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Socio-economic and environmental analysis of wind power projects as viable renewable energy resources in Kenya

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The demand for power in Kenya is on the increase with the ongoing growth of the country's economy. There is a need for the country to balance energy efficiency, sustainability and low-carbon technologies. This entails drafting and implementing policies and strategies towards a low-carbon development path, ranging from fuels, technologies and infrastructure. This work examines the drivers of renewable energy resources in Kenya, focusing on Ngong Wind Farm. Results show that most low-carbon innovations in Kenya are driven by government tariffs and policies. Funding, and political and community goodwill remarkably influence the success of wind power projects in Kenya. The case study is a novel experiment that offers sustainable alternatives in the energy sector. There is need for more investment in the renewable sector, especially in the set up of power plants and power storage. To address the shortcomings in the renewable energy sector, there is a need for further research and development, and collaborations to foster innovations in the wind power sector in country. A combination of knowledge and resources, and leveraging local and national policies are potential ways in which institutional platforms can foster wind technology advancement and dissemination.

Keywords: renewable energy, wind power, low-carbon innovations, Kenya

Introduction

Energy is a very key component for the socio-economic development of any given community. Different communities thus strive to maximize utility of all forms of energy at their disposal to foster development. The conventional energy sources such as oil, coal and natural gas are however highly costly to the environment and human health. These traditional energy sources are thus facing increasing opposition on environmental grounds; with the most challenge being the looming threat of the effects of climate change and global warming. Scientists are thus calling for a reduction in emission of greenhouse gases to contain the environmental situation (Mathur, Bansal, and Wagner 2002; Foxon, Reed, and Stringer 2009).

The need for balancing between energy efficiency, renewable energy and other low-carbon technologies is yet to be achieved globally. While the main drive in the past has been to produce more energy to cope with demand by introducing more low-carbon alternatives (Ngui et al. 2011), the focus is now shifting from not just the amount of energy but to the forms. Many countries, especially developing ones are thus in the process of drafting and implementing policies and strategies towards a low-carbon development path, ranging from fuels technologies and infrastructure.

Policies determine to a large extent the uptake of renewable energy resources in a given country. In Kenya, most low-carbon innovations are driven by government policies. Most of the innovations target existing natural resources. However, most ventures require a huge upfront investment. Implementation of renewable energy sources such as wind and solar power in Kenya just like in many sub-Saharan Africa face challenges since most of these energy sources are often located far from population centres. Thus, a high upfront investment cost and further research and development are required to set up transmission lines to carry the power from remote locations to major population centres (GoK 2014). Given that both wind and solar power are intermittent energy sources, there is need for developing technology for storing intermittent power sources, which are generally technology and capital intensive. Other determinants of the success such projects include societal values, ideas, and practices that result in challenges such as land ownership and compensation disputes. Thus, there is need for employing Strategic Niche Management (SNM), aimed at understanding the working environment under which innovations for sustainability thrive, for guiding governance of related innovations.

Despite the numerous advantages associated with low-carbon technologies, its uptake is very low since the community highly depends on the alternatives such as conventional oil in the energy and transport sectors (Onuonga, Etyang, and Mwabu 2011; GoK 2011a). Financial resources and political goodwill, among other factors, tend to limit such initiatives, rendering the developing and strengthening of innovation systems challenging.

The role of different stakeholders – government, sponsors/financiers, research institutions and users, among others – plays a vital role in the success of building low-carbon energy innovation systems, just like any other project (Magnus and Clarissa 2013). This coordination is lacking in Kenya, where competition characterizes most institutional relationships. For example, a recent study in Kenya by Muok and Kingiri (2015) observed that although civil society plays a vital role in low-carbon innovation in terms of learning and competence-building at the grassroots level, most policies do not recognize their role. The study called for swift interventions in terms of a policy framework to recognize and institutionalize civil society as important players in innovation. The intervention can go further by funding experimental initiatives brought up by civil society actors and create connections with supply avenues for the products.

This study moves beyond Muok and Kingiri's work that focuses on the role of civil society organizations in the building of low-carbon energy innovation systems in Kenya (Muok and Kingiri 2015). Through a wind power case study, the Ngong Wind Farm in Kajiado County, this work looks into how an innovative system can be built. A lot of focus is given to more supporting actors and how they affect overall performance of the system. The outcome of this work will form a good basis for identification of the system gains and weaknesses and propose appropriate measures aimed at boosting functionality of innovation systems related to low-carbon emission technologies in Kenya.

The remaining sections of this work are arranged as follows. The next section provides a literature review, the section after that presents data and methodology, while the results and discussion are given in the penultimate section. The final section gives the conclusion and way forward.

Building a wind energy industry in Kenya

Wind energy resources and energy access for development

Access to the reliable modern energy is critical for socio-economic development today, especially among the poor or in developing countries. The access to grid-based electricity in Kenya is still low despite numerous efforts to boost grid penetration, especially in rural areas. On the other hand, the consumption of energy is on an upward trend as a result of the country's growing economy, especially the manufacturing sector. The country's mix is mainly dependent on geothermal, hydropower, fossil fuels and wind generating sources (Ngui et al. 2011). The country has various forms of renewable energy ranging from hydro-electric power, solar energy, geothermal, wind power and biomass energy, among others. The renewable energy accounts for over 50% of the power sources in the country (Kiplagat, Wang, and Li 2011). These energy forms are generally cheaper to produce in the long run as compared with non-renewable forms, and have minimal or no emission of carbon into the atmosphere (Ullah, Chaudhry, and Chipperfield 2010; Pueyo, Bawakyillenuo, and Osiolo 2016). Although using coal to produce electricity is often the lowest cost choice in developed countries such as the USA and China, taking into account the costs of coal to society in the form of air pollution and climate change makes it very expensive in the long run. The exploitation of renewable forms of energy is dictated by a number of factors, ranging from availability of natural resources, capital, technology, policy and market demands, among others. For instance, hydro-electric power is facing various challenges in Kenya and other developing countries owing to climate variability and change that adversely affects water levels in dams (Kaunda, Kimambo, and Nielsen 2012).

Wind energy stands out as the energy source that is growing at the highest rate in India and globally (Shikha and Kothari 2004). Wind power presents itself as an avenue for reducing electricity cost (Pueyo, Bawakyillenuo, and Osiolo 2016). In remote and inaccessible areas, smaller wind turbines can be used alone or alongside other technologies in hybrid systems, notably diesel generator sets, to meet individual household or community electricity demand (Li et al. 2009); reducing the need to buy as much diesel as before. Urbanized settings that already have ready access to electricity can employ smaller wind turbines in individual establishments (hospitals, factories, schools, government offices, etc.) to reduce reliance on grid electricity to save costs, assist the environment and/or provide a back-up against unreliable or unstable grid produced electricity. Despite the known high potential of renewable energy in Kenya, most of the resources remain untapped.

Policies driving the energy sector in Kenya

Although the implementation of the major wind farms in Kenya was mainly donor driven, currently, the wind sector and the entire energy sector is mainly driven by policies. For instance, the establishment of the Ngong Wind Farm was dependent on the donation from the Belgian Government, but the driver of the whole project turned out to be policy driven when it was left to the Government of Kenya. The government has formulated and effected a number of policies to manage the energy sector by way of policies, institutions and legal frameworks which are revised from time to time whenever there is a need. The country's main regulatory framework and policies driving the renewable energy are: National Energy Policy (NEP), Feed-in Tariff-Scheme (FiT), Power Purchase Agreement (PPA), Electricity Licensing Regulation and Energy Efficiency. Other policies that greatly influence the sector include: Least Cost Power Development Plan (LCPDP), the Kenya National Climate Change Response Strategy (NCCRS) (GoK 2010a) and Kenya Vision 2030 (GoK 2010b). A summary of the regulatory frameworks and policies that govern the energy sector in Kenya is given in Table 1.

The formulation of the NCCRS in 2010 was aimed at strengthening and focusing nationwide actions towards climate change adaptation and greenhouse gases emission mitigation (GoK 2010a). For instance, the NCCRS recommends zero rating of taxes on renewable energy technologies; this will help ease the high upfront cost of wind power technologies. The same policy promotes the promotion of alternative renewable energy, a category in which wind energy falls. Today, wind power stands out as the most attractive energy venture, especially for private firms following the government's introduction and implementation of FiT (GoK 2012a). Through the FiT programme, exclusion from payment of customs duties on equipment used in wind harnessing which are costly has increased importation of the equipment. The scenario is likely to change for the better, on introduction of the expected auction to replace the FiT programme soon.

Table 1: A summary of the regulatory frameworks and policies governing the energy sector in Kenya.

Policy	Year of formulation	Aim
Least Cost Power Development Plan (LCPDP)	2010	The LCPDP was designed to identify existing potential in generation, possible investments in transmission as well as carefully forecasting future demand for power and how best it can be met at least cost for the period of 2011 until 2031. The main objectives of LCPDP are: (i) To review load forecast assumptions including variables, data set and load forecasting methodology, taking into account anticipated performance of the macro-economy. (ii) To review the commissioning dates for committed power generation and transmission projects. (iii) To review and update the power system simulation data, including plant types, system constraints and costs. (iv) To undertake power system transmission simulation. More information on LCPDP can be obtained at: http://www.erc.go.ke/index.php?option=com_docman&task=doc_download&gid=87&Itemid=429
Energy Act of 2006	2006	The Act brings enforcement of energy sector activities under one body, the Energy Regulatory Commission (ERC). The Act also created the Rural Electrification Authority (REA) to manage the Rural Electrification Programme and the Rural Electrification Fund.
Feed-in Tariff (FiT)	2006	FiT aims at providing investment security to renewable electricity generators, reduce administrative and transaction costs and encourage private investors in establishment of Independent Power Production (IPPs). It achieves this by providing a fixed tariff not exceeding 11.0 US cents per Kilowatt-hour of electrical energy supplied in bulk to the grid for wind generated electricity.
Kenya National Climate Change Response Strategy (NCCRS)	2010	NCCRS was adopted to strengthen and focus nationwide actions towards climate change adaptation and greenhouse gases emission mitigation.
Kenya Vision 2030	2007	Kenya has a long-term development strategy, Vision 2030, whose aim is to drive the country into a globally competitive and prosperous economy with a high quality of life. It aims to transform Kenya into a newly industrializing, middle-income country providing a high-quality life to all its citizens by the year 2030. In reference to energy, Vision 2030 observes that the current energy costs in Kenya are higher than those of her competitors in the face of growing energy demand. It thus prioritizes the growth of energy generation and increased efficiency in energy consumption. This will be realized through continued institutional reforms in the energy sector, including a strong regulatory framework, encouraging private generators of power, and separating generation from distribution, as well as securing new sources of energy through exploitation of geothermal power, coal, renewable energy sources, and connecting Kenya to energy-surplus countries in the region.

The Government of Kenya, just like many other Africa countries, is encouraging Independent Power Producers (IPPs), in the renewable energy sector and has introduced a FiT law to attract investments in the energy sector (GoK 2012a). The policy provides a fixed tariff of approximately 11 US cents per Kilowatt-hour for electricity generated by wind-farms in grid connected mode. This tariff applies to all individual wind power plants whose effective generation capacity is above 500 kW, and does not exceed 100 MW.

This has been realized after zero rating/reduction of duty on importation of renewable energy technologies/equipment and the introduction of FiT that promises returns on investment for the risk takers (GoK 2008). The government has zero-rated import duty and removed Value Added Tax (VAT) on renewable energy equipment and accessories. By introducing FiT, the government aims at increasing the number of renewable energy projects and eventually to reap benefits from carbon credits and a reduction in greenhouse gases emissions.

Despite the initiatives the government has put in place, there remains a need to improve technologies that use low-carbon energy. Part of the problem with wind power, for instance, is that it tends to be intermittent. This shows that wind power and many other kinds of renewable energy need to be stored somehow, be it in batteries or other solutions that are being developed. Addressing the challenge of storing intermittent energy sources, like wind and solar power at low cost, can help in reducing the overall costs of a low-carbon electricity system. The whole process implies that another part of the policy of decarbonizing the primary energy system is research and development. Government should therefore invest heavily in new technologies, for instance, in the storage of energy from intermittent power sources.

Climate change and negotiations related to the energy sector in Kenya

Climate change is unequivocal all over the world, with its impacts varying from one region to another, depending on the region's vulnerability to climate change impacts. East Africa is, for instance, just as many developing nations, very vulnerable to the effects of climate change. In Kenya, climate change in characterized by change in variability of extreme climate events and shifts in rainfall patterns. Although rainfall is observed to decrease (Yang et al. 2014; Ongoma and Chen 2017), it is projected to increase throughout the twenty-first century (Shongwe et al. 2011), a case that has not been witnessed so far. In a recent study, Rowell et al. (2015) termed the rainfall condition over Kenya and East Africa at large as a paradox.

At global scale, various institutions such as the United Nations Framework Convention on Climate Change (UNFCCC) advocate for reduction of greenhouse gases to mitigate impacts of climate change. One of the approaches suggested is the adoption of and investment in renewable energy technologies such as wind energy. The UNFCCC pushes its agenda through instruments of climate governance, for example, the famous Kyoto Protocol.

At a country level, a number of negotiations have been concluded to guide in the mitigation of or adaptation to climate change effects. In 2012, Kenya's Climate Change Bill was passed by Parliament (GoK 2012b). The Bill provides a framework for mitigating and adapting to the effects of climate change. This is applied to different sectors of the economy. The Bill further outlines response measures to the effects of climate change, and the funding avenues, coordination and management of climate issues in the country. On the other hand, the country's National Climate Change Response Strategy (NCCRS) points out indicators of climate change in Kenya and climate change impacts on the country, and suggests actions that the country can adopt to reduce these impacts, as well as take advantage of the beneficial effects of climate change.

There are a number of institutions that are working on climate change issues in Kenya. The country has come up with initiatives to promote innovations in and uptake of renewable energy. One of such efforts is Kenya's Climate Innovation Centre (CIC) (www.kenyacic.org). This is an institution that spearheads country-driven support to accelerate development, deployment and transfer of locally relevant climate and clean energy technologies. The institution achieves its mandate by providing incubation, capacity building services and financing to Kenyan entrepreneurs and new ventures that are developing innovative solutions in energy, water and agribusiness to address climate change challenges. The Kenya CIC is funded by the United Kingdom's UKaid and the Danish Ministry of Foreign Affairs.

Kenya Climate Change Working Group (KCCWG) (http://www.kccwg.org) is another institution, but different from CIC. It was formed by members of various civil society organizations and donor partners in Kenya. The group that is mainly donor funded plays a key role as far as climate change is concerned in Kenya. The group advocates and campaigns for positive policy and legislative frameworks that factor effects of climate change on livelihoods. The organization as well coordinates civil society fraternity and government institutions to take part in reasonable climate change talks at various levels, including subsidiary bodies and Conferences of Parties (COP).

Energy institutions in Kenya

The grid-connected facility to the main grid has its electric energy sold and distributed by Kenya Power and Lighting Company (KPLC) under PPA. This is a PPA that is standardized to help cut transaction costs in the process of negotiation and signing contracts. It applies to all projects up to 10 MW. Other key players in the energy sector are: Ministry of Energy (MOE), Energy Tribunal, Energy Regulatory Commission (ERC), Geothermal Development Company (GDC), Rural Electrification Authority (REA), Kenya Electricity Generating Company Ltd (KenGen) and Kenya Electricity Transmission Company (KETRACO). Table 2 gives a summary of institutions in the energy sector and their roles.

Despite the fact that the country is well endowed to produce wind energy, the present contribution of wind as a source of energy in Kenya to the total energy generated is only 0.3%. Recent statistics estimate total annual electricity generation from the wind sector at 17 GWh as compared with 3569 GWh produced by the hydro sector in 2014 (KNBS 2015). Small wind turbines have been used in isolated cases across Kenya since the late 1800s.

Table 2: The institutions in the energy sector in Kenya and their mandate.

Institution	Mandate
Ministry of Energy (MOE)	The MOE formulates and articulates policies through which it provides an enabling environment to all operators and other stakeholders in the energy sector.
Energy Regulatory Commission (ERC)	The ERC is responsible for economic and technical regulation of electric power, renewable energy and the down-stream petroleum sub-sector.
Kenya Generating Company (KenGen)	KenGen is the leading electricity generator, producing almost 80% of the electricity in Kenya. It develops and manages all public power generation facilities in the country.
Kenyan Power and Lighting Company (KPLC)	KPLC is the national power utility responsible for electricity distribution and supply across the country. KPLC retails electricity to customers in Kenya.
Rural Electrification Authority (REA)	REA implements the rural electrification programme, develops and updates the rural electrification master plan, and promotes the uptake of renewable energy sources.
Kenya Electricity Transmission Company (KETRACO)	KETRACO plans, designs, constructs, owns, operates and maintains high-voltage (≥132 kV) electricity transmission infrastructure that will form the backbone of the national transmission grid and regional interconnection.
Geothermal Development Company (GDC)	GDC is charged with the duty of accelerating geothermal development in the country.
Independent Power Producer (IPPs)	IPPs are private investors in the energy sector involved in generation either on a large scale or in renewable energy projects under the Feed-in-Tariff Policy. As at December 2013 there were seven IPPs, accounting for about 24% of the country's installed capacity.
Energy Tribunal	The tribunal arbitrates disputes within the energy sector.

Source: GoK, 2011a

Larger scale, grid-connected wind energy farms in Kenya were only established in the early 1990s. These continue to grow for many reasons, the main one being to diversify the electricity generating sources in Kenya through increasingly 'green' mechanisms. Other reasons include creation of employment as well as enhancement of technology for efficiency purposes.

The Ngong Wind Farm was one of the first to be established in the 1990s. In addition, the country has a list of other wind projects that are either underway or in the planning phase, each at a range of different sizes. The projects are listed in Table 3. Although the Government of Kenya (GoK 2014) classified the 110 MW power plant at Kinangop as committed, the project has failed to take off owing to land disputes between the project management and the local community (The Standard 2016). The local farmers opposed the construction saying they would be forced to sell their land. They also claimed that the turbines could cause health problems.

The country is among Africa's top 27 developing countries with the highest potential for wind energy, measured in years of domestic energy consumption (Buys et al. 2009). The other leading countries in Africa include: Somalia, Sudan, Libya, Egypt, Madagascar and Chad. According to Oludhe (2008), the country has relatively high wind speeds, averaging between 3 and 10 m/s with northern parts recording speeds of up to 11 m/s. The highest wind power potential is observed mostly in Marsabit, Ngong and the coastal areas. In the coastal region, the wind tends also to have both onshore and off-shore potential. Studies (e.g. Oludhe and Ogallo 1996; Oludhe 1998) show that the topographical features around Marsabit and Turkana regions in the north of the country have a marked influence on the wind flow over the northern corridor. There are also a number of small hills and flat plateaus within the country, such as Nyika/Yatta plateau, that have a marked influence on the general characteristics of the surface wind speeds over Kenya (Kamau, Kinyua, and Gathua 2010).

Kenya (Figure 1) experiences tropical weather, mainly influenced by the country's position relative to the equator. The other factors that influence the weather of the country are its nearness to the Indian Ocean and Lake Victoria, and its varied topography (Indeje et al. 2001; Hulme et al. 2005; Oettli and Camberlin 2005; Hession and Moore 2011). The Inter-Tropical Convergence Zone (ITCZ) is also a major synoptic feature that influences the climate over the country. Annual rainfall in Kenya follows a strong bimodal seasonal pattern; the 'long rains' season occur in March to May (MAM), while the 'short rains' season is experienced in October to December (OND) (Camberlin and Philippon 2002; Ogwang et al. 2014; Yang et al. 2015; Ongoma and Chen 2017). Kenya has average estimated wind speeds of 3–10 m/s.

This study investigates the drivers of renewable energy in Kenya, with an emphasis on how social and environmental factors influence the establishment and operations of wind energy. The findings of this study give insight into the factors that drive the building of low-carbon emission systems in Kenya, including their approval. The information is of great importance to policymakers in the energy sector, sponsors and investors.

Area of study

The Ngong Wind Farm project is situated on Ngong Hills, in Kajiado County, in Kenya. The county has an area of 21,900 km^2 and a population of 687,312 people (KNBS 2010). It experiences moderate rainfall ranging from 500 to 1250 mm per annum, and temperatures ranging from a minimum 16°C to a maximum of 32°C. The topography of the county varies greatly; it is mainly characterized by plains and valleys. The altitude spans from about 500m around Lake Magadi to the tune of 2500m around the Ngong.

The Ngong Wind Farm is the first wind project in Kenya. It began its operations as a pilot project in 1993, initiated by Kenya Power, formerly Kenya Power and Lighting Company (KPLC). The project started with two wind turbines as a donation from the Belgian Government. This exemplifies how international cooperation, guided by national and international policies and instruments can greatly assist in the building of low-carbon innovation systems in many developing countries. During the inception, other technology/project/solution choices available included extension of the then existing network, solar panels and diesel generators.

Following the successful completion and operations of the pilot project, KenGen reached an agreement with TPF-Econoler SA (TPFE) of Belgium in 2007 to run the project. The phase two of the Ngong Wind Farm was started in 2008, and was officially commissioned in 2009. The phase two of the project has six turbines of 850 KW each.

The Kenyan government has an installed six windmills with a capacity of 5.1 MW wind power plant. The plant is owned and run by KenGen at the Ngong site near Nairobi County. The wind farm currently consists of six 52 – 850 kW wind turbines. The plant feeds relatively cheap and reliable energy to the country's grid. However, it still operates below it optimum potential. This is attributed to a number of reasons ranging from insufficient wind resource data, lack of financial resources, inadequate infrastructure and extent of grid.

The project is partly financed and fully managed by the government. The KenGen has put in place Stakeholder Coordination Committees (SCC) in all its operation zones which have power plants. This approach was taken to address all key issues of concern through discussion with stakeholders. This has built a harmonious co-existence to the mutual benefit of KenGen, local communities and other stakeholders. A Stakeholder Coordination Committee (SCC) for Ngong Wind farm was initiated and launched in May 2014.

Research methods

This paper outlines the results of a study of the drivers of renewable energy resources in Kenya, focusing on wind power. It is based on primary data collection utilizing document reviews and interviews with key informants. The data collection fieldwork took place in the months of July and August 2015.

Table 3: List of wind power projects in Kenya.

Project	Description	Players
Kipeto Energy Wind Park in Kajiado County	This is the second-largest wind farm project to be constructed at a total cost of US$316 million. The funding is mobilized by the Overseas Private Investment Corporation (OPIC), a US public agency. The total installed capacity of the wind farm is 102.06 MW. It comprises 63 wind turbines, each with a generating capacity of 1.62 MW. Detailed information on the project can be sourced at http://www.evwind.es/2014/10/23/ge-to-install-63-wind-turbines-for-new-kenyan-wind-energy-project/48284 http://www.businessdailyafrica.com/Kajiado-wind-power-farm-gets-Sh17bn-boost/-/539546/2082030/-/7xvyg5/-/index.html	International Finance Corporation (World Bank); General Electric; KPLC; Kipeto Energy Limited; African Infrastructure Investment Managers
Lake Turkana Wind Power Project (LTWP) in Marsabit County	This is expected to be the largest wind power farm in Africa. The project is expected to be finalized by 2017 and begin generating power, nearly after 10 years after its inception. It will be constructed near Laisamis, 550 km north of Kenya's capital Nairobi with a total of 365 wind turbines (each with a capacity of 850 kW). The project is expected to produce 310 MWp when completed, which will save the country US$178 million in fuel imports every year. 'A consortium of investors under the auspices of the European Union is financing this US$690 million project with the African Development Bank as the lead arranger.' This investment by a consortium of European banks makes this wind energy project in Africa unique as most other wind projects are often financed by the Chinese. At a total cost of KES. 70 billion (US$800 million), the LTWP is considered as the 'the largest single private investment in Kenya's history'. The LTWP was 'registered as a Clean Development Mechanism (CDM) project by the United Nations Framework Convention on Climate Change (UNFCCC) in February 2011 with the Gold Standard rating'. The power produced will be sold to the national grid on the basis of the Kenya's FiT policy over a period of 20 years. More information on the project can be found at the project's website: http://www.ltwp.co.ke/	Vestas Wind Systems (Danish wind company); Lake Turkana Wind Power Consortium (LTWP) comprising KP&P Africa B.V., Aldwych International, Industrial Fund for Developing Countries (IFU), and Norwegian Fund for Developing Countries (Norfund); DEWI, Government of Kenya; KETRACO; Spanish Government; Spanish contractor, Isolux Corsan S.A; Aldwych Turkana International Limited; KLP Norfund Investment AS; Danish Investment Fund for Developing Countries (IFU) Denmark; Finnish Fund for Industrial Cooperation Ltd (Finnfund); Sandpiper Limited; African Development Bank; The government of the Netherlands
Kinangop Wind Park in Nyandarua County	This is a 60.8 megawatt wind farm in Kenya's Kinangop region primarily owned by the African Infrastructure Investment Managers (AIIM). 'The project has reached Financial Close and commissioning is expected to occur in mid-2015.' The power it generates will be sufficient to power over 150 000 homes in the county. Similar to Lake Turkana Wind Power Project, Kinangop Wind Farm has been registered for United Nations Clean Energy Mechanism. The power generated will be fed to the national grid under the Power Purchase Agreement with the KPLC. The objective of the 60 MW Kinangop Wind Park Project, which has been proposed by Aeolus Kenya Limited, is to add about 178,520 MWh per year of wind-generated electricity to Kenya's national grid system. More information on the project can be obtained at http://www.norfund.no/eastern-africa/kinangop-wind-park-article1027-319.html	Iberdrola Engineering; General Electric; Aurecon; Aeolus Kenya; Kinangop Wind Farm Ltd.

(*Continued*)

Table 3: Continued.

Project	Description	Players
Ngong Wind Project, Phase II in Kajiado County	The Ngong Wind Power Station was installed in 1993 supported by the government of Belgium. The station had two turbines, which at present are no longer operational. However, in 2009 the second phase of the project was commissioned and upgraded to a 5.1 MW power station. The project was further expanded to consist of 24 additional turbines with a total installed capacity of 25.5 MW at the cost of KES 1.6 billion (US$ 18 million). More information is available at http://www.evwind.es/2015/07/03/wind-power-in-kenya-kengen-develops-400-mw-wind-farm/53156	KenGen; Vestas Wind Systems (Danish wind company)
Baharini Electra Wind Farm in Mombasa County	A news article (dated March 17, 2013) shows that the National Environment Management Agency (NEMA) has received an environmental impact assessment report on a proposed 90 MW Baharini Electra Wind Farm power project. The proposed wind farm will consist of a maximum of 45 wind turbines (each with a generation capacity of 1.8 to 3 MW). Details on the project can be accessed at http://www.businessdailyafrica.com/Nema-seeks-public-views-on-90MW-Lamu-wind-power-project/-/539552/1722624/-/ed8kx2/-/index.html	Electra Winds Kenya Limited (subsidiary of Belgian power company Electrawinds NV)
400 MW wind farm in Meru, Meru County	A recent news article (dated July 3, 2015) shows the KenGen has embarked on developing a 400 MW wind farm in Meru county. The project is expected to be financed by 'a consortium of development financiers namely the French Development Agency and the German Development Bank'. The first phase of the project is planned to be finalized by the end of 2017. Detailed information is available at http://www.evwind.es/2015/07/03/wind-power-in-kenya-kengen-develops-400-mw-wind-farm/53156	The KenGen; French Development Agency; German Development Bank
Isiolo Wind Project in Isiolo County	Isiolo Wind Project is expected to produce a total of 150 MWp when completed in two phases. The first phase is planned to produce 50 MWp. The feasibility study for the project was completed in 2014. It is estimated that the project will cost at total of $400million. More information is available at http://www.renewableenergy.go.ke/asset_uplds/files/Wind%20Sector%20Prospectus%20Kenya.pdf	

Source: AHK, 2013; IREK, 2015

The literature sources included reviewed articles drawn from both national and international print, electronic media, government documentaries, and selective use of secondary sources. The study employed questionnaires to collect data utilized herein. The interviews were carried out using mainly qualitative questionnaires. The questions that featured in the questionnaire included questions on approval of the Ngong Wind Farm, factors that influenced the establishment of the project, challenges faced in its establishment, how government policies have influenced the project's operations, the existing linkages and interactive learning mechanisms and outcomes of low-carbon energy innovation.

The study targeted 100 respondents drawn from the public and power-producing and supply companies, based on desk study mapping. The study only managed to get views from half of the targeted number of respondents. The respondents were distributed by occupation/profession as given in Figure 2. The least fraction of the population was drawn from the public. This public was featured to gauge their understanding, perception and, where possible, their uptake and role in wind power sector in Kenya.

The responses from the questionnaires were analyzed using frequency analysis in Microsoft Excel, and the output displayed using OriginPro 8.

The study, however, had a few limitations;

(1) The questionnaires were only administered in two institutions: KenGen and Kenya Power Limited. The two are government institutions charged with the mandate of production and distribution of electricity, respectively. The response rate from the two institutions was low, citing their restrictions on sharing some information.
(2) Only a few respondents from the public, only within Nairobi County, were interviewed. This is because generally the level of awareness of the existence and operations of the project is limited to Narok and Nairobi counties.

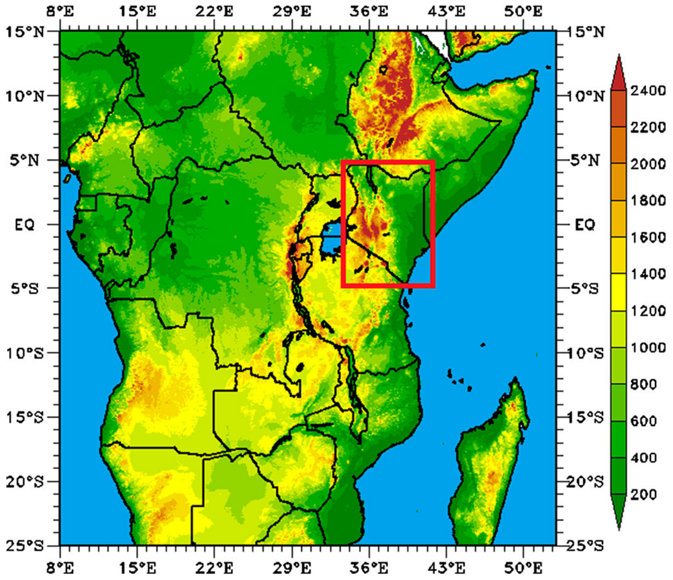

Figure 1: Topographical elevation map (m) of Kenya (Rectangle [35° E–41.5° E, 3° S–4.5° N]). ***Data source:*** Hastings and Paula, 1999

Despite having an introduction letter from African Network for Economics of Learning Innovation and Competence Building Systems (AfricaLics) on the intended research, some respondents from the two institutions could not release the requested information. Getting the responses reported in this work involved visiting the offices concerned to clarify some of the information such as the background and motive of the research. It was however cumbersome to cover all the targeted respondents within the stipulated timeline, consequently compromising the quality of the outcome. The challenges were partly addressed by searching for the desired information through a comprehensive literature review which was time-consuming and limited to the literature within reach.

It is advisable to address such logistical challenges prior to commencement of the data collection exercise in future. In addition to having an introductory letter from the research or sponsoring institution, it is also advisable to seek government and local authority approval for the work, to instil trust in the respondents about the motive of the exercise, especially where government institutions are involved.

Results and discussion

Evolution of the sustainable energy innovation

Understanding the role that a community and/or community-based initiatives play in a transition to a low-carbon sustainable economy in any setting is very important for upscaling engagement with resourceful actors and diffusing the knowledge to different localities. The majority of interviewees have knowledge of wind power and totally support wind farms in Kenya (Figure 3). The main reason wind farms received high approval is the need for supplementary power sources to address the recurrent power shortage in the country. However, a few people approved the wind power projects on the basis of being

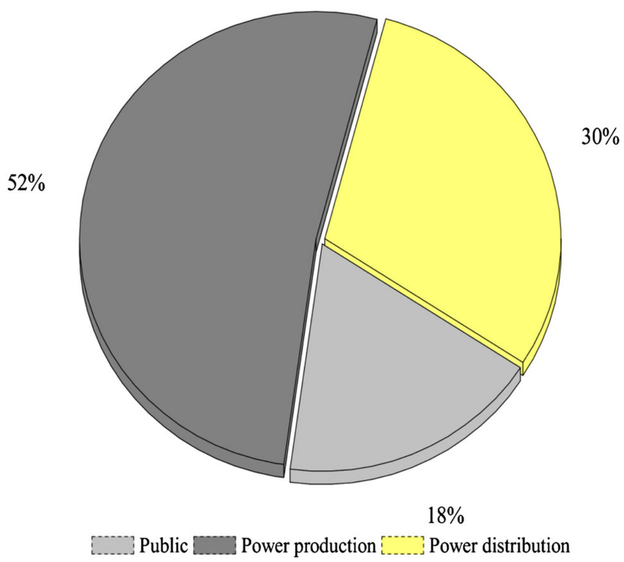

Figure 2: Distribution of respondents as per occupation/ profession.

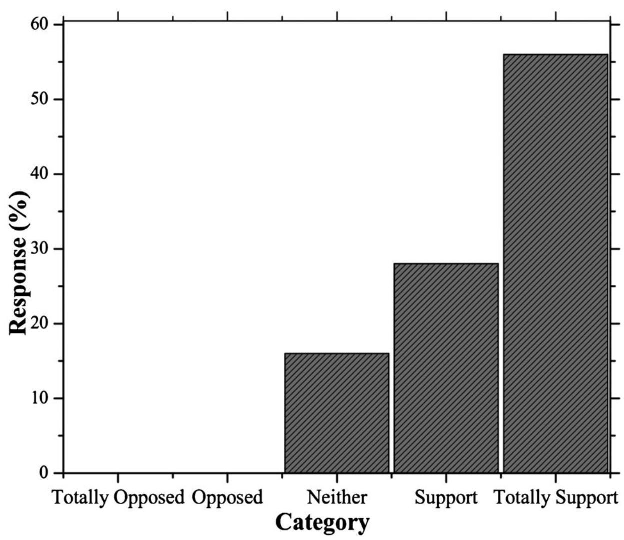

Figure 3: Public's approval of winds farms in Kenya.

a low-carbon emission initiative. This shows the low awareness the general public has regarding low-carbon emission innovations in society, aimed at reducing greenhouse gases emission. This is the case despite the fact that many developing nations, mainly in sub-Saharan Africa and in parts of South Asia, use very little energy and emit very little carbon dioxide and other greenhouse gases per person. The knowledge of greenhouses gases and their relation to climate change in developing nations is taken with seriousness since the same nations are the most vulnerable to the effects of climate change.

Currently, the electricity generated by KenGen is sold to KPLC which then feeds it into national grid supplies and sells it to various users in the country. More than 68% of interviewees are aware that they consume power from the Ngong Wind Farm, with the majority using it for domestic purposes (Figure 4).

The Ngong Hills wind project was chosen mainly for enhancement of technology (Figure 5). For instance, the northern part of the Ngong hills that was finally settled on by KenGen as the ideal site was a result of two experimental wind turbines that had been under study since early 1990s. The project has continued to develop as a government strategy to meet the growing demands for energy.

At inception, the project faced several hurdles. The most challenging was the assessment of wind resource in the locality, while the least challenging was finance (Figure 6). Finance was not a hindrance to the inception of the project since the Belgian Government was willing and able to sponsor it. However, today, the expansion of the project and the establishment of new ones has been slowed down by funding since potential areas for wind energy harnessing are a distance away from the main grid and load centres, requiring high capital investment for the transmission lines (GoK 2011b). Generally, in the entire sub-Sahara, studies (Beck and Martinot 2004; GoK, 2010a) identified a number of factors that limit low-carbon development and energy access, among them being high startup capital costs, limited skilled manpower, and poor coordination and linkages in renewable energy related programmes.

The project received opposition; lack of goodwill from the locals, while the residents and herders were initially worried that noise from the turbines would scare their animals, and that the project would take over their grazing fields. This raises cultural views that tend to limit the uptake of low-carbon innovations. The residents in the sites where the wind projects are viable such as Ngong Hills, who are in most cases the beneficiaries, tend to raise issues that could significantly impact the projects' progress despite the good policy strategies in place. The Ngong Hills project has however advanced to overshadow the fears of the locals by improving transport and communication infrastructure in the area, among other benefits. A similar challenge was faced by an independent developer, African Infrastructure Investment Fund (AIIM), for the 61 MW Kinangop wind project, leading to its cancellation (The Standard 2016; Windpower 2016).

Selection of appropriate technology also emerged as a key factor that challenged the establishment of the wind farm. The wind turbine generators (WTGs) used in the project, Vestas V52 Model turbines, were imported into the country from a Danish company. The model was preferred based on the topography and accessibility on site which has a complex terrain. Higher power WTGs which are in most cases big in size and heavy would make the logistics of the project very challenging in their installation owing to the topography.

Models of sustainable low-carbon energy innovation

The wind farm was initiated as a flagship project, a donation from the Belgian Government. The operation of the projects were mainly carried out by the donors, qualifying the model of innovation to be donor-driven. Following technological evolution, the project has grown from a pilot project to a power producing plant that feeds its output into the national grid. The project owned by a parastatal is currently driven by government policies and donors. The donors still have a significant role to play in the project since the project still requires high capital investment for expansion to full potential. It is also

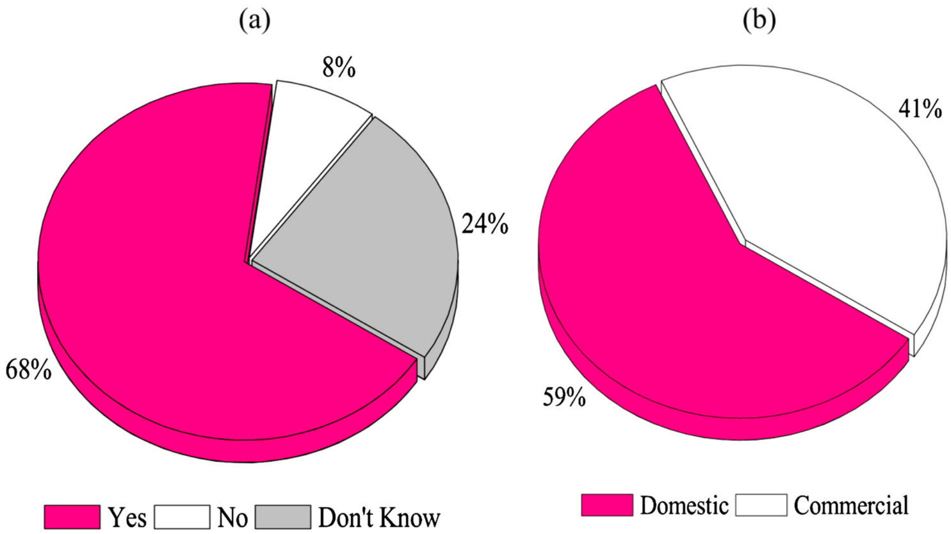

Figure 4: Wind energy usage: (a) Awareness of use of energy from Ngong Wind Farm, (b) Purpose of energy usage.

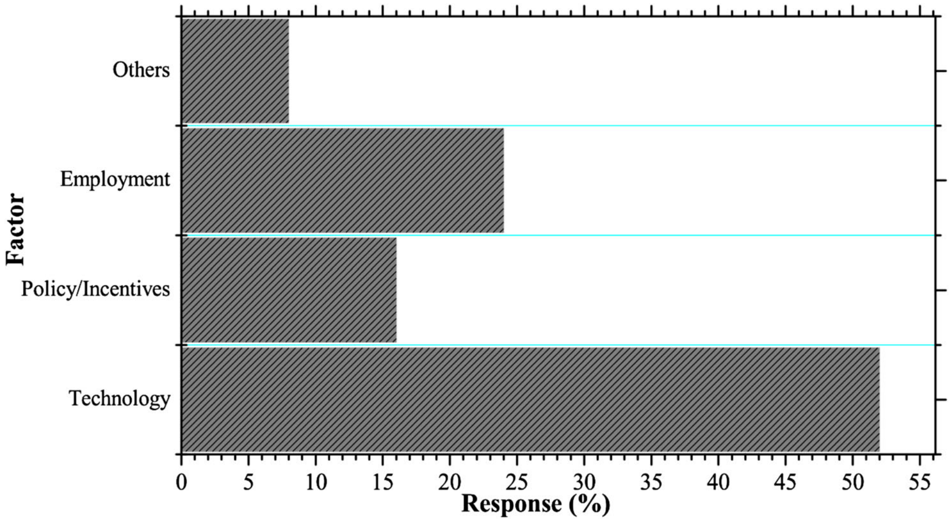

Figure 5: Factors that influenced the project selection.

notable that most wind energy potential areas are located in arid and semi-arid areas, the majority of which are undeveloped. Establishment of wind farms in these areas thus requires a huge financial base to buy the necessary machinery as well as open up the sites in terms of transport and communication networks, security and water, among other key essentials. In addition to these costs, further capital injections into the project are required since most potential areas for wind energy generation are far away from the grid and load centres, requiring high capital investment for transmission lines (GoK 2014).

The models that are driving low-carbon innovation in Kenya are policy-driven and donor-driven models. The interviewees acknowledged that the Government of Kenya recognizes implementation of renewable energy sources (RES) to enhance the country's electricity supply capacity and diversification of generation sources (Figure 7). The recognition of the implementation of renewable energy sources was based on formulation and implementation of energy policies that promote renewable energy.

Linkages and interactive learning mechanisms

The project has both technical and non-technical learning mechanisms, depending on the interested parties. The transfer of knowledge happens at various levels: experts–experts, experts–learners, experts–visiting students, among other forms. The uptake of the knowledge on the operations of the wind power plant and the associated benefits, especially by the community in the energy generation zone, helps to reduce the hostility between the management of the power plant and the locals.

The technology at the time of inception in terms of expertise locally was low, leading to importation of both material and manpower. The importation of many technological inputs such as energy extraction and supply technologies has faced a number of challenges such as unreliable external donor support. The inputs are generally expensive and, in the absence of a sponsor or a financier, the projects on renewable energy have a tendency to slow down.

The primary entrepreneur, KenGen, has a number of linkages with other entrepreneurs. The major

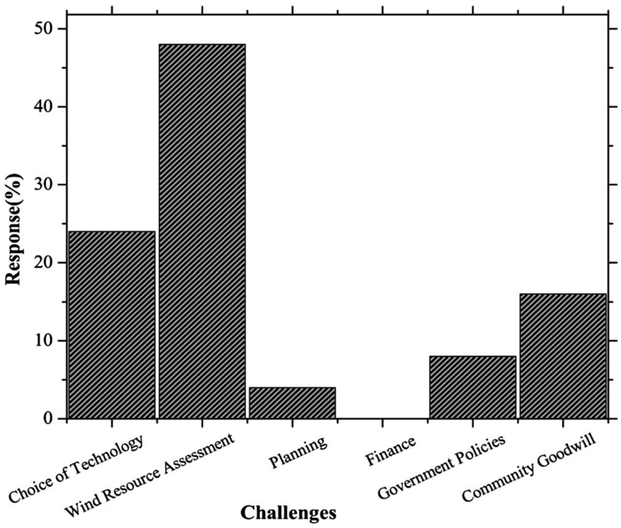

Figure 6: Challenges faced in the establishment of the Ngong Wind Farm project.

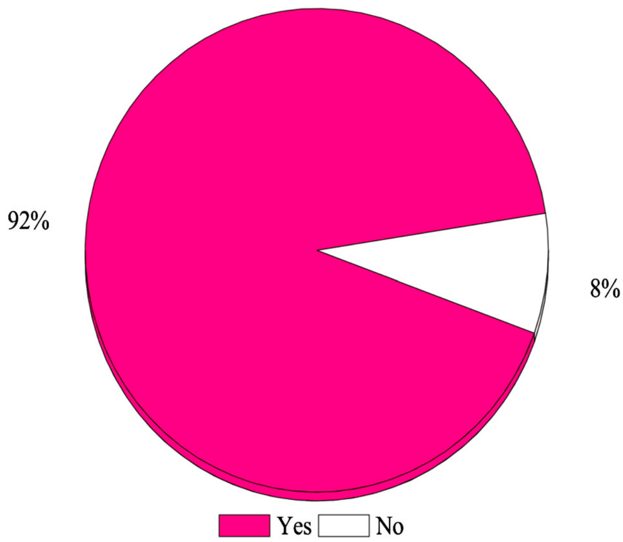

Figure 7: Acknowledgement of government support for the renewable energy sector in Kenya.

entrepreneurs that are closely linked with KenGen are the suppliers of both the input and distributors of the electricity with KPLC being the leading partner. The linkages between the primary entrepreneur and knowledge generating institutions is however informal.

The accumulation of knowledge in the design and plant operations is however still limited. This is evidenced by the continuous outsourcing of wind turbine generators and resource personnel to expand the project. It was expected that by today the country should be designing and setting up its own wind turbine generators, using locally trained engineers. The importation of skilled manpower and equipment is generally expensive. As part of the effort by the government to create jobs for its citizens, as well as sustaining the wind projects by availing locally available experts and materials, there is need to train more specialists in this field. Given that the profession, with specialization in wind power is not well developed locally (GoK 2014), the government can continue sponsoring potential experts abroad to master the art of design and maintenance of wind plants.

The country still faces technological challenges in the development of climate technologies. The same hurdles are faced in the wind energy sector, with the Ngong Wind Farm serving as an example. This has seen KenGen seek the expertise of TPF-Econoler, through a contract signed in 2010 involving supply, installation and commissioning of 8 Vestas V50 wind turbines for Ngong Wind I Phase II, at a cost of 12 million euros. Another contract was signed between KenGen and Iberdrola/Gamesa consortium in 2010 that involved supply, installation and commissioning of 16 Gamesa wind turbines, going for 20 million euros (MoE 2013). However, there is hope of overcoming the technological challenges. Pueyo, Bawakyillenuo, and Osiolo (2016) pointed out that there is a likelihood of running the installed wind mills with minimal challenges as time goes by. They attributed the observation to learning effects and improvements in Kenya's infrastructure.

Outcomes of low carbon energy innovation

The project has recorded high performance in terms of acceptance, accessibility, employment/entrepreneurial activities, sustainability, cost-effectiveness and management (Table 4). These are the views shared by the interviewees when the closed questions were posed to them. The figures give an indication of how the public has understood and continue to appreciate the operations of wind power plants. Although the rating of job creation by power plants appears to be low, this may not be true. Most operations in the sector are technical, which cannot be handled by the community/neighbourhood of the project, resorting to outsourcing to foreign experts. Similarly, there is possibility that the public, especially that in neighbourhood of the project, only look at the direct employment opportunities created by the wind plant, yet there are several indirect employment chances created by it indirectly. The public ownership of the wind farm makes the facility accessible to the public, especially for viewing and learning/sharing experiences.

The observations regarding Ngong wind project are in agreement with an earlier study by GTZ (2009) on Kenya's wind energy market. According to GTZ (2009), the wind market is slowly gaining acceptance by both local and foreign investors, with the government and NGOs taking roles towards grid connected power generation. The shift of Kenya towards wind energy was attributed to climate change and human degradation of water towers that affect hydropower production, introduction of FiT rates for wind power and a general increase in demand for power.

The project has created a range of jobs and business opportunities for both the local and the international business community, such as technicians in charge of maintaining the plant and distribution of the electricity. Other beneficiaries include manufacturers of wind plant parts. The electricity generated from the site is fed into the national grid, which contributes to the economic development of the country.

The wind farm project is considered to reduce greenhouse gases emission by reducing the consumption of fossil fuel based electricity from the grid by generating electricity from wind and feeding it into the national grid. The estimate of annual emission reduction stands at 9,941.11 tCO_2e (UNFCCC 2014).

The energy generated from wind energy is generally affordable. The energy is preferred for its price stability as compared with fuel based projects since the latter will always be subject to variations in price and availability. The cost of wind power is likely to even go down and stabilize further if proper storage for the power is put in place. This is however not very easy to realize since it requires meaningful investment in terms of research and development, and capital. This remains a challenge to the government.

The project is self-sustaining, being a renewable resource. Owing to its high efficiency, plans by the Ministry of Energy and KenGen are underway to upgrade the

Table 4: Assessment of the project performance.

Category	Rating (%)				
	Very low	Low	Moderate	High	Very high
Accessibility	12	36	40	8	4
Acceptability	0	4	20	60	16
Employment	24	52	16	8	0
Sustainability	0	0	16	68	16
Cost-effectiveness	12	28	44	16	0
Management	0	32	64	4	0

project, to provide 11 MW overall to the existing total of 5.1 MW. This has been made possible by a 20-million-euro loan from Spain.

The project has created several benefits for the locals and the Kenyan economy at large as part of indirect spillovers. The project is credited for improving the local economy by creation of employment opportunities, both directly and indirectly. The number of opportunities created by the Ngong Wind Farm cannot however be determined easily since the electricity generated is fed into the main grid. The project has also contributed significantly to opening up of the area through construction of roads to improve accessibility to the farm. KenGen in liaison with the wind farm Stakeholder Coordination Committee (SCC) launched in May 2014 agreed on Corporate Social Investments (CSI) projects for Ngong and the implementation process got underway (KenGen 2014). The country still relies on foreign firms in the acquisition of machinery and expertise. In the process, the project is helping in facilitating technology transfer from the suppliers.

Conclusion and policy recommendations

Kenya is a fast-growing country in Africa, and to sustain its growth, it needs reliable and sufficient sources of energy. Indeed, most parts of Kenya such as Marsabit, Turkana, Samburu and Garissa, and coast counties such as Tana River, Lamu and Kilifi have relatively high wind speeds capable of driving small-to-large wind energy turbines. However, most of the wind potential areas remain unexploited. The utilization of the available wind power resources can greatly boost economic activities in those counties and in the nation at large. This will be a forward step towards the realization of Kenya's blueprint Vision 2030 as well as to achieving environmental sustainability in the long run.

The government has and continues to put in place an enabling environment of renewable energy through the formulation of policy frameworks that promote the production and uptake of wind energy. These include the Energy Act 2006, Kenya Vision 2030, the FiT policy, the National Climate Change Response Strategy (NCCRS) and the Least Cost Power Development Plan (LCPDP). The attractive policy frameworks the country is putting in place are likely to result in high equity returns for any investor in wind energy projects, implying more investment in the sector in Kenya. However, there are limited platforms for collaboration in industrial development, especially in the wind energy sector.

It is evident that successful innovations coming from an efficient system bring together all actors, ranging from research teams, financiers, users and policymakers, among others. There is a need for further research and collaboration to assess the potential of wind power across the country and to initiate sustainable operations. The government should form and support an institution that will foster innovations in the energy sector, mainly focusing on wind energy. Similarly, there is a need for organizations that bring together government officials, academic institutions and climate entrepreneurs to exchange skills and knowledge on wind energy technologies. Pooling knowledge and resources, and leveraging local and national policies are potential ways in which institutional platforms can foster wind technology development and dissemination.

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