



Scaling up renewable energy in Africa: measuring wind energy through econometric approach

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Abstract

Wind energy continues to make inroads in Africa due to falling costs and technological advancements. Most African countries are planning, exsiccating and connecting their renewable energy projects with national grid system with giving high propriety to energy security, sustainable energy consumption and low carbon emission. Many policies have been enacted by countries to promote the scaling up of wind energy and renewable energy in particular, across the globe. However, these policies have mixed effects on the deployment of wind energy. For this purpose, current study used panel data and fixed effects model for 17 African countries with wind installed generation capacity to determine the driver of wind energy development on the African continent between 2008 and 2017. The variables were grouped into three thematic areas: policy, socioeconomic, and country-specific factors. After conducting the analysis, socioeconomic variables (GDP, CO₂, energy use) and energy security variables (energy import, electricity consumption) have significant effects in determining the scaling up of wind energy in Africa. However, the policy variables of FITs, licensing during, and Tax did not have significant effects on wind energy capacity addition for the case of Africa. This study adds to the drivers of nascent wind energy deployment literature in Africa. This study suggests that set of effectitive policies are deem necessary to scale up wind energy in Africa.

Keywords Renewable energy · Wind energy · Electricity · CO₂ · Scaling up

Nomenclature

RETS renewable energy technologies
FITs feed in tariffs
GDP gross domestic product
CO₂ carbon dioxide

PIDA African Union's Programme for Infrastructure Development in Africa
GWEC Global Wind Energy Council
DTU Denmark Technical University
AREI Africa Renewable Energy Initiative

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MW	Megawatts
SEWEA	South Africa Wind Energy Association
REIPPP	Renewable Energy Independent Power Procurement Program
IRENA	International Renewable Energy Agency
IMF	The International Monetary Fund
RD&D	research development and demonstration
VRE	variable renewable energy
C O V I D	-Coronavirus
19	

Introduction

Wind energy is an infant industry in Africa while growing rapidly in Europe and other developed area of the world this source of energy (wind). It is one of the renewables energy that can aid Africa to meet its numerous energy needs for rapid population growth, urbanization, and can help to meeting the Paris Accord of halting global temperature rise above 1.5° pre-industrial levels. This wind energy can enhance Africa capability to deliver cleaner, cheaper, and environmentally friendly energy with ensuring energy security, creating energy economy and reducing energy poverty (Mohsin et al. 2019b; Mohsin et al. 2018b; Mohsin et al. 2018a; Iqbal et al. 2019). Most African countries face these challenges of growing energy demand, oil price volatility, CO₂ emissions levels, and national security risks due to overly consumption of fossil fuels (Moerenhout et al. 2019). Despite these compelling reasons for Africa to scale up wind energy on the continent, the installed capacity of wind on the continent was paltry amount of 5464 MW in 2018 (Asim et al. 2020). Today, Africa is sharing about 1% of the total global installed wind capacity. However, there has been a political commitment from the heads of states to scale up renewable energy sources (RES) on the continent with the formation of the Africa Renewable Energy Initiative (AREI), which aims to scale up RES capacity to achieve the sustainable development goals, by leapfrogging Africa to a low carbon development economy and economic growth. This initiative aims to install 10 GW by 2020 and 300 GW by 2030 (AREI 2017). There are laudable initiatives aimed at scaling up wind and renewable energy technologies (RETs) in general Africa: The Africa–EU Partnership program, the African Union’s Programme for Infrastructure Development in Africa (PIDA), Power Africa, the Africa Clean Energy Corridor and as well as multilateral, bilateral and civil commitments to scaling up wind energy on the continent (Ahmed and Bhatti 2019).

In the course of the decade, Africa’s population is expected to grow at 3% per annum, while its gross domestic product (GDP) would increase only by 1.4% until 2030 (GWEC Africa Wind Energy Handbook, 2019). However, even this growth cannot be achieved and sustained unless there are

reliable, accessible, and cheaper sources of energy to meet the demands of an increasing population. In Sub-Saharan Africa, only 48% have access to electricity; this is hindering the advancements in their socioeconomic well-beings such as education, health delivering, access to clean water, and food. According to the first continental report of the implementation 2063 Agenda, household access to electricity has increased nominally to 63% in 2019 continent wide. Furthermore, for the continent to industrialize and create shared prosperity and transform the various sectors of the continent’s economic structure, the role of energy is very important. Africa today generates about 81% of its electricity from thermal sources, which is very expensive and creates macroeconomic instability in many countries due to the import-based electricity generation (Morales and Hanly 2018). So, this is not good for both economic as well as environment. Thus, mitigating these unbearable situations, wind energy is the panacea for them. It is the source of energy that can help Africa leapfrog to a sustainable electricity generation.

This study aims to contribute to existing research in many ways. First and for most, it uses an econometric approach to assess the determinants of scaling up wind energy on 17 African countries with wind installed generation capacity, using four thematic variables such as socioeconomic factors, energy security, policy factors, and country-specific factors. These factors have been further subdivided into GDP, energy import, energy use, and electricity consumption from non-fuel sources, wind capacity, CO₂ Emissions levels, and electricity consumption. This study will contribute to a growing literature on the drivers of wind energy deployment on the African continent.

Secondly, the study focuses on the entire African continent, unlike Ogbe and Ogbe (2018); Komendantova et al. (2019); and Mukasa et al. (2015) who studied only Sub-Saharan Africa (SSA) and focused only on all RES, not wind energy only. This gap in literature gives the opportunity to analyze a full length of policy instruments such as tax incentives, FITs relevant to the deployment of wind energy on the African continent. The time period for this study has been taken between 2008 and 2017; while existing studies used not much longer time period. Finally, under the analysis using an econometric model, a panel data fixed effect technique was used to determine the effects of policy instruments and exogenous variables on the deployment of wind energy on the African continent. The fixed effect technique was applied because of the time-invariant geographic factor (country) that could correlate with the exogenous variables (Mohsin et al. 2019d; Mohsin et al. 2019a). The study, therefore, confirms that GDP, energy use, energy import, electricity consumption, CO₂, and electricity from the non-fuel sources are very significant in determining the scaling up of wind energy on the African continent. Surprisingly, none of the dummies for the

policy instrument was significant in scaling up wind energy on the African continent. They had varied magnitudes of direction for their coefficients. These results are identical with several previous studies such as (Zhang et al. 2018), (Bublitz et al. 2019) and (Ahmadi et al. 2020). The study is expected to provide a wider perspective on discourse regarding scaling up wind energy on the African continent to meet growing energy needs.

The rest of the paper is organized as follows: “[Model for wind energy development in Africa](#)” section gives a background to the study; “[Data and methodology](#)” section is research and methodology. The results of the panel model econometrics analyses are described in “[Results and discussion](#)” section. “[Conclusion and policy implication](#)” section ends the paper with conclusions and recommendations.

Model for wind energy development in Africa

From the model below, it explains how integrated the various energy systems are in meeting the energy needs of African countries. The quantum of national resources, prices of crude at the global markets, energy demand, and the demand for energy services are exogenous to the model. The Africa continent is endowed with a lot of natural resources, which serve as a source of foreign exchange for them when they are exploited. These are fossil fuels like oil and gas, coal, etc. In the case of fossil fuels, it has subjected them to price volatility in the global markets, leaving most economies worse off (Asbahi et al. 2019; Sun et al. 2019a, b). Those who do not have it, spend a huge amount of hard currencies to import it for powering their economies, and facing macroeconomic instability in the long run. For Instance, Ghana was projected to spend over a billion dollars in 2019 to import crude to power its thermal plants (Government of Ghana, 2019). For Africa to move to a sustainable future, it has to develop its renewables resources, which are local, abundant, and cheaper than fossil fuels. But generating energy from this VRE comes with system challenges (Olsen et al. 2020), known as the integration challenges and needs system planning and management to ensure its efficient adequate to generate to meet demand at the least the costs (Iram et al. 2019; Sun et al. 2020a; and Sun et al. 2020b). On the other hand, the green boxes are endogenous to the model, that is, residential, transport, public services, power, oil, and gas models are all given in the model. The endogenous variables in the model have to adapt energy efficiency to consume electricity to ensure that the system is maintained. Actors in the electricity sector in Africa can ensure demand side responses like behind the meter solutions are implemented; consumers can use the smarter meter and purchase energy efficient products in the market. On the part of transport, Africa can build infrastructure for electric vehicles (EVs) that will do away with higher transport fares in the cities and electrify all public transport. Industry individuals can undertake distributed wind generation

to free the grid of pressure and ensure regular supply and energy security. African countries need to modernize their tariffs’ designs as a demand response tool to ensure optimal energy consumption without any backlash from customers (Zhou et al. 2020). Figure 1 shows the overall energy situation.

Overview of the wind industry in Africa

The wind industry in Africa is promising and looking forward. There is a growing number of African countries that have embraced wind energy and are taking practicable steps to generate power from this renewable source. For example, Egypt, Morocco, South Africa, Kenya, Ethiopia, and Tunisia are the leading economies which are driving wind capacity installation in Africa. The likes of Senegal, Ghana, Gambia, Chad, and Algeria are equally joining the wind bandwagon. There has been a political acceptance of RES in Africa and wind in general, with the establishment of the African Renewable Initiative (AREI) 2015. The drivers of wind energy in Africa are South Africa with 6360 MW of power from wind by 2030, that is, 69% from the IPPs, as part of the Renewable Energy Independent Power Procurement Program (REIPPP) (SEWEA 2019). With 1.2.GW wind energy capacity, Morocco is another country which is driver of Wind energy on the African continent. The wind energy program which was launched in 2010, they have decided to enhance wind energy production capacity over 2000 MW till 2020 (Government of Morocco, 2019). Africa is Egypt, which is blessed with superb wind speed, especially around the Suez Canal, which is one of the best areas in the World for harnessing energy. The wind speed sometimes range between around 8 and 10 m/s at height 100 M (IRENA 2018). Egypt targets 40% of RES to make its energy matrix by 2035. Under its distinctive feed-in, tariff program, which was launched in 2014, which seeks to encourage electricity generation from RES, targets 4300 MW generation. Ethiopia’s current wind installed capacity is 324 MW (IRENA 2019). Furthermore, Kenya is a regional leader in the Eastern Africa Power Pool, with 335 MW installed capacity and another 350 MW expected to be procured by 2023 (GWEC, 2019) (Table 1). Kenya has already awarded more than 1 GW of wind capacity under its prevailing feed in tariff rate. Mauritania has a current installed capacity of 34 MW (Chen et al. 2017). However, the country is endowed with an excellent wind speed along its northern coastline between 8.3 and 8.7 m/s, this even increases to 9 m/s in the Nouadhibou region (Mustapha et al. 2015).

Framework for the determinants of wind energy deployment in Africa

The framework above depicts the key variables used in the study. Each variable is being discussed in detail from the under listed. Certain key factors are vital drivers of wind energy development globally and in Africa,

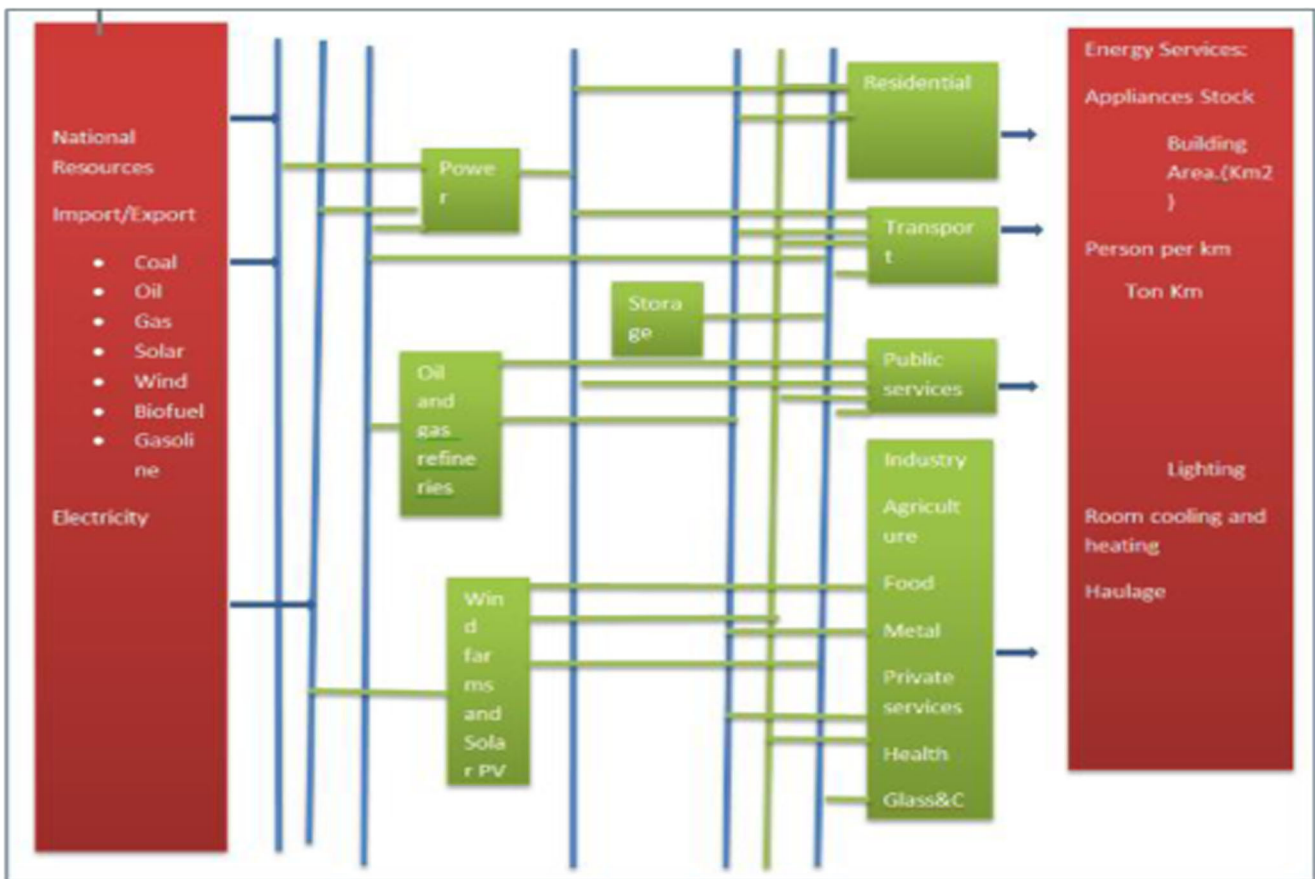


Fig. 1 Schematic diagram

particularly. These are grouped into three thematic areas: socioeconomic, political, and country wise factors, as done by Olanrewaju et al. (2019), Ogbe and Ogbe (2018), Kilinc-ata (2016), Thapar et al. (2018), Menz and Vachon (2006), Aguirre and Ibikunle (2014), and Marques et al. (2010). Zhao et al. (2020) categorized these into pricing and non-pricing policies influencing wind energy development in China. However, Panse and Kathuria (2018) argue that geographical, bureaucracy, technical, and societal factors determine the investments’ firms that make into wind power than technology (WTP) in India. Figure 2 shows the wind development index.

Policy factors

Public policies

The dawn of the 1970s brought a significant development in the energy landscape, which saw increased oil prices, making nations started looking for alternative fuel sources. The oil price shocks were monumental and hence the push for the adoption of alternative renewable energy. The world has never looked back and adopted renewables to power homes. The Paris Accord of 2015, which was brought to being to help

nations voluntarily and compulsorily commit to reducing global temperature below 1.5 pre-industrial levels, through their nationally determined contributions (NDCs), is another driver of the adoption of wind energy (Eickemeier et al. 2014). Prior to this, the 1970s were used for R&D purposes; countries were investing and researching new technologies for scaling up renewable energy sources like wind and solar. Another way to increase the mass deployment of wind energy is to replace feed in tariffs with auctions, which is very effective for utility-scale wind farm projects (International Renewable Energy Agency (IRENA) 2017). Obligations and traded certificates were ubiquitous in the 2000s. Feed in tariff (FITs) has become the practice for many countries to scale up renewable energy deployment (Kilinc-ata 2016). According to Nicolini and Tavoni (2017), the tariff is effective in scaling up renewables; a 1% increase in tariffs leads to renewable generation between 18 and 26%. Hence, this study expects that underlined variable to positively relate to wind capacity addition. Zhao et al. (2020) argued in that feeds in tariffs are the most effective means to scaling up RES, considering factors such as fairness, cost-efficiency, responsibility, by using the dynamic efficiency model. In addition, tax incentives are equally very important in scaling up wind energy. For instance, India’s domestic tax law gives a 10-year tax holiday

Table 1 Installed onshore wind capacity in Africa

CAP (MW)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Africa	739	861	990	1124	1738	2396	3317	2396	3828	4570
Country										
Algeria						10	10	10	10 e	10
Cabo Verde	2	2	16	26	26	26	26	26o	26	27
Chad								1	1	1
Egypt	435	550	550	550	550	550	750	750	750	1125
Eritrea	1	1	1	1	1	1	1	1	1	1
Ethiopia	0	0	81	81	171	171	324	324	324	324
Gambia	0	0	0	1	1	1	1	1	1	1
Ghana							0	0	0	0
Kenya	0	6	6	6	6	6	26	26	26	326
Madagascar	0	0	0	0	0	0	0	0	0	0
Mauritania					4	4	34	34	34	34
Mauritius	1	1	1	1	1	1	1	11	11	11
Morocco	221	221	225	225	495	797	797	897	1017	1220
Namibia	0	0	0	0	0	0	0	0	0	5
Nigeria	2	2	2	2	2	3	3	3	3	3
Reunion	15	15	15	151	15	15	15	17	17	17
Seychelles					6	6	6	6	6	6
Somalia				2	2	2	3		4	4
South Africa	8	10	10	10	257	569	1079	1473	2094	2094
Tunisia	53	53	53	173	200	223	240	245	245	245

to wind energy distribution and generation projects (Cox et al. 2015). In contrast, Texas (2019) disputed this view that production tax credit (PTC) is economically unviable and fundamentally distorts the markets and strains the grid. According to Iqbal and Mohsin 2019; and Mohsin et al. 2019c

the current PTC would cost the nation \$40.12 billion from 2018 to 2027.

Energy security

Energy security is defined as the low vulnerability of energy systems; the vulnerability of energy systems are viewed in three ways: robustness is reducing exposure to risks, such lack of resources, resilience is the ability of the system to recover from shocks, and sovereignty is when energy assets are being controlled by foreign actors (Jewell et al. 2016). Literature is replete with energy security being a necessary condition for countries to develop renewable energy, especially wind energy (Olanrewaju et al. 2019; and Olanrewaju et al. 2019). Energy import is used as a proxy for security. Implying, if the nation imports more of its energy, then it makes economic sense for the nation to diversify its energy mix to include wind energy, which is cost competitive and environmentally friendly. Wind energy, together with storage, can improve energy security by diversifying the energy mix and providing adequately and readily available electricity and fighting climate change (Eberhard and Dyson 2020). Due to the issue of drought caused by climate change in certain parts of Africa, affecting the water levels of dams for hydropower, storage technologies with fewer CO2 emissions could use renewables as a baseload for power generation (Eberhard and Dyson

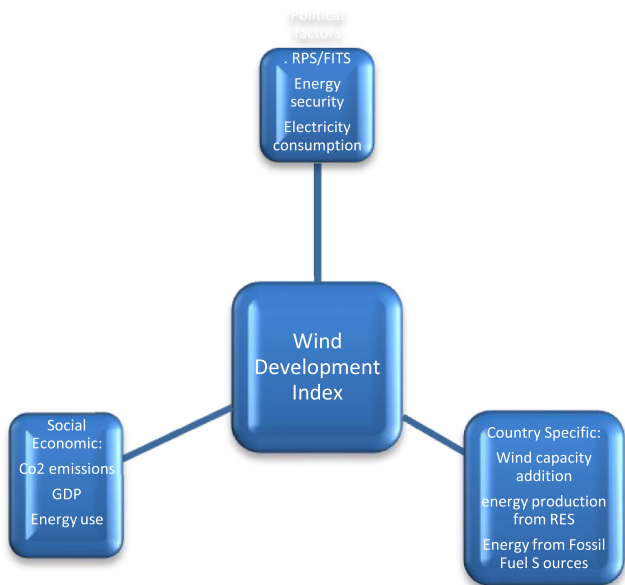


Fig. 2 Framework for the analysis of wind energy deployment in Africa

2020). Thus, this study anticipate energy security to positively correlate with wind capacity addition.

As far as electricity consumption keeps increasing, the question of energy security comes to mind. Electricity forms the foundation for sound industrialization in any country. Hence, Africa's industrialization can jump start the economies to growth trajectories, if they generate enough to meet the need of industries to promote economic growth and development (Olanrewaju et al. 2019). Wind energy is seen as one that can help to achieve this objective on the African continent with ease since the continent has the potential technically and economically to generate power from wind. Shami et al. (2016) concluded wind energy could be harnessed by Pakistan to meet its power needs in the midst of generation deficit. Renewable constitute 25% of global electricity and project to grow to 50% by 2030 and almost a quarter to 100% by mid-century (McKinsey and Company 2019).

Socioeconomic factors and GDP

Referencing earlier works by Marques, Fuinhas, and Manso (2010) and Aguirre and Ibikunle (2014) CO₂ emissions level is used as a proxy for environmental factors. This is anticipated to have a direct correlation with wind capacity addition in Africa. Reducing emissions would help balance the socioeconomic system by redistributing social benefits coming from introducing a national carbon pricing system (Edenhofer et al. 2019). International monetary fund (IMF) recommended the use of revenue-neutral tax subsidies scheme to promote the generation of cleaner electricity like the wind in member countries without increasing fuel prices (Principle and Practice 2019). Africa's part of total global emissions levels is anticipated to increase from 3% to 23% by 2100 (Lucas et al. 2015). Africa must take steps to control its emission levels by using the clean development mechanism to generate its power from cleaner sources like wind (Purohit and Michaelowa 2007). However, Sei et al. (2016) contends that only about 2% of projects and 7% of certified emission reductions (CER) potential have the likelihood of reducing emissions and not overestimated. Thus, it satisfy the condition of "additionality concept."

Gross domestic growth (GDP) of a country determines the extent a country would invest in renewable energy and wind energy in particular. Countries with higher GDP are better off and have higher income levels and can afford to invest part of their GDP to wind or electricity consumption. Higher the GDP growth rate of a country, more the ability of it to spend money on electricity consumption. Electricity consumption per capita rate in Africa was about 483kwh in 2014, which is among the lowest in developing world. This is equal to electricity needed to power a 50-W light bulb in a year. Even if Africa achieves universal access, many people cannot still afford electrical gadgets to utilize the electricity generated and higher tariffs.

In view of this, there is a need to scale up wind energy, which is cheaper than fossil fuels. Wind energy development helps improve the economic well-being of rural dwellers, by increasing their earnings levels and employing more labor in the primary sector (Du and Takeuchi 2019). Marques et al. (2010) argued that higher income or GDP means two things: the ability to bear regulatory costs, in the forms of fiscal measures and market costs, and the ability to spend more on alternative energies.

Energy use in a country is expected to have a direct link with overall wind capacity addition. It explains the various sectors of the economy, such as commercial, residential, transportation, and industrial consumption of energy. Zhao et al. (2020) argued that other than pricing and non-pricing factors, power demand, wind resources, and technology have a significant correlation with power development in China. Most African countries have high energy demand as a result of increasing population and urbanization. This makes it imperative for more energy to meet the demands of the populace. This, therefore, means diversifying the generation mix to include wind and other cheaper sources to meet this growing demand. More so, wind and solar PV energy are projected to become profitable to 2030, even without subsidies (Bertsch and Di Cosmo 2018), making it profitable for private sector investment in the wind industry.

Country-specific factors

Wind energy is a nascent industry on the African continent. For it to mature and enjoy the economies of scale, the sector has to be de-risked by instituting regulations that compensate for risks and entice private sector investments (Bertsch and Di Cosmo 2018). Kenya, together with the African Development Bank (AfDB) and a private developer, built the largest wind farm on the continent on Lake Turkana. It was achieved through private and public participation (Kazimierzczuk 2019). By 2030, newly build wind farms would cost less than fossil fuel plants, establishing a tipping point for renewables (McKinsey and Company 2019). Africa has to join the bandwagon and have a piece of the pie. Eight African countries are counted as the world's well-endowed wind resource countries (Mukasa et al. 2015). Yet the industry is still underdeveloped. A study by Shrimali, Lynes, and Indvik (2015) asserted that the production credit is effective in scaling up the deployment of wind energy at the state level in the USA by 1.4 GW annually.

African countries generate about 81% of electricity from thermal sources ("GWEC Africa Wind Energy Handbook," 2018). This makes it expensive for electricity generation and places a burden on consumers. Because most of them are independent power producers, they would pass the costs on to consumers in the form of higher tariffs. This, therefore, calls for substituting fossil fuels for renewables. In justifying the costly nature of generating power from fossil fuel sources,

Katuri (2018) found that the equity to debt ratio of 80% debt and 20% equity is a financial burden on the neck of operating thermal plants, due to the incidence of high debt on the capital structure. For instance, Ghana projects to spend a billion dollars in operating its thermal plants in 2019 (Plan 2019). Ghana generates about 69.3% of its electricity from thermal sources (Government of Ghana, 2019). The relationship between the variable and wind capacity is anticipated to an inverse one. Table 2 shows the argument regarding variables.

Data and methodology

The study uses panel regression to rigorously analyze the relationship between wind capacity additions in African countries and polices variables that would influence this relationship. For this purpose, country level data from 2008 to 2017 is used and country level individual fixed effects model and panel data models applied. Panel data models describe individual behavior both across time and across the individual. Thus, panel data controls for individual country level heterogeneity. It is important to consider the quality of the work being done to ensure the right interpretation of the regression output. As a result, the things that would have an impact are taken care (Khandker, 2005). The fixed effect could be used due to the fact the unobserved heterogeneity is constant overtime. A panel data fixed effects’ specification assumes that there is unobserved heterogeneity across individual countries captured in a model by the inclusion of an intercept term, that is, individual fixed effects are the remainder of variation in the regressand variable that cannot be explained by the regressors. Panel data is used to test the hypothesis that wind capacity addition in African countries is related to unobserved and observed heterogeneity in determining wind capacity addition in Africa. The unobserved variables are called fixed effects. Thus, panel data is used to derive consistent estimates of the coefficients of the parameters. In view of this, the country level fixed effect is important to control unobserved heterogeneity that also affects wind energy development in Africa (Olanrewaju et al. 2019) (Ogbe and Ogbe 2018) (Kilinc-ata 2016) (Panse and Kathuria 2016).The regression equation is given in the

$$WINDCAPA = f(, gdpgrwth, resxhydro, energyuse, energyimport, electricrate, electricconsu, CO2, electfrmfssfuel) \tag{1}$$

Equation (1) can be written as a panel model:

$$Windcap_{it}=X_{it} + \varepsilon_{it}$$

Specification of the stochastic term:

$$\varepsilon_{it} = a_i + \gamma + n_{it} \tag{2}$$

where a_i is the unobserved cross-section time-specific

effects, γ is unobservable specific effects, and n_{it} is the mutual cross section time affects series

From Eq (2), X_{it} contains the variables to be used on the model.

Where

$$\begin{aligned} Windcapa_{it} = & \beta_0 + \beta_1gdpgrwth + \beta_2resxhydro + \beta_3energyuse \\ & + \beta_4energyimport + \beta_5electricrate + \beta_6 electricconsu \\ & + \beta_7co2 + \beta_8 electfrmfssfuelD\beta_{9+}D\beta_{10+}D\beta_{11} + \varepsilon_{it} \end{aligned} \tag{3}$$

Equation (3) is written in its logarithmic form as below:

$$\begin{aligned} LnWindcapa_{it} = & \beta_0 + ln\beta_1gdpgrwth + ln\beta_2resxhydro \\ & + ln\beta_3energyuse + ln\beta_4energyimport \\ & + ln\beta_5electricrate + ln\beta_6 electricconsu \\ & + ln\beta_7co2 + ln\beta_8 electfrmfssfuel \\ & + D\beta_{9+} D\beta_{10+}D\beta_{12+}\varepsilon_{it} \end{aligned} \tag{4}$$

where

- $LnWindcapa$ = wind capacity in each country measured in MW
- $gdpgrwth$ = gross domestic product growth in each country measured in (%)
- $Resxhydro$ = electricity capacity excluding measured in Gigawatts (GWh)
- $Energyuse$ = energy use is measured in GWh/capita
- $Energyimport$ = thousand barrels per day
- $Electricrate$ = electrification rate measured in (%)
- $Electricconsu$ = electricity consumption billion kwh
- $CO2$ = metric tons per capita
- $electfrmfssfuel$ = electricity production from fossil fuel sources is measured in GWh/capita
- $D10_i$ = dummy for tax incentives
- $D11_i$ = dummy for feed in tariffs
- β_0 = the constant term
- $\beta_0, \dots, \beta_{11}$ are the coefficients of the model
- ε_{it} = the stochastic term, depicts other variables that determine wind energy addition in Africa but were not captured in the analysis

Where $i = 1, \dots, 11$ $t = 2008, \dots, 2017$.

The similar approach adopted by Thapar et al. (2018); Menz and Vachon (2006); and Shrimali et al. (2015) for their panel set of data to investigate the relation of production tax credit with wind energy promotion.

Table 2 Argument regarding the variables

Explanatory variable	Category	Positive/negative	Reason/argument
Electrification rate	Increase it rapidly	Positive	Increase
GDP	Socioeconomics	Positive	Wind energy is best
Energy consumption		Positive	Wind is cheaper
Electricity combustible fuels		Negative	Ditch fossil fuels for wind
Energy import	Security variables	Negative	Change for wind energy
Energy use		Negative	Pursue wind energy
			Wind emit zero CO ₂
CO ₂ emission	Socioeconomic variable	Positive	Increase RES generation
RES Electricity X hydro		Positive	

Data

A panel data of 17 countries in Africa with wind energy generation into the national grids were collected from 2008 to 2017. With about 170 observations were collected from different sources. The dependent variable is wind capacity addition in the 17 countries with installed wind generation. The explanatory variables were categorized into socioeconomic, country specific, and policy variables. The data was sourced from the World Bank and the International Renewable Energy Agency 2017, as well as the United Nations Statistics system. The 17 countries from Africa were selected because they generate electricity from utility wind sources since 2008, which was the base year for this study. A similar approach was done by Shrimali et al. (2015) on the state level in the USA. After conducting Hausman test and the Breusch-Pagan Lagrange Multiplier test, the fixed effects were the preferred model for the analysis. Thus, it provided consistent coefficients to the estimators. The detail of dependent and independent variable is shown in Table 1 along with their descriptive statistics.

Results and discussions

The analysis of panel data results using fixed effect are shown in Table 4, the descriptive statistics are shown in Table 3.

After running the panel, data by applying Stata, the results of the fixed effects on the three thematic areas of socioeconomic, environment, and country-specific variables, under twelve explanatory variables including dummies has been generated. Here, six of the regressors were significant, and the rest were not significant in determining the development of wind energy in Africa. From the results arrived at, after conducting the analysis, it was realized that a socioeconomic variable of GDP is highly significant, explaining a strong correlation with wind energy capacity development in Africa. It has a *p* value of 0.005%. However, the relationship to wind

capacity development is a negative one, with a coefficient value of [− 0.340]. It indicates a negative relationship with wind capacity development. As wind GDP increases, wind capacity addition reduces, [− 0.340 MW]. This is against an orthodox economics theory that energy and GDP growth tend to go in tandem with an increase in energy consumption. However, the UK is one economy that decoupled its energy consumption for about a decade and albeit a growth trajectory in its GDP (National Statistics 2019)(Syed 2019). This is due to the fact that the structure of the economy has been changed over the years. The UK has outsourced its energy intensive industries. Another developing country that has reduced its energy intensity and yet increased its GDP over the years is Macau, a special administrative region of China. It has 761 Btu per dollar of GDP, yet it has one of the highest GDPs per capita in the world with \$133,341 in 2015. The country’s economy is dominated by the services sector, which is not energy intensive like steel and manufacturing (Phew research, 15). Ameen and Lalk (2019) used same method to study the development of wind energy in two Sub-Saharan Africa countries concluded the GDPs of Namibia and Mozambique have a direct correlation with wind energy development. This study is in line with the orthodox economic theory that GDP growth and energy demand move in sync. On the other hand, another environmental variable, electricity generation from renewable sources, excluding hydro, were not significant in determining wind capacity addition in Africa.

It has also been observed that other renewable sources for electricity generation instead of hydro have no impact on the wind based electricity addition in African continent. Furthermore, energy security variable like energy use is equally significant in determining the development of wind energy capacity in Africa. It came out significant after the analysis, with a *p* value of 0.090. This explains the various sectors of the economy and how they consume energy, that is, residential, commercial, transportation, and industry. Thus, it stands to reason that if all these sectors that form the nucleus of energy consumption are significant, then, there is the need to scale up wind energy in Africa for their consumption. The

Table 3 Descriptive Statistics

Variable	Definition	Source	Obs	Mean	Std.Dv.	Min	Max
Lnwindcapa	Wind capacity(MW)	IRENA	163	2.213	2.401	0	7.64
Lngdpgrowth	GDP growth rate (%)	World Data Bank	158	1.756	1.93	-2.49	8.445
Lnresxhydro	Electricity from non-hydro sources GWh capita GWh/capita	World Data Bank	168	6.392	1.489	0	8.448
Lnenergyuse	Energy use (GWh/capita)	World Data Bank	170	3.869	1.265	-0.844	6.263
lnenergyim~t	Share of electricity imports to consumption (%)	World Data Bank	81	3.726	1.14	1.519	6.019
lnelectric~e	Electrification rate (%)	World Data Bank	170	3.925	0.741	1.707	4.605
lnelectric~u	Energy consumption	World Data Bank	170	5.701	2.533	-2.408	8.448
lnco2	CO ₂ emissions (metric tons per capita)	World Data Bank	170	6.596	3.913	-0.416	13.129
lnelectfrm~l	Electricity from fossil fuel	World Data Bank	170	4.375	2.054	-3.457	7.242
licensingD~n	Dummy	Dummy	170	0.1	0.301	0	1
Tax	Dummy	Dummy	170	0.1	0.301	0	1
_est_re	Dummy	Dummy	170	0.435	0.497	0	1
FITs	Dummy	Dummy	170	0.1	0.301	0	1
_est_fe			170	0.435	0.497	0	1

correlation is a positive one. Hence, if energy use increases by 1 MW, wind capacity will increase by 0.238 MW. In addition, energy import was significant in determining the development of wind energy in Africa. It is an energy security variable which is significant with a probability value of 0.034 and also has a positive correlation, with a coefficient of 1.002%. This implies that for every one thousand barrel of oil imported from a foreign country, about 0.034 MW of wind power could be installed in Africa. A study by (Dong 2012) confirmed this assertion, where wind capacity addition has a direction relationship with net energy imports, showing that energy import helps in developing wind capacity in Africa. This was

anticipated. It is plausible that as a country aims to be energy reliant and sufficient will not continue to import energy when it can develop its local resources like wind, which is cheaper and cleaner for its domestic consumption. This is true in developing Africa, where energy poverty is high and import-based energy consumption lead to fiscal imbalance as well as macroeconomic instability in many countries. A very curious result was obtained for electrification rate or energy access on the African continent. It was not significant. Also, its correlation with wind energy capacity addition is negative. As more than 600 million people have no access to electricity, Africa is considered least electrified continent of this plant.

Table 4 Regression results

Inwindcapa	Coef.	St.Err	<i>t</i> value	<i>p</i> value	[95% Conf Interval]	Sig
lngdpgrowth	-0.340	0.116	-2.93	0.005	-0.573 -0.107	***
lnresxhydro	0.046	0.049	0.94	0.354	-0.053 0.144	
lnenergyuse	0.411	0.238	1.73	0.090	-0.066 0.888	*
lnenergyimport	1.002	0.460	2.18	0.034	0.079 1.925	**
lnelectricrate	-0.250	0.629	-0.40	0.693	-1.511 1.011	
lnelectricconsu	4.803	1.178	4.08	0.000	2.441 7.164	***
lnco2	-0.051	0.028	-1.79	0.079	-0.107 0.006	*
lnelectfrm~l	-0.447	0.134	-3.34	0.002	-0.715 -0.178	***
LicensingDuration(Dummy)	0.004	0.306	0.01	0.990	-0.609 0.617	
FITs(Dummy)	-0.110	0.302	-0.36	0.716	-0.715 0.494	
Tax(Dummy)	-0.068	0.258	-0.26	0.793	-0.585 0.449	
Constant	-29.205	6.616	-4.41	0.000	-42.469 -15.941	***
Mean dependent var	2.411		SD dependent var.	2.482		
R-squared	0.812		Number of obs	74.000		
<i>F</i> -test	21.138		Prob > <i>F</i>	0.000		
Akaike crit. (AIC)	125.108		Bayesian crit. (BIC)	152.757		

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

This variable was expected to correlate directly with wind capacity addition. More so, electricity consumption was equally perfectly significant after the analysis. The probability value was perfect [0.000], suggesting a strong correlation between wind energy capacity addition and electricity consumption. The correlation is a direct one. The coefficient is [4.803 MW]. As electricity consumption increases, wind capacity addition increases. Of course, the variable that has dominated global political discourse, carbon dioxide (CO₂) emissions have proven significant as was expected. CO₂ is highly significant after the analysis, which shows deploying wind will abate CO₂ emissions. It emits no CO₂.

Discussion

On the policy front, the results from the regression were startling. The dummies for feed in tariffs, tax, and licensing duration were not significant in determining the development of wind energy in Africa. This confirms the early literature by Staid and Guikema (2013) and found that the key drivers of wind energy capacity development across the US are geographical and physical, other than policy drivers. Furthermore, Zachmann et al. (2014) argued that, innovation policies like public research development and demonstration and subsidies (RD&D) and deployment policies, would help in scaling up low-carbon technologies and that current wind deployment is as a result of RD&D that interacted with best patenting. Another study that lends credence to this argument of Thapar et al. (2018) which used panel data to analyze 16 explanatory variables on India and concluded that FITs and renewal purchase obligation (RPO) are not significant in influencing the growth of wind energy in India. Indeed, to support this study notion that tax is insignificant in scaling up wind energy in Africa. It is not only economically sustainable, but it distorts the market fundamentals and strains the national grid as well (Tax Credit for Wind and Solar, 2019). Perhaps the reason could be attributed to the fact that most countries are now adopting a competitive auction system against FITs to deploying renewables. In 2018, 48 countries adopted auctions, including African countries, an increase from 29 in the previous year (REN21 2019).

The issue of climate change has dominated global discourse due to the negative impacts it has on the world, especially developing countries, rising temperatures, rising sea levels, hurricanes and typhoons, and the destruction of energy infrastructure (Cantelmo et al. 2019). All these are caused by a climate that results from CO₂ emissions. Even though Africa's emission level is very negligible (Mukasa et al. 2015), the impacts of climate change are global. Notwithstanding, Africa is already at the receiving ends of climate change through natural disasters in Mozambique and Zimbabwe and Malawi, which could cost their GDPs growth by a percentage point and about 1.6% loss in their consumption, as natural

disaster prone countries (Cantelmo et al. 2019). The power sector is the biggest emitter of CO₂, and so decarbonizing the power sector through the adoption of wind energy would reduce CO₂ emission and meet the Paris goals of limiting global temperature rise by 1.5° pre-industrial levels (Chmi and Eea 2019). Obviously, another variable that came out significant was electricity from fossil fuel sources. Indicating it determines the level of wind energy capacity addition in Africa. This means that as electricity generation from fossil fuels increases, wind capacity addition decreases BY 0.447 MW. This is economically true. In that, the continued consumption of fossil fuels would not give priority to African countries to invest in wind energy. There has to be a substitution effect so as to scale up wind.

Conclusion and policy implication

The study examined the drivers to scaling up wind energy on the Africa continent, using three thematic variables of policy, socioeconomic, and energy security. Here a panel dataset used to analyze these variables at the country level. The study used the fixed effect mode to cater for time invariant heterogeneity among country and instrumental variables for policy to analyze the explanatory variables. Countries are 17 on the continent with utility-scale wind projects since 2008. The results exhibit different effects of the policy variables. FITs, tax, and licensing duration were not significant in scaling wind capacity in Africa. The absence of effects of wind capacity addition in Africa, especially the tax element, is in tandem with the argument raised by Tax credit for Wind and Solar (2019) in the USA, where they contend that the production tax credit is not sustainable economically and distorts market fundamentals and at the time straining the grid. Africa can take a lesson from and avoid these pitfalls in structuring the tax system for the wind industry in Africa. This is in sharp contrast to the numerous studies that suggest FITs have effects on scaling up renewables capacity like wind (Menz and Vachon 2006; Case et al. 2010; Nicolini and Tavoni 2017; and Dong 2012). GDP was proved to have a significant effect of wind capacity addition on the continent but an inverse relationship. This was envisaged, but the correlation was not anticipated. Equally significant were CO₂ emissions, energy use, and electricity consumption. All these variables point to a correlation to wind energy capacity in Africa.

An unanticipated result was that of the electrification rate in the analysis, which came out not significant. The fact that Africa has not electrified many households makes this result surprising. Electricity access is very important for Africa so to create and sustain economic growth and development. The absence of the predictive power of the variable was not expected. The reason behind this could be that the rest of the variables are more important in scaling up wind energy than that of

electrification. As electricity from fossil fuel sources is significant, it suggests that more wind energy should be generated and ditch fossil fuels. Another insignificant variable that came out after the analysis was energy generation from renewables excluding hydro sources. It was an unexpected result, as well. This variable being renewable should be significant to boost the RES drive on the continent. Hydro was excluded because it does not enjoy subsidies from the state. Now, the policy implications emanating from this study are that:

1. The study concludes that there are other factors rather than a policy that drives wind energy capacity in Africa.
2. The wind industry in Africa could create well-paying jobs ranging from manufacturing to construction, operation, and maintenance, as the study found GDP growth to correlate positively with wind capacity addition.
3. Future wind energy deployment has to be institutionally, technically, and regionally integrated and modernized grids to take VRE and to achieve synergy. It would enable the access of national boundaries between energy sectors. The Africa Clean Energy Corridor is a laudable project in the right direction. In the West Africa Clean Energy Corridor (WACEC), countries like Ghana, Burkina Faso, Cote d'Ivoire, and Togo have started integrating their power infrastructure.
4. African countries need to halt granting subsidies to fossil fuel companies and divert for renewables. The environmental and economic costs of such subsidies are damning. In 2013, 30 SSA countries granted subsidies worth \$32 billion. Global subsidies to fossil fuel companies reached \$300 billion in 2017, twice the support for RES electricity generation.
5. Africa has to maximize public-private sector financing and leverage on the partnership to catalyze finances for scaling up wind energy deployment on the continent. There are a number of such projects on the continent between the African Development Bank (AfDB) and many countries; for instance, the Lake Turkana Wind Farm in Kenya and the Tangier projects in Morocco.
6. Finally, public research development and demonstration (RD&D) is key to scaling wind energy in Africa. It should be within countries and regional blocs.

In conclusion, despite the robustness of the results, Africa faces many challenges in the energy sector after the COVID-19, such as the oil and gas boom and bust, climate change concerns, the need for governments to find stimulus packages to revamp their economies, and the growing acceptance of RES. Wind energy could come in handy in this regard to create jobs and shield the continent from economic headwinds. Future research could consider the impact of the COVID-19 on the wind industry in Africa. As this analysis is based to find the wind energy impact on African economy.

The limitation is that the wind energy industry in Africa is a nascent one, and there is a paucity of data and research regarding the wind energy drivers on the continent. Hence most references are research related to renewables in general.

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