afflicted with asthma and other respiratory ailments. The advantages of renewable resources also encompass enhanced quality of life and increased longevity by diminishing the prevalence of several diseases through the establishment of a cleaner environment and atmosphere.

5.7 Diminished Risk and Incidence of Cancer

Reduced contaminants in the air and water result in diminished exposure to deleterious gases and fine particles that may cause severe and potentially fatal diseases like as cancer. Individuals residing in regions with lower pollution levels experience a diminished risk of developing these diseases, which constitutes one of the primary health advantages of renewable energy.

5.8 Extended, Healthier Lifespans

Besides enhancing mental and emotional well-being, renewable energy sources can contribute

to longer, healthier lives. These sources may mitigate the risk of physical health problems associated with air and water pollution, alleviate fuel scarcity, and lessen financial burdens on more disadvantaged communities.

5.9 Enhance Mental and Emotional Well-Being

Nonrenewable energy sources are finite and might result in "fuel scarcity." Limited resources induce financial strain and stress, potentially resulting in mental, emotional, and physical health difficulties. Moreover, inadequate air quality linked to nonrenewable energy sources, particularly coal, may adversely affect both physical and mental health. Renewable energy sources may mitigate some of these problems. One significant health benefit of solar energy and other renewable sources is enhanced mental and emotional stability for all, alongside the establishment of a cleaner, healthier environment. Investigate solar energy and its comparison to fossil fuels.

5.10 Mitigate Neurological Injury

The combustion of fossil fuels such as coal results in air and water pollution, which is associated with numerous severe health problems, including neurological impairment. Clean energy methods, such as solar and wind power, do not generate the air and water pollution associated with nonrenewable energy sources, hence mitigating the risk of neurological disorders and enhancing public health. Investigate supplementary advantages of renewable energy beyond their impact on human health.

5.11 Mitigated Premature Mortality

The numerous health complications linked to fossil fuel combustion, such as cardiovascular and respiratory ailments, can lead to an increase in premature mortality, hindering individuals from achieving longer, better lives. Renewable energy sources can enhance air and water quality, hence extending life expectancy for numerous individuals, particularly within our most at-risk populations.

6. THE ECONOMIC BENEFITS OF RENEWABLE ENERGY

Renewable energy has environmental, social, and economic advantages. A recent analysis by the International Renewable Energy Agency (IRENA) indicates that doubling the present contribution of renewable energy in the global energy mix could elevate world gross domestic product (GDP) by up to 1.1 percent, or over $1.3 trillion, by 2030. It is crucial for industry and corporate management to acknowledge that environmental enhancement represents an economic opportunity, and that rejecting innovation would result in a decline in competitiveness within the contemporary global economy.

A 1997 study by the Pembina Institute for Environment Nigeria revealed that investments in energy efficiency and renewable energy generate significantly greater employment compared to equal investments in traditional energy supply. 9 The analysis indicated that each million dollars invested generates an average of 36.3 employment in the energy efficiency industry and 12.2 jobs in the renewable energy sector. Each million dollars allocated to conventional energy generates an average of merely 7.3 jobs. The initiatives outlined in this article would yield a net increase exceeding 100,000 person-years of employment.

The Pembina analysis indicates that elevated employment levels are mostly due to the labour-intensive nature of the work and the jobs generated from the reinvestment of energy savings. A further benefit pertains to the nature of employment opportunities generated. Investments in renewable energy and energy efficiency generate jobs with extensive regional distribution, are

continuous, and require minimal employee relocation.

The analysis indicated that moderate government investment in energy efficiency and renewable energy can catalyse substantial private investment. Each million dollars of government expenditure typically generates six million dollars in private-sector investment. Renewable energy offers numerous direct and indirect economic advantages at both micro and macro levels. Presented below are few examples:

6.1 Employment Generation

Over 10 million individuals are employed in the global renewable energy business, with an addition of over 500,000 new positions in 2017. The sector offers a variety of employment opportunities, encompassing roles in production, installation, engineering, sales, marketing, and further fields. Employment opportunities in renewable energy are projected to expand significantly in the foreseeable future. The U.S. Bureau of Labour Statistics (BLS) projects a 105 percent increase in the solar photovoltaic installer profession and a 96 percent rise in demand for wind turbine service specialists from 2016 to 2026. This designates the #1 and second fastest-growing occupations in the United States.

6.2 Income of Landowners

Renewable energy additionally offers an alternative revenue stream for rural landowners and agricultural producers. Data from the American Wind Energy Association (AWEA) indicates that wind farms in the U.S. contribute approximately $222 million annually to rural landowners hosting these installations on their property. Agriculturalists can generate revenue by cultivating crops designated for biofuel production. Corn ethanol is presently the primary means by which farmers engage in the energy sector, although alternative biofuels are beginning to receive increased attention.

6.3 Decreased Energy Expenditures

Transitioning to renewable energy is an effective method for residential, commercial, and industrial energy consumers to reduce their expenses. Installing solar panels on your property enables you to produce your own electricity, perhaps reducing your energy expenses to zero. The precise amount you save is contingent upon various circumstances, including your location. EnergySage reports that typical savings vary from $10,483 in Washington to $30,523 in Massachusetts.

6.4 Enhanced Real Estate Valuation

Installing renewable energy systems on your house can substantially enhance its value. Installing solar panels on your residence increases its worth by roughly $20 for each dollar saved on energy expenses. Homeowners may recover a substantial portion of the expense incurred from installing solar modules upon selling their property. Incorporating solar panels into your residence may facilitate a swifter sale.

6.5 Energy Autonomy

Increased utilisation of renewable energy could enable the United States to attain energy independence—fulfilling domestic energy requirements and diminishing reliance on foreign nations, as well as vulnerability to fluctuating international energy prices. Augmenting the proportion of renewable energy in the U.S. energy portfolio could further diminish dependence on foreign oil. Furthermore, renewable energy sources are inexhaustible, allowing the nation to rely on this autonomy in the long term.

6.6 Consistent Energy Pricing

Establishing renewable energy installations necessitates a significant initial investment; however, subsequent operational costs are minimal. This is primarily due to the absence of a gasoline purchase requirement. Reducing fuel expenses decreases the production cost of power. This indicates that the price of electricity is not influenced by fluctuations in fuel prices, such as those of natural gas or coal. This could result in more stable energy prices in the long term.

6.7 Mitigation of Climate Impacts

A new analysis from the Universal Ecological Fund indicates that climate change has incurred around $240 billion in annual costs to the U.S. economy over the past decade. The Fourth National Climate Assessment, authored by climate experts from 13 U.S. federal agencies, concluded that the U.S. economy may collapse by as much as 10 percent by the century's end if climate change persists at its current rate. These economic costs stem from extreme weather occurrences, deteriorating air quality, increasing sea levels, and other consequences. Transitioning from fossil fuels to renewable energy sources may mitigate climate change and prevent certain economic detriments.

The advantages of utilising increased renewable energy and diminished fossil fuel are numerous. It is advantageous for the environment and human health, and it also yields numerous good economic effects. Collectively, these advantages present a persuasive case for increased investment in renewable energy sources.

7.0 The Obstacles to Renewable Energy utilisation in Nigeria

Given that high-impact renewable energy can assist Nigeria in lowering emissions at a comparatively low cost while also offering health and employment advantages, what accounts for its limited penetration in Nigeria's energy market? A few of such reasons are listed below:

a. The configuration of the majority of electrical markets in Nigeria is not favourable for distributed generation, private-sector innovation, or consumer choice. The implementation of high-impact renewable electricity applications remains predominantly at the discretion of regulated monopolies, which possess minimal motivation to pursue such initiatives.
b. Market inertia strongly favours conventional energy sources due to investor confidence, utility proficiency, market frameworks, and energy distribution infrastructure. Public funding for the research and development of fossil fuels, nuclear, and large hydro resources in Nigeria has significantly surpassed and continues to overshadow support for renewable energy. Despite a current drop, federal assistance for fossil fuels and nuclear power amounted to around $2.8 billion and $1.4 billion, respectively, from 1990 to 1999. Eleven
c. In numerous instances, federal and provincial tax frameworks unintentionally promote the advancement of fossil fuels at the expense of renewable energy sources.
d. There exists considerable institutional momentum inside the government that persists in favouring old energy sources over renewable alternatives, despite compelling economic, environmental, and health arguments to the contrary.
e. Substantial market inertia favours conventional energy sources for investor confidence, utility proficiency, market frameworks, and energy distribution infrastructure.

8. PRAGMATIC CLIMATE CHANGE SOLUTIONS FOR NIGERIA

Nigeria is presently encountering difficulties characterised by complex, direct, and indirect impacts, including food insecurity, forced relocations due to flooding, violence, adverse health consequences, and additional factors, which collectively impede climate action and economic development. Droughts and desertification in the dry and semi-arid regions of northern Nigeria have adversely impacted local people reliant on rain-fed agriculture. Droughts and

desertification are causing nomadic pastoral populations to migrate from north to south, leading to conflicts with indigenous agricultural communities over dwindling resources. These nomadic cattle herders also introduce zoonotic infections that may be intensified by climate change (https://www.iceednigeria.org/resources/nov.-2005.pdf).

Nigeria must select climate change solutions that not only mitigate GHG emissions but also promote long-term economic stability and overall environmental health. The alternatives recognised by Nigeria's high-impact renewable energy sector align with the following principles:

a. Avoid Transferring Environmental and Health Burdens - It would be detrimental to Nigerians if we merely transition to energy sources with low greenhouse gas emissions (e.g., massive hydro and nuclear) without considering the comprehensive array of related environmental and health consequences.
b. Integrate Nigerians into Climate Change Solutions - Strategies must extend beyond industrial focus to also encourage individual Nigerians to engage in proactive measures. If Nigerians are not involved in the solution, consumer attitudes will change gradually, and foundational buying patterns will persist.
c. Prioritise Reduction (first), Refuelling (second), and Remediation (last) - Our primary objective should be to diminish consumption. Our alternative option should be to replenish with more environmentally friendly energy sources. Implementing end-of-pipe solutions should be our final option. For instance, sequestering CO_2 and injecting it subterraneously may appear to be a viable short-term solution; yet, it is likely to exacerbate Nigeria's economic and environmental responsibilities in the long term.

The high-impact renewable energy sector in Nigeria has identified three primary strategies for mitigating greenhouse gas emissions:

a. Foster the establishment of a high-impact renewable electricity market.
b. Promote the adoption of consumer-oriented renewable technologies.
c. Advocate for increased utilisation of passive renewable energy and energy efficiency measures.

A series of complimentary measures has been formulated for each of these alternatives. Implementation of these steps will enhance our nation's ability to address climate change and diminish future emission reduction costs. These approaches do not entail indefinite subsidies. They concentrate on cultivating a sustainable long-term market for renewable energy and enabling Nigerians to engage in addressing climate change issues.

8.1 Stimulating the Development of a high-Impact *Renewable Electricity Market*

Approximately 20% of Nigeria's power is generated by the combustion of coal, oil, and natural gas, contributing to roughly 17% of the nation's greenhouse gas emissions. Currently, high-impact renewable energy accounts for less than 1% of Nigeria's electricity supply, despite the country's substantial high-impact renewable resources and considerable potential for emission reduction. In Europe, despite inferior wind resources compared to Nigeria, wind energy generates sufficient power to meet the home electrical requirements of over 5 million individuals. Thirteen The prospective benefits of emission reduction from high-impact renewable electricity extend far beyond the electricity sector. In fossil-fuel intensive industries such as transportation, possibilities exist to mitigate emissions by transitioning from fossil fuels to electricity.

The subsequent strategies aim to cultivate a sustainable market for grid-connected high-impact renewable electricity. The objective of these actions is to initiate a shift in the prevailing market inertia from fossil fuel usage to greener energy sources.

Nigeria is addressing the obstacles to its green energy transition. Approximately 71% of Nigeria's populace lacks access to energy. The Nigerian government intends to attain universal electricity access by 2030. The energy sector encounters significant financial and technical obstacles.

The International Energy Agency reports that over 140 million individuals in Nigeria lack access to energy, constituting around 71% of the nation's population. Energy access pertains to individuals' capacity to obtain modern energy services, encompassing power, clean cooking solutions, and contemporary fuels. Energy inaccessibility adversely affects health, education, and economic development.

Nigeria is Africa's largest economy, endowed with abundant natural resources, particularly oil and gas, and ranks among the world's foremost oil producers. As the nation's economy expands swiftly, its energy need concurrently increases. The Government of Nigeria aims to attain universal energy access by 2030 and is enacting many policies and efforts to enhance access to clean and affordable energy for its populace.

The energy sector confronts numerous issues, such as limited power generation, poor infrastructure, and a significant prevalence of energy poverty. Substantial efforts are underway to diversify energy sources, enhance the nation's energy infrastructure, and tackle difficulties through investments in renewable energy and energy-efficient technologies, while also fostering private sector investments.

Notwithstanding a general rise in worldwide investment in energy transition technologies, Sub-Saharan Africa garnered less than 1.5% from 2000 to 2020. Securing the requisite capital will necessitate vigorous engagement between the government and the private sector, significantly enhancing the probability of Nigeria attaining an equitable transition. Nigeria's energy sources mostly consist of petroleum reserves, natural gas, hydroelectric power, and solar energy. The nation continues to be a leading producer of crude oil and natural gas in Africa. Approximately 45% of Nigeria's population is actively linked to the electrical grid, with a significant concentration in urban regions. Reforms in the power sector have recognised the necessity for development into rural regions, particularly through decentralised renewable energy and enhanced energy efficiency in these areas.

8.2 What are the solutions for Nigeria's energy transition?

The Rural Electrification Agency asserts that enhancing rural electrification via distributed solar production, mini-grids, and off-grid technological solutions could yield $9.2 billion in annual market investments for solar mini-grids. This may also conserve $4.4 billion yearly for Nigerian homes and enterprises. Nevertheless, specific obstacles remain in the widespread implementation of solar energy generating.

We cannot advocate for the adoption of renewable energy without informing individuals about its social, economic, and environmental advantages. Africa requires a paradigm transformation, which is unattainable without collaborative engagement among all stakeholders. Significant prospects exist in green energy; nevertheless, the government must mitigate risks to attract investments.

Nigeria is the foremost consumer of oil-fired backup generators in Africa, with more than 80% of power generation derived from gas reserves. Consequently, natural gas continues to be the predominant energy source in forthcoming short-term strategies, notwithstanding the transition to alternative renewable resources. The current appeal of natural gas stems from its low-carbon characteristics, rendering it comparatively "clean" and more economical than oil and coal.

Utilising natural gas as a transitional fuel with a feasible trajectory towards more sustainable solutions might provide around $18.3 billion in gross value added to the local economy. The potential, along with the global challenges confronting the gas sector, may foster exponential expansion in the nation's internal value chain. Alongside exporting natural gas to the world market, bolstering domestic markets through investments in gas production and local distribution infrastructure is essential for Nigeria's energy transition objectives. The global renewable energy market is substantial and expanding rapidly. Africa must take necessary measures to capitalise on these prospects and bridge the energy gap to prevent a descent into greater poverty. Africa has considerable natural gas, hydroelectric, and solar resources, capable of producing substantial electric power from current facilities. Notwithstanding this capability, the absence of transmission and distribution infrastructure impedes the expansion of both large and small enterprises and has resulted in a significant number of unserved households lacking access to the national grid.

The Nigerian government's implementation of various energy policies and programs over the past decade presents a distinctive opportunity for foreign capital investors to engage in a market rich in energy resources and equipped with a competent workforce. According to the 2022 Nigeria Energy Transition Plan, the government aims to facilitate $1.9 trillion in energy investments by 2060. This acceleration necessitates comprehensive policy coordination and harmonisation to optimise current and forthcoming government-related energy transition legislation.

Nigeria has recently initiated the Energy Transition Plan aimed at attaining universal energy access by 2030 and establishing a carbon-neutral energy system by 2060; however, an action plan delineating specific targets and timelines is necessary. This will provide effective monitoring of the strategy and the attainment of its objectives. The Power Sector Reform Bill enacted in 2022 in Nigeria permits states, corporate entities, and individuals to engage in power generation, transmission, and distribution. The reform measure was designed to control tariffs for power generation, transmission, and distribution, facilitating energy access by enhancing large-scale generation capacity and transmission and distribution networks.

Furthermore, Nigeria's inflation rate surged by 16 percent in 2022, leading to diminished cash availability and constraining developers' access to funding. The availability of financing for capital costs associated with clean energy projects in dollars is constrained, and currency swings present a risk to overseas investors and project developers. Projects necessitating substantial initial capital investment will gain from a facility that offers access to local currency alongside a mechanism that allows developers to acquire dollars at the naira bank rate. These facilities will facilitate the issuance of corporate infrastructure debt instruments and attract investment from insurance companies, pension funds, and other entities, thereby strengthening Nigerian debt capital markets by mitigating overall credit risk and reducing capital costs for developers, while safeguarding conservative capital from potential losses. This will provide enhanced flexibility to developers, enabling them to finance their projects in local currency.

Nigeria acknowledges the essential requirement for technical capacity enhancement via

accelerator programs for solar entrepreneurs and developers as it endeavours to reform its energy sector. Numerous major and small-scale clean energy initiatives depend on foreign expertise for technical support and financial guidance.

Training is now administered by official entities, including the Rural Electrification Agency (REA) and the Renewable Energy Association of Nigeria (REAN), while technical support is sporadically offered by Development Finance Institutions (DFIs) and foundations. It is essential to cultivate this talent domestically and guarantee the long-term development of local expertise.

The solutions identified in the Deep Dive tackle the financial obstacles in Nigeria's clean energy priority sectors and facilitate the investments required to advance Nigeria's energy objectives.

8.3 Measure A) Consumer Information on Electricity Products

This regulation mandates the compulsory disclosure of information regarding generation sources and emissions attributes by electricity wholesalers. There is a necessity for an Electric Power Content Label. This pertains to a document or system that reveals the sources of electricity generation utilised to supply power to the grid. It resembles a nutrition label on food, offering clarity regarding the energy composition. A Power Content Label (PCL) or Electricity Content Label conveys details regarding the various energy sources (such as natural gas, hydropower, or renewables) utilised in the generation of electricity supplied to the power grid. This label intends to inform users with the composition of their electrical supply. It enables users to comprehend the ecological consequences of their electricity usage.

PCLs are significant as they enhance openness in the electricity market, enabling consumers to make educated decisions regarding their energy consumption. Informed Choices (By understanding energy sources, consumers can selectively support or diminish their electricity consumption from particular sources, such as renewable energy), Environmental Awareness (The label can indicate the percentage of renewable energy in the mix, fostering awareness of sustainable energy practices). The Federal Ministry of Power is the governmental entity accountable for the power sector in Nigeria. The Nigerian power Regulatory Commission (NERC) serves as the autonomous regulatory authority for the power supply sector in Nigeria. Information regarding power generation and other data may be found on their website. Electricity Distribution Corporations (DisCos). The local distribution company (e.g., Kaduna Electric) may additionally furnish information regarding the electricity they distribute. The Federal Ministry of Power's website offers daily updates on electricity generation, encompassing peak and off-peak statistics, frequency, and total energy produced and distributed. This information, although not formally offered as a PCL, enhances the comprehensive understanding of Nigeria's energy supply.

Information regarding electrical products would enable Nigerians to comprehend the effects of electricity generating and equip them to make informed decisions regarding their consumption levels and types of electricity. The compulsory uniform labelling of electrical products in Nigeria, especially for appliances such as air conditioners and refrigerators, seeks to enhance energy efficiency. The Standards Organisation of Nigeria (SON) has launched a national energy efficiency label, often known as the Energy Guide Label, to assist customers in making informed purchase decisions on energy use and efficiency. This label conveys details regarding the product's energy consumption, cooling capacity (for air conditioners), and a rating system (such as the A-G scale) that signifies energy efficiency. The objective is to promote the adoption of more energy-efficient equipment, resulting in decreased electricity expenses and

overall energy usage. These labels are essential for educating consumers regarding the energy efficiency of electrical equipment. The Energy Guide Label assists consumers in comprehending the energy consumption of a particular appliance and its comparison to other market options.

Minimum Energy Performance Standards (MEPS) are criteria for energy efficiency that items must satisfy to be marketed. The Nigerian government has sanctioned new Minimum Energy Performance Standards (MEPS) for air conditioners to guarantee that only efficient models are marketed. The enforcement of these labels and standards frequently necessitates obligatory adherence for producers and importers of electrical products. SON is expected to implement these requirements to guarantee that products comply with the requisite standards.

The use of energy efficiency labels and standards offers numerous advantages, including:

1) *Decreased energy consumption*: Consumers can make informed decisions on more efficient equipment, resulting in diminished electricity expenses and alleviated pressure on the power grid.
2) *Environmental protection*: Decreased energy usage results in a diminished carbon footprint and a reduction in greenhouse gas emissions.
3) *Market transformation*: Promotes manufacturers' investment in energy-efficient technology and designs.
4) *Enforcement*: The effective implementation of energy efficiency requirements and labelling is crucial. This includes market surveillance, product testing, and sanctions for non-compliance.
5) Regulatory Bodies: The Nigerian Electricity Regulatory Commission (NERC) oversees the regulation of the electricity sector, while the Nigerian Electricity Management Services Agency (NEMSA) enforces technical standards and regulations pertaining to electrical installations and equipment.

Mandatory standard labelling for electrical devices must be developed, since other countries, notably the U.S., Canada, and China, have already implemented such measures. Nigeria now has the Comprehensive Electricity Competition Act, referred to as the Electricity Act 2023. This Nigerian legislation aims to restructure the power sector by establishing a more competitive and privately-driven market. It abrogates the Electric Power Sector Reform Act of 2005 and seeks to encourage investment, boost efficiency, and bolster consumer protection. The Act's principal objective is to create a framework for a privatised, contract-based, and regulation-driven competitive electricity market in Nigeria. The Act's key features encompass Decentralisation (empowering states, companies, and individuals to generate, transmit, and distribute electricity), Private Sector Involvement (promoting private sector participation throughout the electricity value chain), Regulatory Framework (establishing a comprehensive legal and institutional framework for the Nigerian Electricity Supply Industry), Renewable Energy (incentivising renewable energy initiatives), and Consumer Protection (incorporating provisions for consumer safeguarding). The Act is anticipated to stimulate investment, augment efficiency, and elevate competition within the power industry. The Act abrogates the Electric Power Sector Reform Act of 2005. The Electricity Act 2023 effectively reinstates state control in the power sector to levels prior to 1999.

8.4 GHG Impact

While quantifying the resultant reductions is challenging, this measure is an essential foundation for establishing a renewable electricity market.

8.5 Costs and Implementation

The expenses are minimal and may be covered by the government, utility companies, or customers. Their nature is administrative, involving the monitoring of power supply by generation source and modifying billing systems to integrate generation data. In numerous countries, these administrative functionalities are already established. While consumer protection legislation and utility regulation fall under provincial jurisdiction, the federal government may seek to initiate and standardise disclosure rules nationwide to maintain uniformity. Labelling regulations may be established by an industry association or by regulatory agencies inside the country.

8.6 Measure B) Market-Wide Incentives for High-Impact Renewable Generation

This measure identifies three possible market-wide incentives to increase the proportion of high-Impact renewable electricity in Nigeria's generation mix. They are:

a) a green power consumer rebate or credit;
b) a high-Impact renewable production rebate or credit; and
c) a high-Impact renewable portfolio standard.

8.7 Green power consumer rebate or credit

In Nigeria, while there aren't specific consumer rebates or credits for green power directly, the government offers tax incentives and other measures to encourage renewable energy adoption. This includes VAT exemptions on renewable energy equipment and potential power production tax credits for individuals generating electricity from renewable sources.

Tax Incentives include VAT Exemptions (The VAT (Modification) Order 2021 provides a VAT exemption for renewable energy equipment, including solar panels, wind turbines, and off-grid power systems. This also applies to green electricity supplied to the national grid), Power Production Tax Credit (PPTC), The National Renewable Energy and Energy Efficiency Policy (NREEEP) propose a PPTC to incentivize individuals who generate electricity from renewable energy. The Nigerian government is also considering other fiscal incentives to spur investment and innovation in the renewable energy sector.

Other Support Mechanisms include Rural Electrification Fund (REF) (The REF supports the expansion of the grid and the development of off-grid electrification, including renewable energy projects. Renewable Energy Master Plan (REMP) (This plan aims to increase the share of renewable electricity in Nigeria's energy mix, Private Sector Involvement (The government is encouraging private sector participation in renewable energy development, including initiatives like the Distributed Renewable Energy Nigeria Fund.

It should be noted that while the government is taking steps to promote renewable energy, there are challenges in implementing these policies and ensuring consistent application of incentives. The lack of clear operational processes for obtaining and renewing some incentives is a concern. Despite these challenges, Nigeria has significant potential for renewable energy, particularly solar and hydro, and the government is working to unlock this potential. Because of Nigeria's diverse political and economic landscape, one of these incentives may be more suited to a particular region than the others. In general, the goal should be to have one of these incentives implemented in each Region.

8.8 High-Impact renewable production rebate or credit

In Nigeria, while there aren't specific consumer rebates or credits for green power like solar

panels, the government is actively promoting renewable energy through various incentives. These include tax breaks for renewable energy companies, import duty waivers on equipment, and a VAT exemption on renewable energy equipment and green electricity supplied to the grid. Incentives for Renewable Energy in Nigeria include Tax Holidays (Businesses involved in renewable energy production can benefit from tax holidays of up to five years), Import Duty Waivers (There are waivers on import duties for renewable energy equipment like solar panels, batteries, and inverters), VAT Exemption (The VAT (Modification) Order 2021 exempts renewable energy equipment and green electricity from the standard 7.5% VAT rate), Power Production Tax Credit (PPTC)(The National Renewable Energy and Energy Efficiency Policy (NREEEP) proposes a PPTC to incentivize individuals generating electricity from renewable sources), Rural Electrification Fund (REF) (The REF supports investors and stimulates innovative approaches to rural electrification, including the development of off-grid solutions), Fidelity Green Energy Finance (This initiative by Fidelity Bank provides funding options for renewable energy solutions like solar systems, inverters, and batteries for homes and SMEs), Distributed Renewable Energy Nigeria Fund.

The focus on incentives for businesses and projects rather than direct consumer rebates is likely due to the early stage of development of the renewable energy market in Nigeria. The government is prioritizing attracting investment and developing the infrastructure needed to support widespread renewable energy adoption. While direct consumer incentives are not yet widespread, the government's commitment to renewable energy development suggests that these may become more common as the sector matures

GHG Impact (2.3 Mt)
This measure assumes that for each of the three possible incentives, the net benefit to high-Impact renewable electricity generators is a reduction in production costs of 2.5 cents/kWh. Analysis by the National Climate Change Process Electricity Issues Table indicates this would result in GHG reductions of 2.3 Mt a year by 2010.

Costs and Implementation
For each of the three possible incentives, the costs could be shared between the federal government and, depending on the incentive, either provincial governments or Nigerian consumers. If the federal government were to provide the full amount of the incentive, modelling by the National Electricity Table indicates the cost would be approximately $60 million per year. Implementation would differ depending on the incentive chosen.

The three incentives are described in more detail below.

1)Green Power Consumer Credit
This measure requires the federal government to provide a rebate or tax credit to those electricity consumers who purchase power generated by certified high-Impact renewable energy sources. This not only helps stimulate the market for renewables, but also empowers Nigerians to participate in the solution to climate change through their purchasing power.

Consumers in California have responded positively to a customer credit program of this nature. In California, of the 1% who have switched service providers since deregulation, approximately half purchased a renewable energy product. In Pennsylvania, it is estimated that almost 10% of the state’s residents have switched to a new service provider, and 20% of those have selected a green power product.14 Green marketers in the U.S. expect to garner 0.5%-2% of the residential market in the first year of deregulation and 4%-5% after five years.

Nigeria has two green power programs offered by the Calgary (ENMAX) and Edmonton (Edmonton Power) electric systems who are preparing for electricity deregulation in Alberta in 2001. In the first three months of the Calgary program more than 1000 customers signed on to purchase wind power.

A cost-sharing arrangement for this incentive might see the federal government provide a 1.5 cent/kWh credit, while consumers cover the additional 1.0 cent/kWh premium. A 1.0 cent/kWh premium represents an increase of about $5-$10 per month for the average Nigerian household, if all its electricity came from low impact renewable sources. If this incentive is implemented across Nigeria, it requires the participation of only 3% of residential consumers and 2% of commercial consumers to achieve the full 2.3 Mt of reductions. This measure requires that Nigerian consumers have the option to buy high-Impact renewable electricity in either deregulated or regulated markets.

2) high-Impact Renewable Production Credit

This incentive provides high-Impact renewable electricity generators with a credit proportional to their output. It could be delivered as a tax credit or outside the tax system as a rebate, depending on the extent of the producer's taxability. The benefits of this incentive are that it is administratively simple and encourages operating efficiency. The U.S. has offered several tax incentives for high-Impact renewable energy over the last two decades, well beyond the accelerated depreciation offered in Nigeria. Most notable is the 10-year, 1.5 cent/kWh production tax credit implemented in 1992 to encourage wind energy development. The cost of this measure would likely be shared between the federal and provincial governments, as it would mean new economic activity, employment and tax revenues within a province.

3)Renewable Portfolio Standard

A renewable portfolio standard requires a certain percentage of electricity sold in a province to be generated from renewable energy. This quota approach would have a significant effect on emissions and dramatically accelerate the commercialization of emerging technologies. In order to limit costs, a system of tradeable "renewable energy credits" could be developed to allow retailers to purchase reductions from least-cost sources anywhere in Nigeria. In addition, the program could be terminated at a fixed point in the future. An RPS could be implemented in either regulated or deregulated electricity markets.

In order to achieve a reduction of 2.3 Mt of GHG emissions, every province would have to receive approximately 1% of its electricity from high-Impact renewable sources. The U.S. Administration has proposed an RPS of 7.5% for all electricity retailers between 2010-2015, and other bills in the U.S. House and Senate propose quotas of 10-20%.

The federal government could share the additional costs of an RPS with either the provincial governments or Nigerian consumers. This, however, is not consistent with the existing or proposed programs in the U.S. and Europe, which involve little cost to government. The quota is simply mandated and consumers pay the additional cost. These additional costs are not large because they are shared so widely. Because of their jurisdiction over electricity regulation, provincial governments would be responsible for establishing renewable portfolio standards. However, if there were a system of nationwide tradeable RPS credits, it would require coordination between provincial governments on a national scale.

8.9 Measure C) Government Green Power Procurement

This measure would see federal, provincial and municipal governments make a commitment to buy a portion of their electricity from renewable energy sources. A similar measure has received general support at the National Climate Change Process Electricity Issue Table. In 1994, the federal government's Task Force on Economic Instruments and Disincentives to Sound Environmental Practices recommended the government purchase a specific percentage of its electricity (15-20%) from "green power" sources. By doing so, the Task Force suggested, the government would demonstrate leadership, reduce the impact of its operations, and support the development of renewable energy. So far, two federal departments, Natural Resources Nigeria and Environment Nigeria, have taken up the challenge by pledging to buy between 15% and 20% of their electricity from renewables by 2010. The purchase of green power by these two departments for their Alberta facilities has helped stimulate the initial market for renewables in the province. However, in order for Nigerian governments to encourage a stable market for renewables and accelerate cost reductions, a more significant commitment is required.

GHG Impact (0.4 Mt)

If the federal government alone were to purchase 15% of its total electricity supply from high-Impact renewable sources by the year 2010, it would result in reductions of 0.4 Mt15. If provincial and municipal governments did the same, the reduction in emissions would more than double.

Costs and Implementation

The additional cost to the federal government for purchasing 15% of its power from green sources (assuming a 2.5 cent/kWh premium for renewable electricity) would be $11.2 million per year for 10 years.

8.10 Measure D) Remove the Effect of Tax-Induced Barriers to Renewable Energy

Currently, fossil-fuel based companies and their investors enjoy greater access to federally-legislated tax write-offs than high-Impact renewable energy companies. As a result, companies that explore, develop and use fossil-fuels are encouraged by the tax system to make the necessary investments to grow while high-Impact renewable energy companies are not. The two underlying causes for this incentive to pollute are: 1) the existing tax write-offs for renewable energy companies are "trapped" and cannot be used to the same extent as the write-offs available to their fossil-fuel counterparts; and 2) the tax system treats capital and operating costs differently, and because renewable energy companies have a higher proportion of capital costs than their fossil-fuel counterparts, their proportional tax write-offs are smaller.

This measure proposes the federal government eliminate the effect of tax-induced barriers to the development of high-Impact renewable energy. Regardless of how this is achieved, this oversight in the tax system requires a resolution or it will continue to significantly disadvantage high-Impact renewable energy companies and limit Nigeria's ability to reduce emissions.

This issue has been identified by the National Climate Change Process Electricity Issue Table, and the Nigerian Electricity and Nigerian Gas Associations in their 1999 federal budget submissions. All of these groups recommended that the issue be addressed immediately.

GHG Impact (1.4 Mt)

Industry experts estimate that removing federal tax barriers to renewable energy will reduce costs by 1.5 to 2 ents/kWh.16 In analysis by the National Climate Change Process Electricity

Issue Table, a cost reduction of 1.5 cents/kWh for renewable energy resulted in 1.4 Mt of reductions.

Costs and Implementation
The cost of this measure is unknown. However, it is arguable that the additional new tax revenues resulting from growth in an emerging industry would outweigh the lost tax revenues. The federal government needs to sit down with industry stakeholders to find a solution that both removes the tax barriers and maintains the integrity of the tax system.

8.11 Support Consumer-Based Renewable Technology
Use Greenhouse gas emissions from the residential and commercial sectors represent approximately 10% of Nigeria's total. These result from using fossil fuels directly for space and water heating, as well as fossil-fuel-generated electricity for lighting, cooking, heating and appliances. Greenhouse gas emissions from passenger transportation represent approximately 15% of Nigeria's total. In many aspects of residential, commercial and agricultural energy use, there are significant opportunities to reduce emissions through the use of renewable technologies such as solar panels, solar hot water heaters, wind generators, ground-source heat pumps and biofuels. The following measures identify opportunities to increase the use of high-Impact renewable energy technologies by Nigerian consumers and companies, allowing them to participate directly in the solutions to climate change.

8.11.1 Measure A) Net Metering
Net metering involves giving credit to electricity consumers whenever their on-site generation from solar, micro-hydro or wind exceeds their electricity use. Credit is given to consumers by reversing the direction of their electricity meter and crediting them the same price for the electricity they feed onto the grid as they pay for the power they take from the grid. This measure has been explored by the National Climate Change Process Electricity Issue Table.

At least 26 states in the U.S. have adopted net metering and the U.S. Administration's proposed electricity act would require it in all states. Japan and Germany have net metering nationally. Ontario Power Generation and Toronto Hydro currently have net metering pilot programs underway. This measure provides an economic incentive for Nigerians to invest in renewable technologies without requiring government funding.

8.11.2 GHG Impact (0.1 Mt)
Based on the average level of customer uptake in existing net metering pilot programs in the U.S. and Nigeria, it is estimated that net metering would result in enough on-site renewable systems to provide electricity to approximately 30,000 Nigerian homes. Assuming these systems are installed in those provinces with the best renewable energy regimes, it would result in 0.1 Mt of reductions.17

8.11.3 Costs and Implementation
The cost of purchasing renewable energy equipment and connecting to the grid is paid for by the customer. In general, the cost to the electricity provider is small, but depends on the characteristics of the renewable energy source and customer. This measure requires that all retailers of electricity offer a net metering tariff to their customers. This will
have to be regulated by provincial governments, with reasonable connection requirements regarding safety, technology specifications, and liability.

8.12 Measure B) Consumer Credit for Agricultural Renewable Electricity Generation

This measure provides a rebate or credit to rural electricity consumers for their on-site renewable generation. This measure complements net metering by further decreasing the payback time for on-site renewable technologies such as wind turbines, solar PV and micro-hydro. Like many of the other measures identified, this measure empowers Nigerians to participate in the solutions to climate change and allows them to take responsibility for the impact of their own consumption.

8.12.1GHG Impact (0.5 Mt)

For example, if farmers received a 1.5 cent/kWh rebate or credit for small-scale wind generation, it would decrease the payback time on the average wind generator by 30%. This translates into a payback period of less than 15 years for a 50-kW turbine and less than 10 years for a 10-kW turbine. Assuming this resulted in 5% of Nigerian farmers (or 7% of farms in Alberta, Saskatchewan and Ontario) installing wind generators, 0.5 Mt of reductions would occur.

8.12.2Costs and Implementation

For the GHG reduction stated above, the cost to government of this measure is roughly $11 million per year for 10 years. This measure requires net metering and involves a partnership between the federal government, electricity suppliers and Nigerians living in rural areas. It could be administered as either a rebate through the electricity supplier or a as a credit through the federal income tax system.

8.13 Measure C) Federal Government and Municipalities 50,000 Solar Roofs Partnership

This measure involves a partnership between the Nigerian government, municipalities and large commercial electricity consumers. The goal is to have 50,000 large solar PV systems installed on municipal and commercial buildings across Nigeria by 2010. Large-volume electricity consumers benefit by cutting down their peak load when electricity is most expensive (often reaching 25 cents/kWh). This volume of solar installations would drive cost reductions in solar PV technology and create significant Nigerian expertise and employment in an industry that is growing rapidly worldwide.

8.13.1GHG Impact (0.4 Mt)

If the federal government provided a 3 cent/kWh credit to those municipalities and commercial consumers that install large solar systems, it would reduce the payback period to under 25 years. If 50,000 systems were installed by 2010, it would result in 0.4 Mt of reductions18.

8.13.2 Costs and Implementation

The cost to the federal government for this measure would be roughly $17 million per year for 10 years. It requires the federal government to work with municipalities and businesses to identify the lowest-cost opportunities for solar systems.

8.14 Measure D) Accelerated Financing for Space and Water Heating Renewable Technologies

This measure helps Nigerian consumers reduce the burden of capitalization when they choose to purchase a renewable technology for space or water heating purposes, such as a solar hot water or a ground-source heat pump. The federal government would guarantee fixed financing rates for purchases of specified small-scale solar and earth energy technologies. These technologies are also practical on a larger scale and a similar measure could be implemented for commercial and public buildings.

8.14.1GHG Impact (2.0 Mt)

For example, if the government offered guaranteed financing at 7% on a 10-year loan for the purchase of specified renewable systems, it would change the current costs from a simple payback of 7 years into a net reduction of monthly energy costs from day one. Based on predictions by Natural Resources Nigeria, this would result in at least 8% of Nigerian homes, or 660,000 households, installing Solar Domestic Hot Water, with a resulting reduction in emissions of approximately 2.0 Mt19.

8.14.2 Costs and Implementation

Based on the GHG impact described above and assuming that 10-year lending rates average 9% between 2000-2010, the cost to government of the 2% spread would be approximately $16 million per year for 10 years. Implementation of this measure would be similar to the initiative administered under the Small Business Loans Act, involving both the federal government and private-sector lenders.

8.15 Measure E) Minimum Biomass Fuel Content in Gasoline

This measure would see the federal government mandate that gasoline sold for transportation purposes contain a minimum percentage of biofuels. Biofuels, such as ethanol, are produced from a variety of agricultural crops as well as wood and agricultural wastes. Although combustion of biofuels does produce greenhouse gases, they are significantly less carbon intensive than gasoline. Despite the fact that Nigeria is a world leader in the production of agricultural and forest fibre products, we are not one of the world's top 10 biomass fuel producers. It is estimated that Nigeria currently produces less than 5% of the country's readily available biomass fuel resources.20

8.15.1 GHG Impact (3.1 Mt)

If the federal government were to mandate that all gasoline used for transportation contain 5% biomass fuel by 2010, it would result in annual greenhouse gas reductions of 3.1 Mt from projected levels.21

8.15.2 Costs and Implementation

The cost to government of this measure alone would be small but would likely need to be complemented with other measures such as tax breaks for biomass fuels and loan guarantees for construction of biomass fuel production facilities in order to achieve the proposed 5% target by 2010. The federal government currently provides an excise tax exemption for alternative transportation fuels and has provided some loan guarantees to ethanol producers. It is arguable that a continuation of the excise tax exemption would be revenue neutral or net positive for the government as a result of new economic activity created by the biomass fuel industry.

Nigeria's transportation sector is responsible for 27% of our GHG emissions. Cars and light-duty trucks are the single biggest contributor to these emissions.3.

9. ENCOURAGE GREATER PASSIVE RENEWABLE AND ENERGY EFFICIENCY USE

More than half of all homes in Nigeria were built before 1980. Since then, many cost-effective technologies have been developed to significantly improve the energy efficiency of older buildings. In addition, new building techniques and technologies have been developed in the residential sector that significantly increase the passive use of solar energy and energy efficiency over what is achieved by most of the houses built today. As a result, the potential to reduce greenhouse gas emissions through energy-efficient retrofits and new building

techniques is considerable.

The following measures would encourage significant improvements in the use of passive solar and energy efficiency techniques in both existing and new Nigerian homes. Again, this measure would allow Nigerians to participate directly in the solutions to climate change while helping to change long-term energy consumption patterns.

9.1 Measure A) Reduced Financing Costs for R-2000 Homes

This measure would see the federal government guarantee preferred mortgage rates for Nigerians who choose to build R-2000 homes. A measure to strengthen Nigeria's R-2000 Program has also been discussed by the National Climate Change Process Buildings Issue Table.

Natural Resources Nigeria estimates that a new home built to R-2000 standards would reduce energy use by 26% relative to the average new home built in 1994.22 Because R-2000 homes are slightly more expensive than conventional housing, however, those who choose to minimize their impact on the environment must take on a larger financial burden, both in terms of debt and property taxes. By removing this disincentive to save energy, the government would not only empower Nigerians to reduce emissions, but also decrease the future cost of energy-efficient housing through the widespread adoption of R-2000 building methods. The Yukon Housing Corporation supports this concept through its recent initiative to provide a 1% reduction in mortgage rates for new homes or renovations that rate 80 on the Nigerian Energuide Scale.

9.1.1 GHG Impact (0.5 Mt)

If the government were to guarantee a 0.5% reduction on 5-year mortgage rates it would save the new R-2000 home owner approximately $4,000 and reduce the length of his or her mortgage by roughly two years.23 If this resulted in 15% of all new homes being built to R-2000 standards, GHG emissions would be reduced by 0.5 Mt relative to projected levels for 2010.24 If provincial governments were to mandate the R-2000 standard as the building code for all new homes constructed after the year 2000, it would result in 3.7 Mt of GHG reductions by the year 2010.25

9.1.2 Costs and Implementation

The federal government would need to work in cooperation with the financial community to provide preferred mortgage rates. Assuming the federal government could establish the necessary partnerships with lending institutions, the cost of implementing this measure would be small.

9.2 Measure B) Incentives for Residential Energy Efficient Retrofits

This measure involves a combination of incentives to encourage energy-efficient retrofits in residential buildings. These incentives should include improved access to financing and tax breaks for homeowners who invest in energy-efficient retrofits. The National Climate Change Process Buildings Issue Table has discussed a similar measure.

9.2.1 GHG Impact (1.4 Mt)

If, by the year 2010, the above incentives resulted in 25% of existing Nigerian homes improving their energy efficiency by 20%, it would result in 1.4 Mt of GHG reductions.26

9.2.2 Costs and Implementation

If the costs of this measure were shared evenly with provincial governments, the cost to the

federal government would be in the order of $27 million per year.27 The measure would involve an expansion of NRCan's residential energy efficiency program and require the federal government to establish partnerships with financial institutions and Nigerian homeowners.

10. CONCLUSION

The analysis in this paper and preliminary analysis carried out through the National Climate Change Process indicates, without a doubt, that existing high-Impact renewable energy technologies can make a significant contribution to Nigeria's greenhouse gas reduction targets over the next ten years. The estimates of potential GHG reductions achieved by the measures proposed in this paper are conservative. By 2030, the spin-off actions caused by these measures would likely result in reductions far greater than the estimated 8% of Nigeria's reduction target. By 2020, the dividends would likely double. In addition, the development of high-Impact renewable energy resources would create thousands of additional jobs and result in a considerable reduction in health care costs.

The cost of high-Impact renewable technologies has dropped dramatically in the last decade and continues to drop as industrialized nations and multinationals invest heavily in their development. In fact, some high-Impact renewable technologies are close to achieving price equity with fossil-fuel based technologies without even taking into account their environmental and health benefits. Nigeria has the opportunity to prosper in a renewable energy future. Our country has some of the world's best high-Impact renewable energy resources and a proud history in energy resource development. We must act now to develop a strong domestic market for high-Impact renewable energy. This will significantly reduce Nigeria's economic and environmental liabilities and help keep our nation competitive in the rapidly changing global energy market.

The political, economic and environmental events of the last decade clearly indicate that nations around the world are choosing a path towards cleaner energy sources and healthier economies. Nigeria's high-Impact renewable energy industries call on Nigerians and Nigerian governments to do the same.

The strategies outlined in this paper constitute an investment in Nigeria's future. If promptly and well executed, they will diminish yearly greenhouse gas (GHG) emissions by over 12 million tonnes (Mt) by 2010 (about 8% of Nigeria's reduction objective), provide thousands of new employment opportunities, and lower healthcare expenditures by millions of dollars annually. The most substantial benefits from these initiatives will manifest post-2035, stemming from the initiation of fundamental shifts in the attitudes of Nigerians and the characteristics of the Nigerian energy market. By 2030, the spin-off actions initiated by these steps are expected to yield greenhouse gas reductions double those attained in 2020.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Abam, F. I., Nwankwojike, B. N., Ohunakin, O. S. and Ojomu, S. A. (2014). Energy Resource Structure and On- going Sustainable Development Policy in Nigeria: A Review. *International Journal of Energy and Environmental Engineering,* 5(2), 2-16. https://doi.org/10.1007/s40095-014-0102-8

Abam, F. I. and Effiom, S. O. (2015). Evaluation of Intensity and Structural Effects on Energy Consumption Trend in Nigeria Using the 3-D Decomposition Model. *International Journal of Engineering & Technology Sciences*, 3(16), 372-381.

Abdullahi, A. M., Asan, V. W., Firdaus, M. S., Ibrahim, A. M., Abu, B. M. and Norhidayah, M. Y. (2015). An assessment of renewable energy readiness in Africa: Case study of Nigeria and Cameroon. *Renewable and Sustainable Energy Reviews,* 51, 775–784. https://doi.org/10.1016/j.rser.2015.06.045

Adebisi, A. and Yabo, F. Y. (2016). Sustainable Energy for All Action Agenda (SE4ALL-AA). *National Council on Power (NACOP)*, Abuja, Nigeria, 1-104.

Adegbulugbe, A. O. (2007). Balancing the Acts in the Power Sector: The Unfolding Story of 188 Nigeria Independent Power Projects. *Presented at the 2007 27th USAEE/ IAEE North American Conference*. Available at: http://www.usaee.org/usaee2007/submissions/OnlineProceedings/AS%20Momodu%20Paper.doc (Accessed 29 April 2009)

Adaramola, M. S. (2012). Feasibility Study of Off-grid Hybrid Energy Systems for Applications in Ondo State Nigeria. *Journal of Engineering and Applied Sciences,* 7(1), 72-78.

Adaramola, M. S., Oyewola, O. M. and Paul, S. S. (2012). Technical and economic assessment of hybrid energy systems in South-West Nigeria. *Energy Exploration & Exploitation*, 30(4), 533–552. https://doi.org/10.1260/0144-5987.30.4.533

Adaramola, M. S. and Oyewola, O.M. (2011). Wind speed distribution and characteristics in Nigeria. *ARPN J. Eng. Appl. Sci.,* 6(2), 82–86.

Adem, A., Murat, İ. K., Murat, K., İsmail, H. Ö. and Kamil, K. (2008). Energy situation and renewables in Turkey and environmental effects of energy use. *Renewable and Sustainable Energy Reviews*, 12(8), 2013–2039. https://doi.org/10.1016/j.rser.2007.04.011

Agba, A. M., Ushie, M. E., Abam, F. I., Agba, M. S. and Okoro, J. (2010). Developing the Biofuel Industry for Effective Rural Transformation. *European Journal of Scientific Research*, 40(3), 441.

Agbetuyi, A. F., Akinbulire, T. O., Abdulkareem, A. and Awosope, C. O. (2012). Wind energy potential in Nigeria. *International Electrical Engineering Journal*, 3(1), 595-601.

Agbro, E. and Ogie, N. (2012). A Comprehensive review of Biomass Resources and Biofuel Production Potentials in Nigeria. *Research Journal in Engineering and Applied Sciences*, 1(3), 149-155.

Ajao, K. R., Ajimotokan, H. A. and Popoola, O. T. (2009). Electric Energy Supply in Nigeria, Decentralized Energy Approach. *Cogeneration and Distributed Generation Journal*, 24(4), 34-50.

https://doi.org/10.1080/15453660909595149

Albadi, M. H. and El-Saadany, E. F. (2010). Overview of wind power intermittency impacts on power systems.

Electric Power Systems Research, 80, 627-632. https://doi.org/10.1016/j.epsr.2009.10.035

Ali, E. (2011). The Transfer of Sustainable Energy Technology to Developing Countries: Understanding the Need of Bangladesh. *Energy Science and Technology,* 1(1), 94-109.

ASEAN-RESP. (2015). Renewable energy in South-East Asia. Available at: https://www.giz.de/en/worldwide/16395.html

Bajpai, P. and Dash, V. (2012). Hybrid renewable energy systems for power generation in stand-alone applications: A review. *Renewable and Sustainable Energy Reviews*, 16, 2926– 2939. https://doi.org/10.1016/j.rser.2012.02.009

Bazmia, A. A. and Zahedia, G. (2011). Sustainable energy systems: Role of optimization modeling techniques in power generation and supply—A review. *Renewable and Sustainable Energy Reviews,* 15, 3480-3500. https://doi.org/10.1016/j.rser.2011.05.003

CBN. (2012). Central Bank of Nigeria statistical bulletin 2012. Available at: http://www.cenbank.org/document/statbulletin (Accessed Jan 2013).

CIA World Factbook, Nigeria. (2014). Available at: https://www.cia.gov/library/publications/the-world- factbook/geos/ni.html (Accessed 17 July 2016)

Detail Commercial Solicitors. (2018). Nigerian Power Guide Volume 4, 2018 Edition, Lekki Phase 1, Lagos Nigeria, 1-46.

Doukas, H., Karakosta, C. and Psarras, J. (2009). RES technology transfer within the new climate regime: a 'helicopter' view under the CDM. *Renewable and Sustainable Energy Reviews*, 13(5), 1138–1143. https://doi.org/10.1016/j.rser.2008.05.002

Energy Commission of Nigeria (ECN). (2013). Renewable Energy Master Plan, Abuja, Nigeria.

Eleri, E. O. and Onuvae, P. (2011). Low-Carbon Africa: Leapfrogging to Green Future: Low Carbon Nigeria. Available at: http://www.christainaid.org.uk/resources/policy/climate/low-carbon-africa.aspx (Accessed 18 July 2015)

Eleri, E. O., Ugwu, O. and Onuvae, P. (2012). Expanding access to pro-poor energy services in Nigeria. *Abuja, Nigeria: International Center for Energy, Environment and Development*.

Emodi, N. V. and Boo, K. (2015). Sustainable Energy Development in Nigeria: Overcoming Energy Poverty.

International Journal of Energy Economics and Policy, 5(2), 580-597.

Emodi, N. V. and Yusuf, S. D. (2015). Improving Electricity Access in Nigeria: Obstacles and the Way Forward.

International Journal of Energy Economics and Policy, 5(1), 335-351.

Emodi, N. V. and Ebele, N. E. (2016). Policies Promoting Renewable Energy Development and Implications for Nigeria. *British Journal of Environment & Climate Change*, 6(1), 1-17. https://doi.org/10.9734/BJECC/2016/24628

Emodi, N. V. and Ebele, N. E. (2016). Policies Promoting Renewable Energy Development and Implications for Nigeria. *British Journal of Environment & Climate Change,* 6(1), 1-17. https://doi.org/10.9734/BJECC/2016/24628

Enibe, S. O. and Odukwe, A. O. (1990). Patterns of Energy Consumption in Nigeria. Energy Conversion and Management, 30(2), 69-73. https://doi.org/10.1016/0196-8904(90)90015-Q

Esan, A. A. (2003). Preparedness on Development Green Energy for Rural Income Generation-Nigeria's Country.
Paper UNIDO, INSHP/IC SHP, Hangzhou, China June 19-23, 2003.

European Photovoltaic Industry Association. (2012). Global Market Outlook for Photovoltaics until 2016.
Available at: http://www.epia.org/home (Accessed 30 June 2014).

Federal Ministry of Power (FMP). (2015). Federal Ministry of Power: National Renewable Energy and Energy Efficiency Policy (NREEEP) for the Electricity Sector (May 2015), Abuja, Nigeria.

Fouquet, D. and Johansson, T. (2005). Energy and environmental tax models from Europe and their link to other instruments for sustainability: policy evaluation and dynamics of regional integration. *In Presentation at the Eighth Senior Policy Advisory Committee Meeting, Beijing, China.*

Garba, N. A. and Zangina, U. (2015). Rice straw & husk as potential sources for mini-grid rural electricity in Nigeria. *Int. Journal of Applied Sciences and Engineering Research*, 4(4), 523 – 530.

GIZ. (2015). Hydro Power Potential Assessment for Partner States, Abuja, Lagos.

Heider, C. Taylor-Dormond, M., Gaarder, M., Atur, V. and Jammi, R. (2015). World Bank Group Support to Electricity Access, FY2000–FY2014, World Bank.

Hepbasli, A. (2008). A key review on exergetic analysis and assessment of renewable energy resources for a sustainable future. *Renewable and Sustainable Energy Reviews,* 12, 593-661. https://doi.org/10.1016/j.rser.2006.10.001

Hogg, K. and O'Regan, R. (2010). Renewable energy support mechanisms: An overview. PricewaterhouseCoopers LLP, Globe Law and Business.

IAEA/ECN. (2007). Assessment of Energy Options and Strategies for Nigeria: Energy Demand, Supply and Environmental Analysis for Sustainable Energy Development (2000-2030).

Idemudia, I. G. and Nordstrom, D. B. (2016). Nigerian Power Sector: Opportunities and Challenges for Investment in 2016. *Number 1930, 1 – 15, Latham & Watkins, Lagos, Nigeria.*

International Atomic Energy Agency (IAEA). (2009). IAEA Tools and Methodologies for Energy System Planning and Nuclear Energy System Assessments. *Department of Nuclear Energy*, Austria, 1-36.

IEA. (2007). Energy Poverty Action Initiative, Brochure. Paris, France:
International Energy Agency. IEA. (2013). Key World Energy Statistics, Paris, France.

IEA. (2014). World Energy Outlook, Paris, France.

Ismaila, H. Z. (2006). Hydro Power Resources in Nigeria. Being a country position *paper presented at the 2nd Hydro Power for Today Conference International Centre on Small Hydro Power (IC-SHP) , Hangzhou, China.*

Iyke, B. N. (2015). Electricity consumption and economic growth in Nigeria: A revisit of the energy-growth debate.
Energy Economics, 51, 166–176. https://doi.org/10.1016/j.eneco.2015.05.024

Joelsson, J. (2011). On Swedish bioenergy strategies to reduce CO_2 emissions and oil use.

Karakosta, C., Doukas, H. and Psarras, J. (2008). A decision support approach for the sustainable transfer of energy technologies under the Kyoto Protocol. *American Journal of Applied Sciences*, 5(12), 1720–1729. https://doi.org/10.3844/ajassp.2008.1720.1729

Karakosta, C., Flamos, A. and Doukas, H. (2010). Sustainable energy technology transfers through the CDM? Application of participatory approaches for decision making facilitation. *Int. J. Environmental Policy and Decision Making*, 1(1), 1-16. https://doi.org/10.1504/IJEPDM.2010.033908

Kela, R., Usman, K. M. and Tijjani, A. (2012). Potentials of Small Hydro Power in Nigeria: The Current Status and Investment Opportunities. *Natural Gas*, 9(12), 1703.

Kok, M., Metz, B., Verhagen, J. and Rooijen, S. V. (2008). Integrating Development and Climate Policies: National and International Benefits. *Climate Policy*, 8, 103–118. https://doi.org/10.3763/cpol.2007.0436

KPMG. (2011). Taxes and Incentives for Renewable Energy. *Energy & Natural Resources*. Available at: https://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/Taxes-Incentives- Renewable-Energy-2011.pdf

Kuku, T. A. (2009). Renewable Energy for Sustainable Socio-Economic Development of the Nation, Nigeria, *Keynote paper presented at the International Conference/Workshop on Renewable Energy, an option to Nigeria Energy Challenges, Covenant University, Ota, 13th to 17th July, 2009.*

Ladan, M. (2009). Policy, legislative and regulatory challenges in promoting efficient and renewable energy for sustainable development and climate change mitigation in Nigeria. *In: Proceedings of the 2nd Scientific Conference of Assellau, University of Nairobi Nairobi. ABU Press, 23–25 Mar 2009. Nairobi, Kenya*. https://doi.org/10.2139/ssrn.2336130

Lahmeyer. (2005). Wind Energy Resource Mapping and Related Works Project. *Lahmeyer International, 2005, Bad Vilbel, Germany.*

Lawal, D. and Ojo, T. (2017). Power Sector Report – Changing Potential to Reality. *Cardinalstone Research*, 1-50.

Lazarov, V. D., Notton, G., Zarkov, Z. and Bochev, I. (2005). Hybrid power systems with renewable energy sources types, structures, trends for research and development. *Proceeding of International Conference ELMA*, 515- 20.

Lorenzini, G., Biserni, C. and Flacco, G. (2010). *Solar Thermal and Biomass Energy*. WIT Press Ashurst Lodge, Ashurst, Southampton, SO40 7AA, UK.

Ministry of Economy. (2002). Planning of the sectors of electricity and gas development of the networks of transport 2002–2011. *Madrid: Secretary of State of Energy*, Industrial Development and of the Small and Medium Company. Main directorate of Power Policy and Mines.

Ministry of Economy Trade and Industry (METI). (2014). *New Strategic Energy Plan*, METI, Japan.

Mohammeda, Y. S., Mustafa, M. W., Bashir, N. and Mokhtar, A. S. (2013). Renewable energy resources for distributed power generation in Nigeria: A review of the potential. *Renewable and Sustainable Energy Reviews,* 22, 257–268. https://doi.org/10.1016/j.rser.2013.01.020

NBS. (2009). Social Statistics in Nigeria*,* Abuja: National Bureau of Statistics.

NBS. (2011). National Bureau of Statistics (NBS) Annual abstract of statistics 2011. Available at: http://www.nigerianstat.gov.ng (Accessed February 2015).

NERC. (2012). Nigerian Electricity Regulatory Commission Regulations for Embedded Generation 2011 (January 2012).

NERC. (2015). Order No. NERC/REG/3/2015. Amended Multi Year Order Tariff (MYTO)-2.1 for the period April 1st, 2015 to December 2018, Abuja, Nigeria.

Nigerian Minister of Power, Works and Housing. (2016). Opportunities for off-grid solutions in the Nigerian power sector. Available at: http://www.nipc.gov.ng (Accessed 30 June 2016).

Nnaji, C. E., Uzoma, C. C. and Chukwu, J. O. (2010). The Role of Renewable Energy Resources in Poverty Alleviation and Sustainable Development in Nigeria. *Continental J. Social Sciences,* 3, 31-37.

Nwanya, S. C. (1998). Modelling Energy Pattern in the Industrial Sector of Nigeria. *M.Sc Project, University of Nigeria*, Nsukka, Nigeria, 1-79.

Obideyi, O. O. (2017). Integrating Renewable Energy into Nigeria's Energy Mix: Implications for Nigeria's Energy Security. *Master's Thesis, Norwegian University of Life Sciences, Norway*.

Odhiambo, N. M. (2014). Energy dependence in developing countries: does the level of income matter? *Atl. Econ. J.,* 42, 65–77. https://doi.org/10.1007/s11293-013-9402-2

Ogwueleke, T. (2009). Municipal Solid *Waste Characteristics and Management in Nigeria. Iranian* Journal of Environmental Health Science and Engineering, 6(3), 173-180.

Okafor, F. N. (2017). Improving Electric Power Sector Performance: The Role of Nigeria Electricity Regulatory Commission. *Nigerian Academy of Engineering 2017 Public Lecture held on March 29, 2017 at University of Lagos*, Akoka, Lagos, Nigeria, 1-14.

Okoligwe, N. E. and Okezie, A. I. (2014). Relationship between Electricity Consumption and Economic Growth: Evidence from Nigeria (1971-2012). *Academic Journal of Interdisciplinary Studies*, MCSER Publishing, Rome-Italy, 3(5), 137-152.

Okundamiya, M. S. and Omorogiuwa, O. (2015). Viability of a Photovoltaic-Diesel-Battery Hybrid Power System in Nigeria. *Iranica Journal of Energy and Environment*, 6(1), 5-12. https://doi.org/10.5829/idosi.ijee.2015.06.01.03 Oladeji, A. S. and Sule, B. F. (2015). Electrical Load Survey and Forecast for a Decentralized Hybrid Power System at Elebu, Kwara State, Nigeria. *Nigerian Journal of Technology,* 34(3), 591-598.https://doi.org/10.4314/njt.v34i3.23

Olatomiwa, L., Mekhilef, S. and Ohunakin, O. S. (2016). Hybrid renewable power supply for rural health clinics (RHC) in six geo-political zones of Nigeria. *Sustainable Energy Technologies and Assessments,* 13, 1–12. https://doi.org/10.1016/j.seta.2015.11.001

Olurinde, L. (2015). Renewable Energy in Nigeria: A Final Report Prepared for Embassy of the Republic of Korea. *Centre for Renewable Energy Technology*, Nigeria, 1-69.

Oseni, M. O. (2011). An analysis of the power sector performance in Nigeria. *Renewable and Sustainable Energy Reviews*, 15, 4765-4774. https://doi.org/10.1016/j.rser.2011.07.075

Oseni, M. O. (2012). Improving households' access to electricity and energy consumption pattern in Nigeria: Renewable energy alternative. *Renewable and Sustainable Energy Reviews,* 16, 3967-3974. https://doi.org/10.1016/j.rser.2012.03.010

Osueke, C. O. and Ezeh, C. T. (2011). Assessment of Nigeria power sub-sector and electricity generation projections. *International Journal of Scientific & Engineering Research*, 2(11), 1-7.

Otuna, J. A., Onemano, J. A. and Alayande, A. W. (2012). Assessment of the Hydropower Potential of Kangimi Reservoir in Kaduna State Nigeria. *Nigerian Journal of Technology (NIJOTECH),* 31(3), 300-307.

Oyedepo, S. O. and Fagbenle R. O. (2011). A Study of Implementation of Preventive Maintenance Programme in Nigeria Power Industry—Egbin Thermal Power Plant, Case

Study. *Energy and Power Engineering*, 3, 207-220. https://doi.org/10.4236/epe.2011.33027 https://doi.org/10.1186/2251-6832-3-7

Oyedepo, S. O., Adaramola, M. S. and Paul, S. S. (2012). Analysis of wind speed data and wind energy potential in three selected locations in south-east Nigeria. *International Journal of Energy and Environmental Engineering*, 3(7), 1-11. Available at: http://www.journal-ijeee.com/content/3/1/7 https://doi.org/10.1186/2192-0567-2-15 Oyedepo, S. O. (2012a). Energy and sustainable development in Nigeria: the way forward. *Energy, Sustainability and Society*, 2(15), 1-17. Available at: http://www.energsustainsoc.com/content/2/1/15

Oyedepo, S. O. (2012b). On energy for sustainable development in Nigeria. *Renewable and Sustainable Energy Reviews*, 16, 2583– 2598. https://doi.org/10.1016/j.rser.2012.02.010

Oyedepo, S. O. (2013). Energy in Perspective of Sustainable Development in Nigeria. *Sustainable Energy,* 1(2), 14- 25.

Oyedepo, S. O. (2014a). Towards achieving energy for sustainable development in Nigeria. *Renewable and Sustainable Energy Reviews,* 34, 255–272. https://doi.org/10.1016/j.rser.2014.03.019

Oyedepo, S. O. (2014b). Development of Small Hydropower: A Pathway towards Achieving Sustainable Energy Development, In: Rupert, C.E (Ed.) Hydropower Types, *Development Strategies and Environmental Impacts*, Nova Science Publishers, Inc., New York: 67-119.

Oyedepo, S. O., Fagbenle, R. O., Adefila, S. S. and Adavbiele, S. A. (2014). Performance evaluation and economic analysis of a gas turbine power plant in Nigeria. *Energy Conversion and Management,* 79, 431-440. https://doi.org/10.1016/j.enconman.2013.12.034

Painuly, J. P. (2001). Barriers to Renewable Energy Penetration: A Framework for Analysis. *Renewable Energy*, 24, 73–89. https://doi.org/10.1016/S0960-1481(00)00186-5

Pereira, E. G., Da Silva, J. N., De Oliveira, J. L. and Machado, C. S. (2012). Sustainable energy: A review of gasification technologies. *Renewable Sustainable Energy Review*, 16, 4753-4762. https://doi.org/10.1016/j.rser.2012.04.023

Renewable Energy Master Plan. (2006).

Sambo, A. S. (2008). Matching Electricity Supply with Demand in Nigeria. *International Association for Energy Economics*, 4th Quarter, 32 – 36.

Sambo, A. S. (2018), Energy Crisis in Nigeria: Engineers' Proactive Steps towards Energy Self-Sufficiency. *Lecture as the First in the Series of the Distinguished Lectures in honour of Engr. Dr. E. J. S. Uujamhan, at the University of Benin*, Benin City, on the 6th Day of April, 2018, 1-27.

Shaaban, M. and Petinrin, J. O. (2014). Renewable energy potentials in Nigeria: Meeting rural energy needs. *Renewable and Sustainable Energy Reviews*, 29, 72-84. https://doi.org/10.1016/j.rser.2013.08.078

Siddaiah, R. and Saini, R. P. (2016). A Review on Planning, Configurations, Modeling and Optimization Techniques of Hybrid Renewable Energy Systems for off Grid Applications.

Simonyan, K. J. and Fasina, O. (2013). Biomass resources and bioenergy potentials in Nigeria. *African Journal of Agricultural Research*, 8(40), 4975-89.

Sustainable Energy for All Initiative (SE4ALL). (2012). *In Support of the Objective to Achieve Universal Access to Modern Energy Services by 2030*. Technical Report of Task Force 1: New York. http://www.sustainableenergyforall.org/about-us.

Twidell, J. and Weir, T. (2015). Renewable Energy Resources (3rd Ed.), *Routledge, Taylor & Francis Group, 711 Third Avenue, New York, NY 10017.*

Usman, Z. G. and Abbasoglu, S. (2015). An Overview of Power Sector Laws, Policies and Reforms in Nigeria. *Asian Transactions on Engineering,* 4(2), 6-12.

Udoudoh, F. P. and Umoren, V. E. (2015). An Appraisal of Public Electricity Performance and its Implications on Economic Development in Nigeria. *Sacha Journal of Environmental Studies,* 5(1), 63-73.

United Nations. (2006). The millennium development goals report, United Nations, New York.

Vincent-Akpu, I. (2012). Renewable Energy Potentials in Nigeria. *IAIA12 Conference Proceedings Energy Future The Role of Impact Assessment, 32nd Annual Meeting of the International Association for Impact Assessment*, 27 May-1 June 2012, Porto-Portugal.

WADE. (2009). More for Less: How Decentralised Energy Can Deliver Cleaner, Cheaper and More Efficient Energy in Nigeria, ICEED. Available at: http://www.localpower.org

Wei-Ming, C., Hana, K. and Hideka, Y. (2014). Renewable energy in eastern Asia: Renewable energy policy review and comparative SWOT analysis for promoting renewable energy in Japan, South Korea, and Taiwan. *Energy Policy,* 74, 319-329. https://doi.org/10.1016/j.enpol.2014.08.019

Werner, D. and Faruk, Y. Y. (2015). *An Overview with a Special Emphasis on Renewable Energy, Energy Efficiency and Rural Electrification*. 2nd Edition, June 2015, Nigerian Energy Support Programme (NESP), Federal Secretariat Complex Shehu Shagari Way, Maitama, Abuja, Nigeria, 1-152.

World Bank. (1991). World Development Report: The Challenge of Development. Oxford University Press. World Bank, New York (https://openknowledge.worldbank.org/handle/10986/5974 License: CC BY 3.0 IGO).

World Bank. (2013). Low-Carbon Development Opportunities for Nigeria, Raffaello Cervigni, John Allen Rogers, and Max Henrion, (eds.), (International Bank for Reconstruction and Development/The World Bank, Washington, 2013), Washington, USA.

World Bank. (2014). World Development Indicators. Available at: http://data.worldbank.org/products/wdi Zubairu, G. U., Serkan, A., Neyre, T. E. and Murat, F. (2015). Transforming the Nigerian Power Sector for Sustainable Development. *Energy Policy,* 87, 429–437. https://doi.org/10.1016/j.enpol.2015.09.004