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Innovating for sustainable, reliable and adequate electricity supplies in South Africa and Nigeria: Which way and why

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Abstract

This research sought to determine the most readily available modes of innovation in South Africa and Nigeria to exploit both conventional and renewable energy sources to generate adequate and reliable electricity as part of meeting sustainable development objectives. The qualitative research analysed a variety of documents and made two important findings. First, both South Africa and Nigeria's innovation abilities lag those of competing economies, most notable China, with Nigeria facing the most severe innovation constraints. Second, despite limitations, both country's have exhibited innovation abilities that can be applied to increase the supply of sustainable, adequate and reliable electricity. However, the modes of innovation towards this end differs between the two countries. South Africa's economic structure, particularly an established manufacturing and service industry base make it fertile ground for innovations around the commercial scaling-up of established innovations. In contrast, Nigeria's economic structure characterised by a limited but growing manufacturing and service industry base renders the country suitable for adaptation innovation involving the development of acceptance of innovative technologies and preparing the market for these technologies. The study concludes that although these innovation modes are not at the technology frontier, they offer both countries opportunities to increase their global trade status through the lowering of barriers of integration into global value chains, simultaneously with increasing the commercial and social acceptance of technologies, retarding environmental degradation, creating employment and improving social welfare.

Key words: Electricity, innovation, adequate, reliable, sustainable development

Introduction

The search for means to improve the living standards of the majority of citizens in the developing countries has been the pre-occupation of a variety of stakeholders. The intensity of the search increased towards the end of the 20th century and continues in the 21st century. One of the reasons for underdevelopment is the difference between the attention that developed economies pay for improving the output, efficiency, and profitability of economic activity compared to their lesser developed counterparts. Improvements result from either the employment of new technologies or the reconfiguration of existing technologies. This process is the essence of innovation. It partly explains the state of being developed or underdeveloped.

A major economic development and growth challenge of the 21st century is the sustainable provision of appropriate, adequate and reliable stock of infrastructure in a manner that addresses social, environmental and economic inequities and related concerns. The sustainability consideration has gained currency against the challenge of balancing these three concerns that traditionally have been viewed as being in conflict (Campbell, 1996). This is because the modern world has come to realise that achieving 'harmony' between these objectives is critical for long term human survival. The argument is that not only are economic growth and development compatible with environmental protection but in fact, equal consideration of the two aspects can actually yield better economic growth and development (Jacobs, 2013). For developing economies this realisation is important because the economic development technologies that previously gave minimal consideration to this balance are now frowned upon. Policy advice is to avoid or minimise the employment of such technologies and instead seek those that simultaneously enhance economic, environmental and human welfare.

The question is; how can this policy advice be implemented? A readily available and viable response to this question is; innovate. Innovation can make a difference in addressing developmental challenges such as the provision of relevant, adequate and reliable infrastructure that is appropriate to the sustainable development objective(s). Accepting this assertion, this paper explores the current and potential role of innovation in supplying sustainable electricity to power the economic, social and environmental development aspirations of Nigeria and South Africa. The two countries make up the largest (Nigeria based on gross domestic product, GDP) and the most sophisticated (South Africa) economies in Africa. Noting that the nature of innovation is determined by available capacities and capabilities inherent in both the hard and soft infrastructure, this article seeks to meet a single objective; determining the appropriate mode (s) of innovation available to Nigeria and South Africa that can enable the development of appropriate, adequate, reliable and sustainable electricity supply infrastructure. The focus on electricity is important. A reliable supply of electricity is, *ceteris paribus,* critical for the development and maintenance of a competitive manufacturing and service industry base. One of the oldest policy recommendations advanced to primary resource-rich developing economies is creating an adequate and reliable stock of hard and soft infrastructure to support the development of a manufacturing and service industry base to reduce dependence on primary commodities (Auty, 2004; 2000). The advice derives from the political and economic ills that resource richness has been identified to present under specific institutional and policy regimes (Sachs and Warner, 1995; 1999; Auty, 1998).

African governments appear to have taken this policy advice and are diversifying their economies. The Economist (2015), reports that in 2015 the African continent was host of the 12 of the 20 fastest-growing global economies with a footprint in the manufacturing, services and technology sectors. This development implies that these economies are increasingly availing themselves to the positive terms of trade offered by these manufactures and services. This has international trade implications. One such implication is that they are entering the global competitive market of international trade in manufacturers and services. Being innovative is important for staying at the forefront of these industries and earning the associated higher rents. Under the current international development policy regime, a major challenge is to ensure that the appropriate and desired competitive advantage is built and maintained in an economically, environmentally and socially sustainable manner. This paper explores this endeavour through the lenses of electricity supply. The paper unfolds in five major sections including this introduction. The next section briefly outlines the methodology that guided the research.

Methodology

The research advanced to answer a single question: what is the appropriate mode of innovation in South Africa and Nigeria to develop and exploit a sustainable, adequate and reliable electricity supply infrastructure stock? Sustainable development and its related concepts of climate change management and green economy transition have gained prominence. They are key considerations in the formulation, development and operation of almost all modern economic and social infrastructure and activities. To this end, this qualitative research followed the document analysis route to analyse policy and practice sustainability issues in the electricity industry. Document analysis is a systematic procedure for reviewing or evaluating documents (Bowen, 2009). Documents contain text and images that have been recorded without a researcher’s intervention. The researcher examines and interprets the text and images (the data) to develop empirical knowledge and gain understanding of the meaning of the data (Ibid). The data informing this research were accessed data from a variety of sources. Secondary data on competitiveness indicators and manufacturing output were retrieved from the Global Competitiveness Index and World Bank databases. Data on government policy and legislation was retrieved from online available and accessible publications. Further, the research also analysed relevant academic publications on innovation theories and policy analysis.

Conceptualising the electricity supply-sustainable development- innovation links

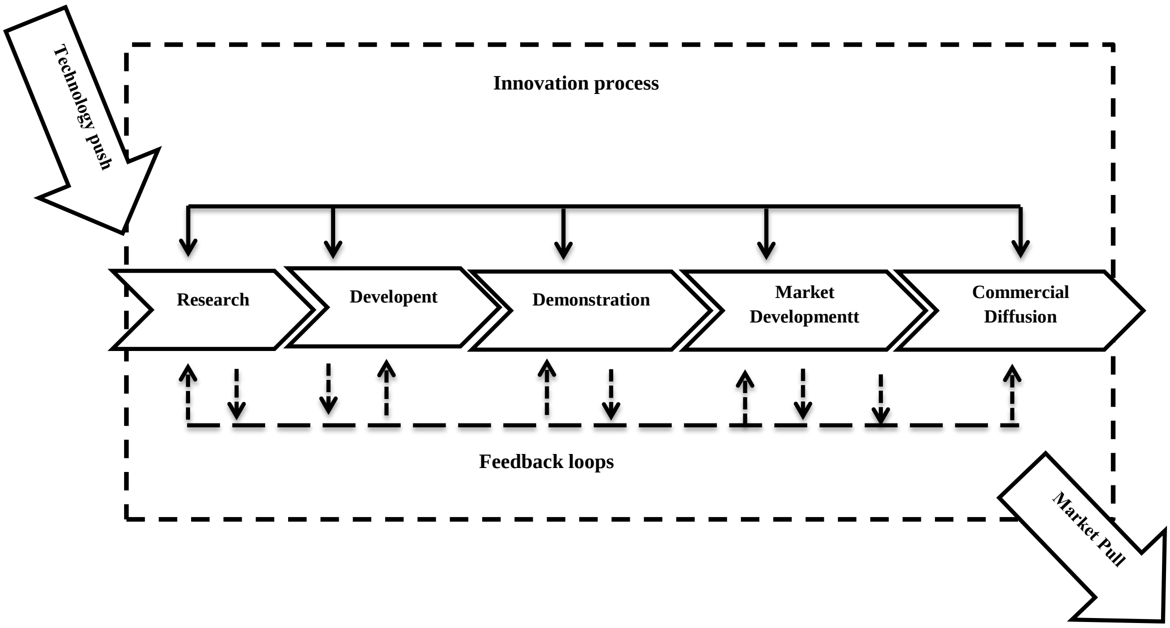
Adequate and reliable energy supplies have been positively identified as key determinants for economic growth (and development) and the reduction of poverty (International Energy Agency [IEA], 2002). Lorde et al., (2010) used a neo-classical aggregate production model treating capital, labour, technology, and energy as separate inputs to demonstrate the effect of electricity supply on economic growth. They established a positive relationship between economic growth and non-residential electricity consumption. Wolde-Rufael (2006) emphasised the same. The scholar added that while an adequate and reliable electricity supply was not the panacea for economic development (in sub-Saharan Africa) it was nevertheless an important one. They further stated that such infrastructure should be developed together with the necessary policy and legislative adjustments to ensure an efficient delivery of electricity and other growth and development facilitating factors.

However, there is a challenge. The current sources of electricity have been identified as major contributors to environmental degradations most notable climate change. The electricity industry contribution to the climate change phenomenon is through the burning of fossil fuels that emit greenhouse gases (GHGs). A key focus of climate change management under the broader sustainable development concept umbrella is seeking means to reduce or eliminate electricity generation activities that emit GHGs. However, and cognisant of the importance of electricity for economic development and growth and human well-being, the challenge is to ensure that the alternative technologies do not compromise any aspect the triple objectives of sustainable development (Kates et al., 2005). Within this realm, the sustainable development discourse has evolved over the years and has come to be viewed under the green growth concept lenses. The evolution and new name derive from the need to spur the global economy out of an economic recession triggered by the 2008 financial collapse first in the United State of America and later in Western Europe. Thus, the green economy concept has emerged as a conduit for realising some of the sustainable development objectives. Climate change management remains the core of the concepts' practice and policy focus. This management falls into two broad theories and practices: climate change adaptation and climate change mitigation.

Climate change adaptation refers to all adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects which, moderate harm or exploits beneficial opportunities arising from climate change (International Panel on Climate Change [IPCC], 2001). The adjustments seek to moderate the adverse effects of climate change and/or to exploit any arising opportunities. The adjustments involve the development of infrastructure that can withstand or aid to cope with the adverse impacts of climate change such as floods, storms and droughts. Climate change mitigation pertains to all human activities aimed at reducing the emissions or enhancing the sinks of greenhouse (Klein et al., 2005). This is realised through technical and infrastructure investments, renewable energy implementation (to reduce climate change and improve energy security), as well as improving energy generation, transmission and use efficiencies (Laukkonen et al., 2009). A common feature of both climate change management approaches is the need to invest in the appropriate, adequate and reliable infrastructures. One of the challenges to this end is modifying entrenched infrastructure hardware and economic and social practices and replacing them with a combination of novel and modifications of this infrastructure and practices. This task dictates the need for innovation(s) that cuts across disciplines, social and economic, political and all other socially constructed boundaries.

Innovation describes the process of searching for, developing, adapting, imitating and adopting technologies that are new to a specific context (Dosi, 1998). Two opposing schools of thought conceptualise this process. The first is a linear model of innovation that argues that "science leads to technology and technology satisfies market needs," (Gibbons et al., 1994:51). The second is the systems of innovation model that disputes the linear model presentation of innovation as a unidirectional process following a linear path that begins with research, then proceed to the processes of development, design and engineering, and production, and terminates with the successful introduction of new products and processes. Instead, it argues that the process in non-linear as it comprises a series of feedback loops (Dantas, 2015) (Figure 1)

Figure 1: An illustration of feedback loop in an innovation system



Source: IRENA, 2014: 4

The systems-oriented perspective argues that rarely do individual organisations internally possess all the capacity and capabilities to fulfil the whole process of innovation (Edquist and Hommen, 1999). Instead, the process is realised through a network of organisations within an economic system. Often, separate and distinct organisations are directly and indirectly involved in the creation, diffusion and use of specific aspects of scientific and technological knowledge, including the coordination, regulation and support of these processes (Dantas, 2015). The system of innovation approach provides an effective framework for analysing the disparate processes that make up the innovation process. Its value is the consideration of production, adaptation, adoption and imitation of new technologies as a system that transcends organisational, sector institutional, regional, national and international boundaries and the series of feedback loops that characterise the innovation process (Dantas, 2015; Edquist, 2001). This system is commonly referred to as the 'innovation system'. Freeman (1987:1) defines it as "The network of institutions in the public and private sector whose activities and interconnections initiate, import and diffuse new technologies". Its structure comprises actors, relations and institutions (the rules of the game). The structural elements are important for marking the boundaries of a system. As a result, the systems often differ considerably between countries and technologies (Negro, Hekkert and Smits, 2008). This difference is an important determinant the mode of innovation that prevalent and/or suitable for a particular country or an industry sector to practice and/or adopt. There are numerous modes of innovation. In this paper, I focus on three modes premised of the degree of fit between available resources and the desired innovation (technologies).

The first mode is adaptation (Internation Renewable Energy Agency [IRENA], 2014; Stum, 2009). This mode pertains to the introduction of existing technologies into new markets (IRENA, 2014). An example is the introduction of solar technologies into economies such as rural settlements that are not served by the electricity grid. Even though the introduction of such technologies to ‘virgin’ territories requires some innovation, such innovations are, however, by design not at the technology frontier. Although this innovation mode applies globally, its domain is largely the developing economies with deficits in skills, finance, markets and other infrastructure and markets to conduct innovations at the technology frontier (IRENA, 2014). Economies operating in this mode primarily focus on innovations around business practices encompassing, marketing, financing and improving the social acceptance of an innovation (Ibid).

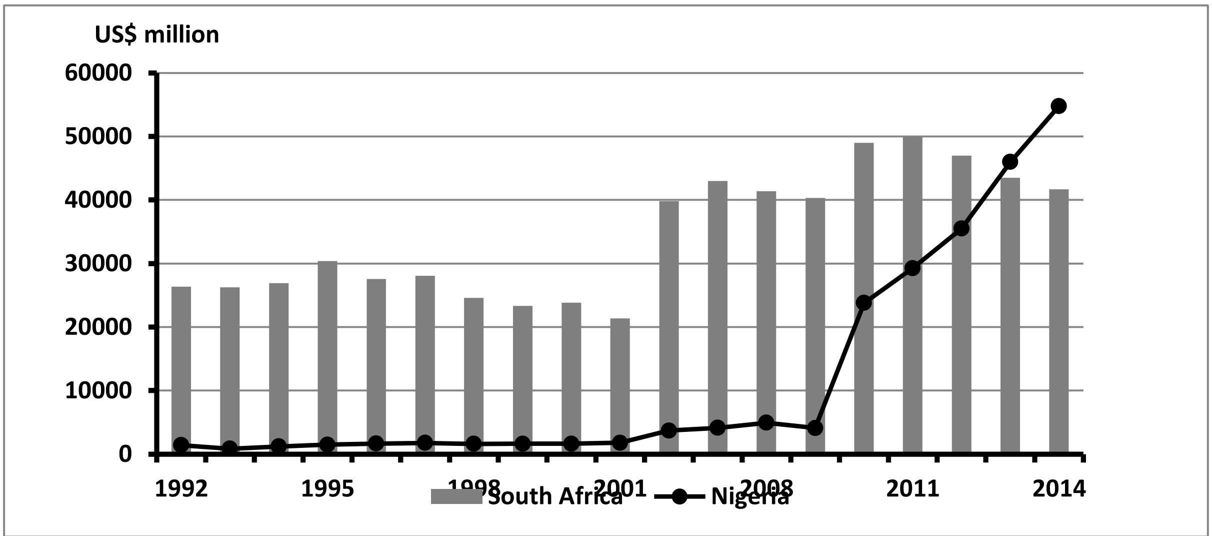
The second mode of innovation is the commercial scale-up (IRENA, 2014). This mode pertains to the process of expanding, adapting and sustaining successful policies, programmes or projects (innovations) in different places and over time to reach a greater number of people (Hartmann and Linn 2008). Its main focus is building industrial capacity around proven technologies across the value chains. Innovation activities range from manufacturing to retail deployment innovations (IRENA, 2014). Building industrial capacity allows for incremental innovation around proven technologies. An enabling environment is critical for this mode of innovation. Issues in this regard include financial resources and financing mechanism, an enabling macro and micro policy and institutional framework, market demand, government and private sector support among others (Linn, 2012). The third and final mode of innovation is the technology venturing mode. This refers to the development efforts to propel a particular technology or system from the research and development stage to the demonstration stage through either by establishing a firm and/or securing financing or by licensing a technology to an existing firm (IRENA, 2014). Typically, this innovation mode involves the production of novel systems, products or both. It is also typically highly research and capital-intensive and is thus largely the preserve of the economies endowed with highly developed human and infrastructure capital. Such economies include Germany, the United States of America and China. Their innovative work has given rise to advanced clean energy technologies that include multi-junction PV cells, third-generation biofuel production systems, and utility-scale tidal power systems (IRENA, 2014).

An important point to note is that although these modes of innovation are discussed as separate, they are not mutually exclusive. Instead countries are at liberty to engage across the entire range of modes and to migrate between (and within) the modes. In this work the distinction serves as an analytical tool to identify the current and the ‘most’ appropriate mode of innovation in South Africa and Nigeria as they engage with the challenge of supplying sustainable electricity to power their economic development and growth. The next section presents the status quo on the electricity industry, innovations and potential for innovation for deepening sustainable electricity in the two countries.

The state of affairs in Nigeria and South Africa

Bildirici et al. (2012) posit a unidirectional relationship between electricity consumption to real gross domestic product (GDP) growth in the United States of America, China, Canada and Brazil. Their findings show that non-domestic electricity consumption acts as a stimulus to economic growth. This and other similar findings to an extent corroborate the experiences of South Africa and Nigeria. For example, the sluggish economic growth of the South African economy is in part attributed infrastructure gaps most notably inadequate energy supply (Kumo, Omilola and Minsat, 2015). Optimism of a two percent GDP growth, and a reversal of current (2015) sluggish growth in based on the anticipated completion of two coal-fired electricity generation plants, the Medupi and Kusile plants (Ibid). Nigeria also suffers a similar deficit with its electricity supply commonly referred to as being unreliable and epileptic (Ologundudu, 2014; Ajao et al., 2009). Electricity outages and voltage fluctuations are a daily occurrence leading to disruptions in the manufactures and service production and in some cases resulting in damages to machinery and equipment (Chete et al., 2012). As a result, most firms rely on self-supply of electricity by using generators. Self-supply electricity is expensive and renders local manufacturing and service provision uncompetitive relative to foreign competition. Unreliable electricity supplies, in part, explain the limited growth in manufacturing in Nigeria compared to South Africa, despite reported increased growth manufacturing in Nigeria as shown in Figure 2.

Figure 2: A comparison of manufacturing value added* of South Africa and Nigeria in current United States dollar (US$) 1992-2014.



Source: World Development Indicators, World Bank, 2015

**Manufacturing refers to industries belonging to ISIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Data are in current U.S. dollars*

The figure shows that based on the current United State dollar (US$) measure, Nigeria has moved to overtake South Africa with regards to manufacturing output. Growth in the Nigerian manufacturing sector is driven by food, cement and textile producers and real estate (Ernest and Young, 2014; Chete et al., 2011). A comparison of economic sectors after GDP re-basing shows a manufacturing sector that is currently growing faster than the telecommunication, oil and gas, and agricultural sectors (Dobbs et al., 2014). However, there are concerns that unless issues that include a reliable and adequate supply of electricity are not addressed, then the further growth in manufacturing may be limited. In contrast, South Africa's manufacturing is showing a contraction. The high cost and erratic electricity supplies have been identified as one the leading cause of limited manufactures production in South Africa (Allix, 2015; Pan-African Research and Investment Services, 2012).

Both South Africa and Nigeria openly admit that the electricity supply challenge is hampering economic development in their desired rate of economic. The two countries have implemented a number of initiatives and are considering additional ones to address this development impediment. An interesting similarity is that the two economies are actively seeking to diversify their sources of electricity for both security and sustainable development reasons.

South Africa's electricity supply security concerns derive from its reliance on fossil fuels for the generation of electricity. Up to 95% of the country's electricity is coal generated in is produced in local power stations (Trollip et al., 2014). The balance is supplied nuclear, petroleum liquid fuel generators and imported from the Cahora Bassa hydro-power plant in Mozambique (Ibid). Coal is a finite resource that will be exhausted in the medium to long term. Under the current conditions this will be disastrous for South Africa. Liquid petroleum products are also similarly finite in addition to their price and supply volatility. The oil price spikes (and volatility) of the 1970s, the first decades of the 2000s and the troughs in between demonstrate the price volatility challenges that present planning difficulties (Radetzki, 2006). The supply challenges in response to price fluctuations and political concerns that include war over the same period illustrate the supply from source challenge (Trollip et al, 2014). South Africa as a net importer of liquid petroleum fuels is thus exposed to these supply and price variation hazards. An additional challenge for coal and petroleum generated electricity is that the burning of the two energy sources emits GHGs, the drivers of climate change.

Noting these and other complexities South Africa has undertaken to address its electricity challenge by seeking to exploit all technically and financially feasible energy sources to generate enough electricity to meet its economic and social demands of this energy. Despite committing to a low carbon development strategy (National Planning Commission, 2011), coal will remain a key component source of electricity in South Africa. The construction of the Medupi Power and Kusile plants indicates commitment to the development of coal generated electricity supply infrastructure. This is a 'logical' development given the country's a substantial reserve of coal deposits. A study by the Council for Geoscience estimated South Africa's coal reserves and resource to be at 66.7-billion tonnes run-of-mine, ROM (Ryan, 2014). ROM refers to raw coal potentially available for delivery to coal preparation facilities or for stockpiling after it has been mined. Noting the carbon emission challenge of coal powered power stations, the new power stations were and are set to be designed as super-critical coal-fired power stations (Glazewski, Gilder and Swanepoel, 2012). This means that the new power stations are set to more efficient compared to older ones. The improved efficiency means that the power station will produce more electricity with less coal, thereby reducing emitted GHGs per unit of electricity generated. In addition, the power plants will have ancillary plants to reduce GHG emissions. Further, the construction and operation of the two plants and other future coal plants is expected to stimulate local manufacturing and services industry to supply input good and services (Glazewski, Gilder and Swanepoel, 2012). For example the power utility Eskom reports that the construction the Kusile plant involves local enterprise development. Through this initiative the Kusile project has spent more than R6.2 billion on 604 companies in the Mpumalanga Province. The majority of the developed enterprises are both black owned and black women owned (Eskom, not dated.)

While coal plants are set to remain the major generators of electricity in South Africa, the government also recognises the importance of renewable energy sources for both energy security and low carbon development vision reasons. To this end, in March 2011 the government of South Africa promulgated the Integrated Resource Plan as informed by Electricity Regulation Act, 2006 (Government of South Africa, 2011). The plan covers the period 2010-2030 and seeks to direct the expansion of electricity from local and regional private, own and public generation and power purchase projects (Ibid). Through a target a mix of electricity sources that include hydro power, solar energy, biomass, gas, nuclear and wind, the IRP seeks to ensure that South Africa has electricity supplies that enable it to meet its sustainable development objectives (Ibid). Consequently the plan seeks to ensure that electricity is generated through an appropriate mix of technologies that can: (1) meet its climate change management objectives, (2) ensures an adequate and reliable supply of electricity, (3) ensure sustainable use of its local and regional resources and (4) creates a local manufacturing base, among other objectives (Ibid). However, there is no quantitative estimate of the renewable energy reserves within this mix (*Viz*, Nigeria Table 1).

The creation of local manufacturing base to serve both the construction (including the design) and maintenance of the mix of electricity generation technologies is a key driver of programmes such the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) launched in 2011. A 2015 Department of Trade and Industry's Industrial Policy Action Plan (IPAP) report states as at December 2014 the programmes had added 4,944 MW of electricity from 64 projects dominated by solar photovoltaic and wind energy technologies (Government of South Africa, 2015). An important development in these projects is that there has been visible progress in developing local manufacturing capacity. Examples in that regard include SMA Solar Technology's establishing of a manufacturing plant in Cape Town in December 2014, the setting up of a solar PV plant in Cape Town by the Chinese firm Jinko Solar and the participation of local South African goods and service providers in the construction of the R 1.5-billion, 100-hectare solar power photovoltaic (PV) plant facility comprising 165,000 solar PV panels in Droogfontein near Kimberly (Ibid). Sentiments from government officials in the department of Trade and Industry, Environmental Affairs and Science and Technology are that the REIPPPP is progressing well despite challenges. They refer to increases in local content. Local supplies have progressed from a threshold of 25 percent in the initial bids to (bid window 1) and 40percent the last bid in 2014 (Government of South Africa, 2015).

While South Africa has been engaging with the IRP, Nigeria has been battling its own electricity supply challenges. Nigeria commercial electricity generation of is from four major sources: natural gas, oil, hydro and coal (Shaaban and Petinrin, 2013). The dominance of the petroleum industry in the Nigerian energy sector means that oil and gas contribute over 70 percent of commercial electricity generation fuel with coal and renewable energy sources relatively neglected (Ibid). As at 2014 Nigeria had a 13,308 MW installed electricity generation capacity comprising both hydro and fossil fuel plants (Ley, Gaines and Ghatikar, 2014). However, the country is yet to fully exploit this capacity resulting in a generation output averaging only 5,000MW to service a population of over 160 million people. This output pales in comparison to South Africa's output of over 40,000 MW for its population of 52million (Omuju, 2014). The government of Nigeria has made attempts to address the electricity supply challenge. A most notable move to this end has been formulation and implementation of the National Electric Power Policy (NEPP) which sought to liberalise the electricity industry of Nigeria (Federal Government of Nigeria, 2001). A major outcome of the reform has been the dismantling of the vertically integrated national utility National Electric Power Authority (NEPA). The NEPP was legally grounded by the Electric Power Sector Reform Act, 2005. The Act formed the legal basis for the transformation of NEPA through fragmenting its assets into separate power generation, transmission and distribution firms under now the Power Holding Company of Nigeria(PHCN as well as the establishment of the regulatory authority, the Nigerian Electricity Regulatory Commission (NERC) as the government agency responsible for regulating operations in the electricity sector.

Further reforms have and are taking place post NEPP. Most notable was the formulation of the National Energy Policy which sought to ensure the efficient and optimal utilisation of the nation's energy resources; both conventional and renewable, for sustainable development and with the active participation of the private sector (Federal Government of Nigeria, 2003). A significant point in the electricity and entire energy sector reforms is the extent to which the government has sought wide systemic policy reforms through outline development visions and targets that match international trends and thinking. Sustainable developments and its offsprings climate change management and green economy transition feature prominently in the electricity industry and general economic reform processes. For instance Nigeria's economic development policy, Nigeria Vision 20:2020 explicitly refers to a need for sustainable development (Federal Government of Nigeria, 2010). The plan explicitly states the need for development projects that consider environmental impacts by promoting the use of renewable energy and halting environmental degradation (Ibid). This vision is complemented by the National Adaptation Strategy and Plan of Action on Climate Change for Nigeria, NASP-CCN (Federal Government of Nigeria 2011). The plan reiterates the government's sustainable development focus, stating the need for the integration of climate change management consideration in development projects and programmes in all economic sectors (Ibid). The importance of exploiting renewable energy sources features prominently in both documents. Consequently, Nigeria has set policy to develop and exploit renewable energy sources.

The first Renewable Energy Master Plan (REMP) for Nigeria was produced in 2006 with support of the United Nations Development Programme, UNDP. The plans articulates a vision of sustainable developing Nigeria with a set roadmap to exploit and utilise renewable energy sources to power its economic growth and development. The vision is to ensure that Nigeria transitions to a nation that is capable of exploiting the available renewable energy sources in quantities and prices that enable equitable and sustainable economic growth and development. The REMP was revised in 2011 and that version seeks to increase the supply of renewable electricity from 13% of total electricity generation in 2015 to 23% in 2025 and 36% by 2030 (Federal Government of Nigeria, 2011). The plan is set to incentivise the formulation and implementation of renewable energy projects development through of a set of fiscal and market policies that include a moratorium on import duties for renewable energy technologies, tax credits, capital incentives and preferential loan opportunities for renewable energy projects. These and other related incentives are envisaged to facilitate the exploitation of the wide variety of potentially exploitable renewable energy sources in Nigeria as shown in Table 1.

Despite this abundance of exploitable renewable energy, their potential contribution to the electricity generation mix is currently not receiving prime consideration. The development of both small and large-scale hydro power plants has been limited by concerns around high development costs and long lead times to complete such projects (Newsom, 2012).

Table 1: Renewable energy reserves and production in Nigeria as at 2014.

Resource type	**Reserves**	**Production**
Small Hydropower	3500MW	30MW
Large Hydropower	11,250MW	1938MW
Wind	Wind speed vary from 1.0 to 5.1 metres/second	No data
Solar Radiation	3.5–7.0kWh/m^2/day (4.2 millionMWh/day using 0.1% landarea	6MWh/day
Biomass		
Fuel wood	11million hectares of forest and woodland	0.120millionton/day
Animal waste	211million assorted animals	0.781million tonnes of waste/day
Energy crops and agriculture residue	28.2 million hectares of arable land(about 30% of total land)	0.256 million tonnes of assorted crops/day

Source: Shaaban and Petinrin, 2014.

There are also concerns about climate change impacts on precipitation patterns and levels that may affect the power generation capacity of such infrastructure (Ibid). These concerns are limiting the exploitation of Nigeria's vast natural water channels. Innovations around the pumped storage present the means of mitigating water losses from hydro-power dams through pumping it back.

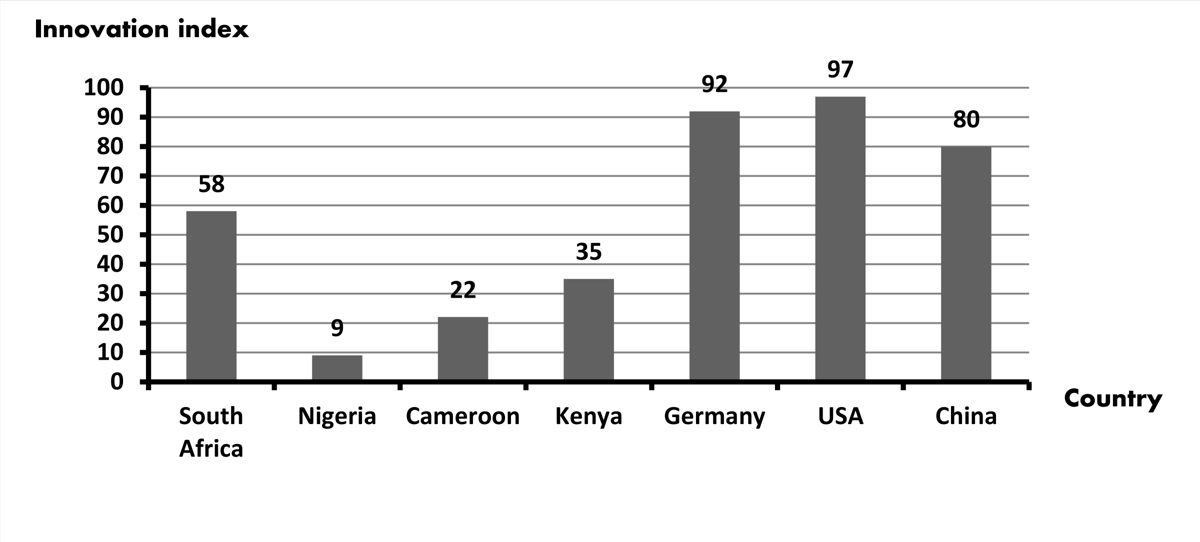
Solar energy is the most promising renewable energy source in Nigeria. The country receives solar radiation with the potential to generate 120, 0000 times more electricity that the NEPA 2002 generation output (Ohunakin, 2010). To this end, solar has received considerable attention with a particular focus on lighting and refrigeration. The lack of political will, skills and commercial activity have been identified as a major factor impeding progress in fully exploiting this energy source (Ibid). Although there have been limited local innovations around solar technologies that include solar water heaters, solar water distillation and refrigerators, and cooker, the supply and innovation in components that include solar module, batteries, inverters, chargers and pumps still relies on imports. One of the most notable local innovations and manufacturing development is the international award winning KXN Nigeria solar fridge. Despite this innovation frontier fridge, there still is a limited development in the country's manufacturing capacity around solar components.

Biomass is another under-exploited energy resource. Biomass, most commonly firewood remains a major source of fuel in rural Nigeria, where wood harvesting is leading to deforestation leading to the reduction of carbon sinks (Shabaan and Petinrin, 2014). The Netherlands has innovated and demonstrate the efficacy of biomass as a viable feedstock for electricity generation plants. Driven by government's climate change management policies, the country's electricity generators have developed a number of co-firing and stand-alone electricity generation plants (Negro et al., 2008). The Netherland's experience provides potential learning points for Nigeria to similarly and innovatively exploit its large biomass reserves for electricity generation. Similarly, wind power has not been exploited because the country falls on the poor to moderate ranking in terms of its wind regime (Ohunakin, 2010). Despite this, some parts of Nigeria have exploitable wind power sites. Among others the sites include: Borno, Yobe and Sokoto with potential generation capacities of 9,561; 5, 897and 3, 801Megawat hour per year respectively (Shabaan and Petinrin, 2014). Innovations largely around the development of turbines that can viably exploit lesser wind potentials, could enable the country to exploit this energy resource.

While both South Africa and Nigeria wrestle the challenge of supplying adequate and reliable electricity through the sustainable exploitation of their abundant conventional and renewable energy sources, a major question is: how ready are the two economies for innovations that can propel this objective? The answer to this question is partly resident with each country's ability to innovate within and outside the power industry. The Global Innovation Index (GII) is a useful measure of a country's ability to innovate. The index relies on sub-indices and key pillars that support each of the sub-index. The GII framework is adjusted annually to accommodate changes in indices, sub-indices and pillar. The 2015 GII used in this article is informed by two sub-indices, the Innovation Input Sub-Index and the Innovation Output Sub-Index. Each sub-index is constructed around pillars that incorporate components of national economies that enable innovative activities, namely: (1) 1nstitutions, (2) human capital and research, (3) infrastructure, (4) market sophistication, and (5) business sophistication; two output pillars that capture actual evidence of innovation outputs: (6) knowledge and technology outputs and (7) creative outputs. The ability to innovate is indicated by a percentage score ranging from zero to 100 where zero indicates a lack of ability to innovate and 100 percent absolute ability. An inter-country comparison of the GII between the two countries against other leading innovators is shown in Figure 3.

The figure shows three interesting results. The first is that South Africa's scores above Nigeria with a score of 58percent in comparison with nine percent for the latter. The second is that although Nigeria is Africa's largest economy measure by GDP (after re-basing of GDP in 2014), its ability to innovate is far below that of Kenya a powerhouse of the East African community and Cameroon an economic powerhouse of the Economic Community of Central African States (ECCAS). Third and finally, all the highlighted African countries trail the leading economies in innovation ability. Germany has leveraged its innovation capacity to develop a viable solar technology industry, even though the country's solar resource is far less than that of South Africa, Nigeria, Kenya and Cameroon (IRENA, 2014). This raises the question of the source of Germany's (including China and the USA) greater ability to innovate better that the respective African countries. An examination of the pillars of innovation explains the innovation ability disparities (Table 2). The table shows that Nigeria scored low in all the key pillar aspects, scoring a paltry three percent on the human capital and research and business sophistication measures. South Africa on the other hand scored above 50 percent on the institutions, knowledge and technology output and market sophistication measures. The latter confirms South Africa's status as Africa's most sophisticated economy.

Figure 3: A comparison of the 2015 GIIs of South Africa, Nigeria, Cameroon, Kenya, Germany, the USA and China.



Source: GII 2015

Table 2: A comparison of 2015 innovation pillar sub-indices of South Africa, Nigeria, Cameroon, Kenya, Germany, the USA and China.

	Parameter						
Country	**Institutions**	**Human Capital and Research**	**Infrastructure**	**Knowledge and technology output**	**Creative output**	**Business sophistication**	**Market sophistication**
South Africa	70	47	37	59	46	49	84
Nigeria	6	3	12	26	21	3	14
Cameroon	11	21	6	19	52	27	22
Kenya	32	11	22	42	40	39	31
Germany	86	94	88	94	91	86	85
USA	89	91	91	98	84	94	100
China	36	79	78	99	62	79	59

Source: GII, 2015

An interesting observation is that China; the "world factory" and a source of a number of innovations scored high on all pillars except for the quality of its institutions. However, the country is rated a better innovator compared to Africa's most sophisticated economy, South Africa. This indicates that it may not be necessary to develop all key pillar aspects to similar levels before notable innovations begin to flow. This tacitly implies that innovations from the least developed countries are possible. The case of the energy efficient solar fridge developed in Nigeria, despite its low GII index reinforces this assertion. However, this is not applicable to all key pillars. The 2014 GII report states that the Human Capital is an indispensable component of the innovation process and a such the development of this capital is critical.

Where to and how South Africa and Nigeria?

The need for adequate, reliable and sustainable electricity supply is critical for both South Africa's and Nigeria' low carbon development visions. Such supplies will enable the development, deepening and widening of local manufacturing and service industry bases fulfilling the long-sought vision of economic diversification. An important component of realising this vision is innovation. The accumulation of innovation capacities has played a pivotal role in the growth dynamics of successful developing countries. A major challenge for developing countries is identifying and **accepting** [emphasis added] how to innovate and why. Identifying and accepting the appropriate innovation mode for any economy is important to avoiding the inefficient utilisation of scarce resources (human, finance and infrastructure) in pursuit of goals that are not immediately attainable.

I base this assertion against the background of economic 'rivalry' that exists between South Africa and Nigeria. Although both countries have had primary commodities (oil in Nigeria and gold, coal and diamonds in South Africa) playing central roles in their economic development efforts, a major distinction is that South Africa has leveraged its mineral wealth to develop a significant manufacturing and services sectors. Nigeria on the other hand has not been equally successful in that regard, although there are important and significant movements in that direction. This difference carries important implications for the development of innovation ability and mode of innovation. It is generally accepted that manufacturing offers great chances for technology spill-overs and innovation. The innovation arises as manufacturers learn more about the products they are producing and thus innovate around its production (learning by doing) (Sagar and van der Zwaan, 2006; Cohen and Levinthal, 1990). Accepting this assertion, it therefore means that the points of departure for South Africa and Nigeria in the pursuit of sustainable, reliable and adequate electricity supply will be and should be different.

As a country with a fairly established manufacturing base, South Africa is most suited to adopting the commercial scale-up mode of innovation. This mode allows the country to adapt and expanding on already tested technologies for commercialisation (IRENA, 2014). This approach relates to one of IPAPs objectives of building a renewable energy manufacturing base in South Africa. Closely related to this is the Green Economy Accord that seek to create green jobs up to five million green jobs by the year 2020 (Government of South Africa, 2011). As a key component of climate change management and green economy transition process, the energy sector will be pivotal in the endeavour. The establishing of solar technology assembly plants and the manufacture of component of electricity windmills indicate a country moving in that direction. The majority of the manufacturing (both fabrication and assembly) is largely under the management and branding of foreign firms[1]. However, this does not mean that South Africa should lock itself to this innovation mode in perpetuity. The country has previously indicated innovation ability and leadership, particularly in underground mining technologies where it is (was) at the frontier of innovation (Kaplan, 2011). This innovation capacity and ability can, in principle, be tapped to inform the energy sector. The system that gave rise to these innovations can be exploited for the benefit of the energy sector. However, there is a need for South Africa to improve the quantity and quality of its human capital and research facilities, creative output, address its infrastructure

[1] I am grateful to an official at the Department of Trade and Industry for this comment.

deficits and improve the sophistication of its business environment if it is to compete with other leading innovators including China.

Nigeria on the other hand shows an economy that is appropriate to the adaptive mode of innovation. The limited development of a manufacturing and service industry base means that as Nigeria begins to diversify its economy, one of the low hanging fruits would be the focus on increasing the social acceptance of alternative energy technologies and improving the marketing and distribution of these technologies in Nigeria. Indications are that Nigeria embarked on this route from the 1990s with a special focus on solar technology (Newsom, 2012). Solar technologies have been applied to water pumping and rural lighting. While the innovation of eliminating the need for batteries and inverters for the water-pumping solar technology by opting for a system that pumped water during the day has been acknowledged, the system faces a number of challenges. Most notable in this regard are: the high capital costs for the targeted beneficiaries, limited technical capacity and capabilities to maintain the system and limited operating times of the system as it does not pump water overnight (Ibid). Similarly, the initial lighting systems were limited by cost and durability. Despite these and other challenges Nigeria has continued to innovate. A significant effort to this end efforts aimed at addressing the 'misconceptions' around solar technology failures that characterise the first stab at introducing this technology in Nigeria. Newsom (2012: 21) refers to Nigeria's solar market as the 'broken market.' The source of the break is the numerous failed projects regarding that technology. An example of such projects is the failed solar street lighting projects in Rivers State and Bayelsa and improperly designed, installed and at times even incomplete projects arising from patronage contracting (Ibid). The author states that future movements in the renewable energy supply market need to address trust issues through educating the private and public sector stakeholders so as to develop a full captive market. In addition, there is a need to address all the weak pillars of innovation initially focusing on those that relate to the adaptation mode of innovation. The pillars include improved marketing to gain social acceptance and affordability of the technologies for the citizens many of whom are unemployed. Through such moves, Nigeria can leverage its huge internal market potential (the highest population in Africa) as well as regional, continental and global markets.

Summing up, both South Africa and Nigeria have to take stock of their abilities and grab the low hanging fruit of a diversified energy mix. This is important to increase the role of manufacturing and services in their economies. Reliance on the primary commodities sector has repeatedly shown the negative impacts of price volatility and the declining terms of trade of primary commodities among other ills. Economic diversification to counter these ills will depend on a diversified and sustainable electricity industry that meet the modern dictates of sustainable development.

Conclusion

Operating in the sustainable development space to manage climate change and responding to the dictates of green economy transition calls for breaking away from the oft-trodden paths. Innovation presents pathways for entrepreneurs to chart new courses and define new boundaries. Innovation is context based and all economies have the adequate stock of hard and soft infrastructure to participate in cutting edge high-rent innovations. However, this deficit is not a barrier to innovating for sustainability. Instead, economies with deficits in the means to participate at the technology frontier of innovation can still profitably exploit lower rent innovation spaces as they slowly build ability to engage in technology frontier innovations.

Through adaptation and commercial scale-up modes of innovation offer developing economies the three means to meet the objectives of the sustainable development concept. The first is that these two modes present an opportunity for participation in labour intensive economic activities. These are critical to addressing the high unemployment levels in the two countries and other developing countries. This is a social as well as an economic issue. The second is that these modes of innovation present low barriers to entry into the manufacturing and service industry. This minimises dependence on primary commodities for economic development and growth. More important, the adaptation and commercial scale-up modes of innovation presents an opportunities for integration into global value chains and earning presently inaccessible higher rents. Such an integration carries positive international trade benefits. Third and finally, the two modes present a means to increase the adoption and use of alternative energy sources and energy producing practices that can mitigate GHG emissions and other environmental ills related to fossil fuel extraction. This covers the environmental management arm of sustainable development.

The challenge for South Africa, Nigeria and other similar countries is identifying and accepting that some technologies are within their abilities and others are not. Policy and institutional regimes need to be adjusted to cater for existing realities if the vision of sustainable electricity supplies is to manifest.

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