MULTI-CRITERIA EVALUATION OF THE APPROPRIATE OFFSHORE WIND FARM LOCATION IN NIGERIA

Energy sustainability requires meeting our energy needs upon which economic development depends. The need to improve on the present power generating capacity of Nigeria, has brought about energy diversification by increasing the present energy sources to include renewable resources and this has led to the idea of this work. This work is aimed at determining the appropriate offshore wind farm location(s) in Nigeria to address the issue of wind energy availability and utilization in the country. Attributes for offshore wind farm location were collected for three Alternatives in Nigeria which are Victoria Island in Lagos, Koko offshore region of Warri and Abbonema of Port-Hacourt. Wind speeds data were collected from the Nigeria Metrological (NIMET) stations in the states under consideration while other required attributes were collected with the use of a Questionnaire which was responded to by professionals. Collected data were analyzed using fuzzy TOPSIS Multi-Criteria analysis tool. Average of a ten years wind speed for Lagos, Warri and Port-Harcourt were 6.251m/s, 7.294m/s and 7.347m/s respectively. Analytic Hierarchy Process gave a Consistency Index of 0.1230 and Consistency Ratio of 0.0843. The consistency ratio from the AHP was used to calculate the required Criteria Weight (C_w) for the fuzzy TOPSIS analysis. The results from the TOPSIS analysis showed that Lagos showed a greater advantage over the two other alternatives been considered. Finally, from the cummulative value of the analyzed attributes, Victoria Island (Lagos) has the highest figure of 233.6677 with a consideration rate of 38% and this places it above Koko (Warri) and Abonnema (Port-Harcourt) with a value of 187.7704 (30%) and 195.4378 (32%).

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Developmental sustainability for any nation is usually evaluated in the nation's economic, environmental and social status. This involves meeting power requirements as a result of which profitable growth depends, while ensuring the environmental safety and improving social conditions. Whichever way we choose to define the term sustainable growth, most recent methods of generating and using energy are obviously not sustainable in economic, environmental and social terms.

Recently, renewable energy has received serious consideration as an alternative energy source in an effort to reduce the increasing risks related to universal environmental changes (Lauren, 2015). The mining and burning of nonrenewable sources of energy damages the ecosystems, contaminates water and air resources, emits greenhouse gases leading to environmental changes, and this endangers the quality of lives around the affected settlements (Klass, 2011). A renewable energy production target has been set to 20% by the year 2020 by the European Union (Snyder and Kaiser, 2009).

Human growth has three basic aspects, which are the environmental, social and economic. All these aspects are highly dependent on energy.Energy provides services that are very essential to environmental, social and economic activity (Sambo, 2008). Two of these human development aspects have attracted serious attentions in recent times. The UNDP describes human growthof any nation as the provision of a healthy environment in which her citizens can achieve their full potential and live a productive and creative lives in line with their needs and interests (UNDP, 2004).

Energy is one of the most essential requirements for a good economic growth. Activities of the major component of a country's economy greatly depends on the utilization of one form of energy or another. Lots of researches into the connection between energy use and economic development have focused on how the latter is affected by the former. Increased energy use always leads to economic growth, at least in the early stages of economic development.

There are numerous ways in which the energy demand of a country can be met; there is the gas, hydro, wind and solar. Nigeria's major sources of energy supply are hydro and thermal power stations. The Hydro is usually affected by water level at different hydro-power stations varies due to climate seasonality and this has led to irregular generating power during the periods of near to the ground water levels. The thermal power stations are also accompanied with insufficient supplies of gas from the various gas wells, and this makes the continuous production of energy from these installations difficult (Iwayemi, 2008).

A way out is energy diversification, growing the present energy sources which has been unacceptably insufficient and unreliable to include renewable resources. These resources are cheap, accessible, massively available, friendly to the environment, non-diminishing and non-harmful source of energy, among which is the wind energy.

1.2 Statement of the Problem

The most valuable elements for National growth are the amount of energy been provided and consumed by a Nation. (Ajayi and Ajanaku, 2009).

Currently, energy production of the country is below 3000 MW owing to variations in the readiness and lack of proper maintenance of the equipment used for production (Ajayi, 2010). Consequently, Nigeria is far from achieving energy sufficiency.

A way out is to employ other forms of energy production, growing the existing energy sources which has been unacceptably insufficient and unreliable to consist of renewable forms of energy production. These forms are economical, reachable, enormously available, friendly to the environment, non-diminishing and non-harmful source of energy, among which is the wind energy.

1.3 Aim and Objectives

To carry out a multi-criteria evaluation of the appropriate offshore wind farm location in Nigeria.

The objectives of this study are to;

i. Collect the required attributes for wind farm siting from Lagos, Port-Harcourt, and Warri.
ii. Utilize the analytic hierarchy process to determine the consistency index, consistency ratio and the appropriate weight value for each of the attributes.
iii. Use FUZZY TOPSIS multiple criteria evaluation technique, to analyze the collected attributes after dividing them to Factors and Constraints.
iv. Determine the most suitable site(s) for wind farm development in Nigeria using a multiple-criteria analysis tool.

1.4 Justification of the Study

Water level declination at the several hydro-powers station in the country due to climate seasonality has leads to irregular availability of power at periods of low water heights. The country's thermal stations are also inefficient due to inadequate supply gas and this affects continuous production of energy from these installations difficult. Nigeria is known to have some great potential in offshore winds which if properly harnessed can be used to improve power generation. This work intends to use FUZZY TOPSIS multiple criteria evaluation technique to determine the possibility of installing wind farms at offshore locations in some part of the country.

1.5 Scope of the Study

This research is limited to the determination of some wind farm criteria that is required for installation of wind farm in offshore locations (Lagos, Port Harcourt and Warri) in Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical fundamentals

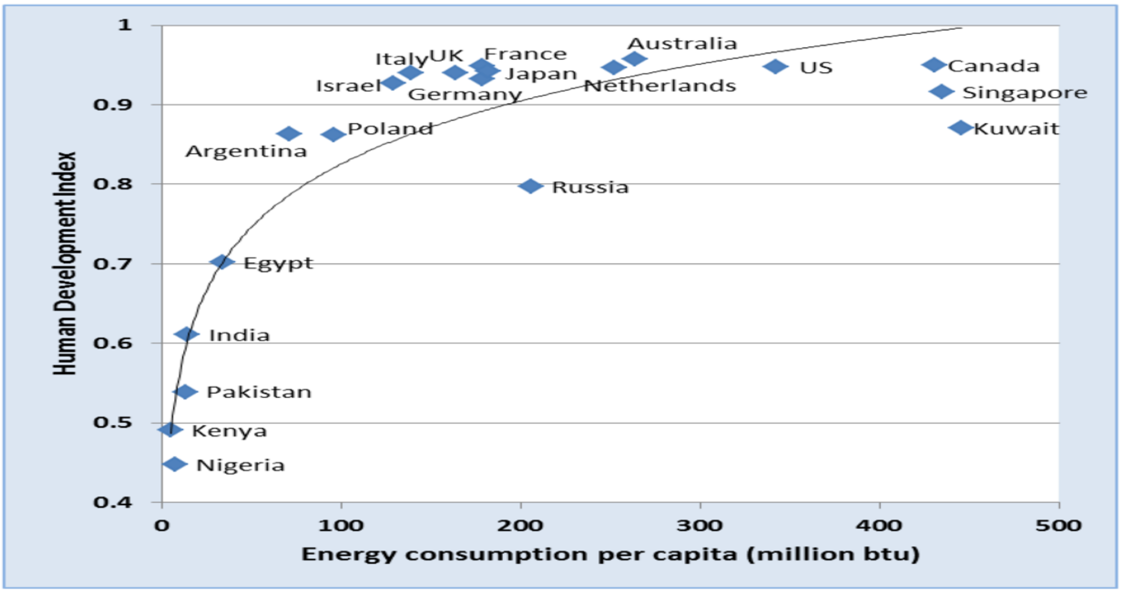
2.1.1 Energy and the world

Modern industrial economy depends on Energy as it is a vital component for all human activities: it offers services for cooking, space and water heating, lighting, health, food production and storage, education, mineral extraction, industrial production and transportation (Gelbspan, 2004). These services are influential to the economic and social development of any country and no nation has succeeded to develop much without ensuring at least minimum access to energy services for a broad section of its population (Heltberg, 2003).

2.1.2 The role of energy for development

Sustainable development includes; increasing access to energy for the poor, Energy efficiency and demand-side management, reforms of energy sector, fuel competence and cleaner energy for transportation, managing transportation demand, capacity-building in energy policy formulation and management, advanced energy technologies, innovative financing solutions and technology transfer, Energy and rural development Consumer education and awareness-raising. Economic development most times is considered to be path towards the achievement of social goals (Corina, 2012).

Existing literatures have stated that there exist a definite correlation between the rate of energy utilization and economic growth and this is measured by GDP per capital which is also used as an alternative for the measurement of the standard of living (Yuan et al., 2008). It is understood from existing literatures that the energy consumption of any country is directly proportional to the living standard in that country and the higher the living standards in a particular country, the higher is its energy consumption rate. This relationship has been extensively studied for developed countries (Bowden and Payne, 2009), and has been a subject of the recent research for the less-developed countries (Apergis et al., 2009). Figure 2.1 shows the relationship between human development and



energy consumption per capita

Figure 2.1: Energy Consumption vs Human Development Index
(Source: firstgreenconsulting.press.com)

2.1.3 Wind energy potentials

From history, wind has always been harnessed as form energy by the early people. Boats and canoes were propelled by means of wind energy as far back as early 5000 B.C. By 200 B.C., pumping of water for domestic use was already been carried out with the help of an uncomplicated windmills in china, and windmills with vertical axis were used for grinding grain in Persia and the Middle East (Yuan *et al.*, 2008). Fresh methods of utilizing the energy of the wind eventually spread around the world. People in the Middle East by the 11th century were already using windmills extensively for the production and processing of food (Costantini and Monni, 2005). Windmills were refined and adopted for lakes draining and marshes in the Rhine River Delta. When the technology was taken to the new world in the late 19th century by settlers, windmills started gaining usage for irrigation and pumping of water for farm and ranches and was later utilized for the generation electricity for homes and industry.

Windmills were also used by the American colonist in wheat and corn grinding as well as in water pumping and in sawmills for cutting of woods. With the desire for an improved supply of electrical power, energy of the wind found new applications in illumination of structures remotely from centrally generated power. Throughout the 20th century, there was the development of small wind plants that are suitable for ranches and homes, and higher industrial-scale wind farms that could be linked to electricity grids (Narayan *et al.*, 2008).

The United States government from 1974 through the mid-1980s, worked with reputable industries to further the wind energy technology and allow the development and implementation of large scale commercial wind turbines. Due extensive study, wind turbines were developed under a program overseen by the National Aeronautics and Space Administration to create a utility-scale wind turbine industry in the United States (Piebalgs 2007). Today, there are every size range of wind-powered generators been operated, from small turbines for battery charging at remote dwellings to large near-gigawatt-size offshore wind farms that generates electricity to national electricity transmission systems. Figure 2.2a, 2.2b and 2.3 shows the world energy capacity by the year 2012 and the global cumulative installed wind capacity between the years 2000 and 2015 respectively.

Table 2.1a: Top 10 New Installed Capacity from January to December 2012

Country	MW	% Share
PR China	13,200	30
USA	13,124	29
Germany	2,439	5
India	2,336	5
UK	1,897	4.2
Italy	1,273	2.8
Spain	1,122	2.5
Brazil	1,077	2.4
Canada	935	2.1
Romania	923	2.1
Rest of the world	6,385	14.3
Total Top 10	**38,326**	**85.7**
World Total	**44,711**	**100.0**

(Source: cleantechnica.com)

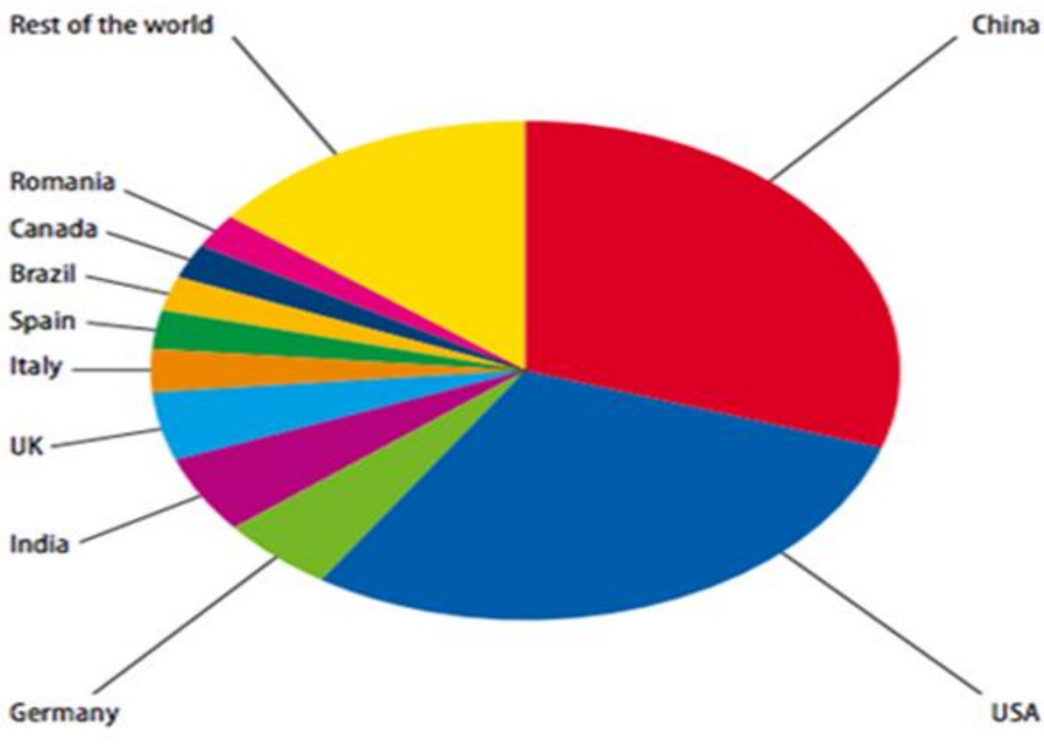


Figure 2.2a: Top 10 New Installed Capacity Jan-Dec 2012
(Source: cleantechnica.com)

Table 2.1b: Top 10 Cummulative Capacity December 2012

Country	MW	% Share
PR China	75,564	26.8
USA	60,007	21.2
Germany	31,332	11.1
Spain	22,796	8.1
India	18,421	6.5
UK	8,445	3.0
Italy	8,144	2.9
France	7,196	2.5
Canada	6,200	2.2
Portugal	4,525	1.6
Rest of the World	39,853	14.1
Total TOP 10	**242,630**	**85.9**
World Total	**282,482**	**100.0**

(Source: cleantechnica.com)

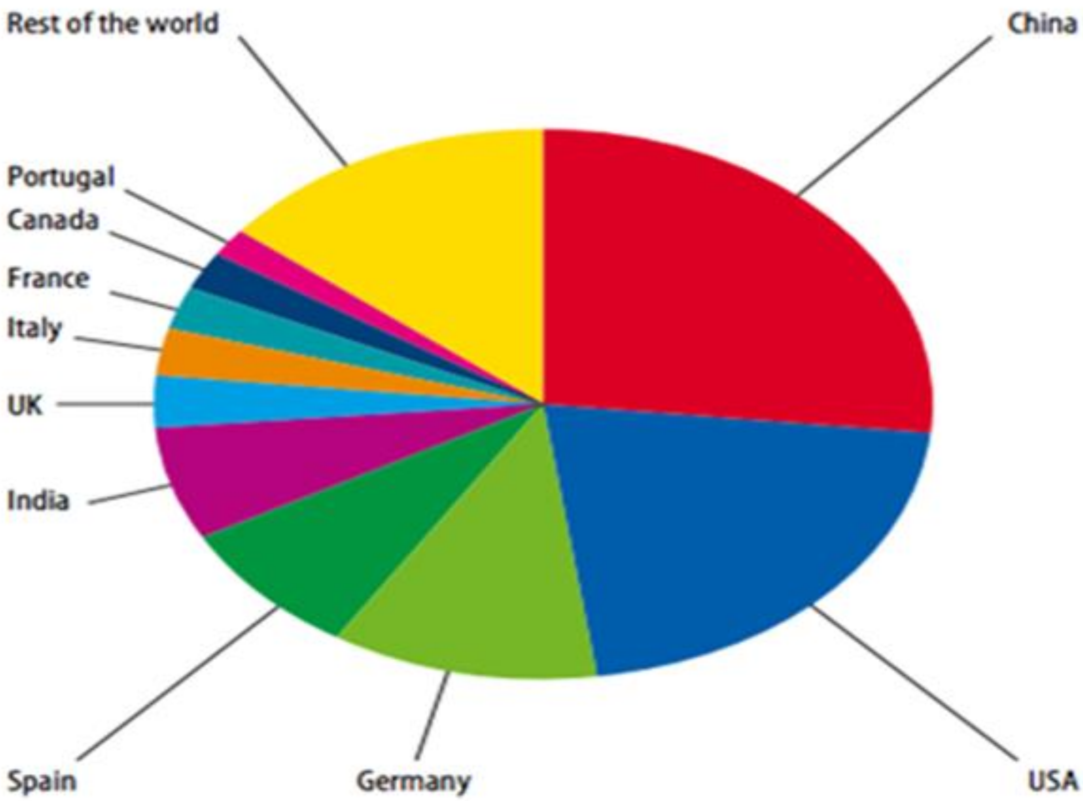


Figure 2.2b: Top 10 Cumulative Capacity Dec 2012
(Source: cleantechnica.com)

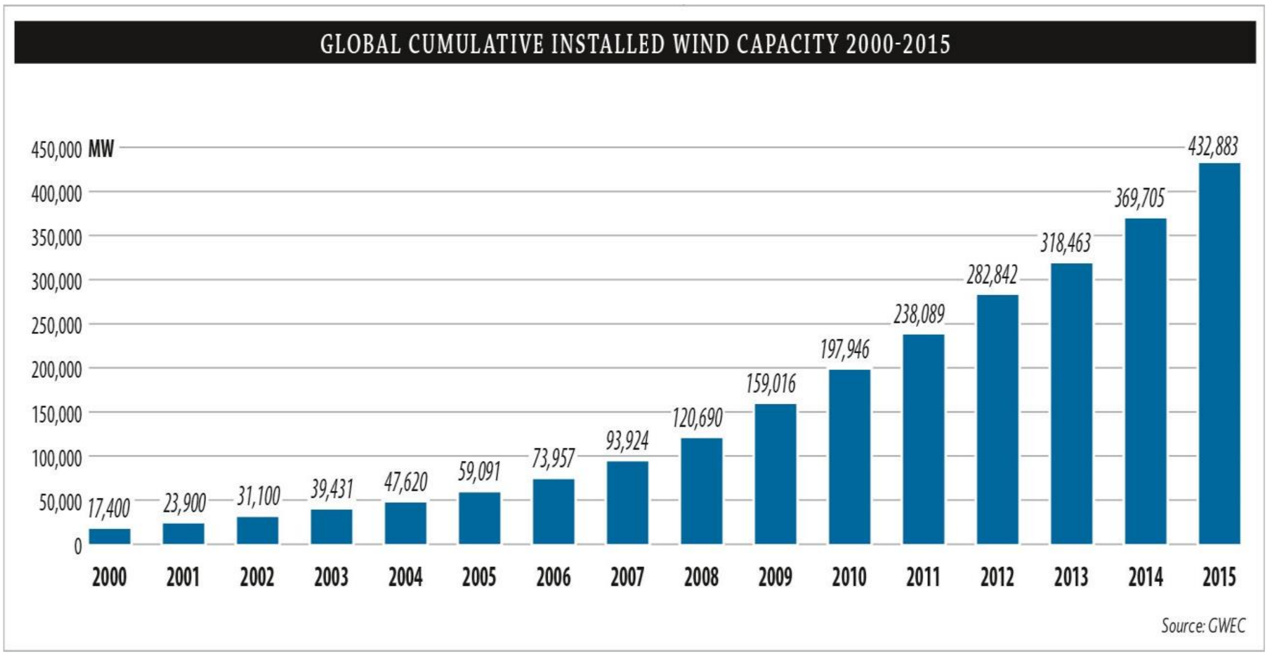


Figure 2.3: Global Collective installed wind energy capacity (2000 - 2015)
(Source: gwec.net)

2.1.4 Onshore wind farms

Energy of moving air is harnessed by using wind turbines to generate electricity. Harnessing of wind energy with use of wind turbines on land are known as onshore wind, while that sited out at sea or in fresh water region is called the offshore wind farm. In the United Kingdom, what is involved in the onshore wind energy, in contrast with other less harmful and fossil fuel energy source, have in recent times been the topic of deliberation and among politicians. This form of energy generation is already playing a leading role in the generation of renewable electricity in the United Kingdom. The onshore form of wind energy utilization generated almost Seven Total Mega-Watt (7 TMW), over a quarter of the electrical energy made available by British renewables by the year 2010 and enough to save six million tons of CO_2, according to government estimates. By 2020, this form of wind energy is expected to produce up to 30 TMW. Onshore wind is one of the cheapest forms of renewable energy source and this is one of the advantages of this method of energy production. Electrical energy generation from onshore wind turbines costs around

7–9p per kW, which is around half the cost of offshore wind and a quarter of the costs of solar photovoltaic panels. Appendix A shows a list of global onshore wind farms and their capacities.

2.1.5 Offshore wind

The exploration of the offshore wind energy was first nurtured in the early 1930s, but the first offshore wind power turbine was built 250 m off the shores of Northern Sweden in the year 1990.Itwas followed by the first offshore marketable wind farm built about 2.5 km offshore of Denmark in 1991 (Bilgili *et al.*, 2011). Since then, the exploration of offshore wind farm has grown exponentially; most specifically in Northern European countries with a total of 2,488 wind turbines in 74 wind farms off the shores of eleven European countries fill the electricity grid, for a total installed capacity of 8,045.3 MW of power (Lauren 2015). This covers roughly about one percent of Europe's power demand (Corbetta *et al.*, 2015).

There are numerous benefits and drawbacks of offshore wind over its onshore counterpart. The benefits of the offshore wind farm comprise of more consistent wind resources due to stronger and more consistent wind speeds and scanty aesthetic impact offered by offshores than onshore (Esteban *et al.*, 2011). The initial expenses associated with offshore wind farm are the major drawback there is over other forms energy production process onshore inclusive (Esteban *et al.*, 2011). Table 2.1 shows the list of global offshore wind farms and their capacities.

Table 2.2: List of Offshore Wind Farms around the world

Wind farm	Total (MW)	Location	Turbines & Model

London Array	630	United Kingdom	175 × Siemens SWT-3.6-120
Gwynt y Môr	576	United Kingdom	160 × Siemens SWT-3.6-107
Greater Gabbard	504	United Kingdom	140 × Siemens SWT-3.6-107
Anholt	400	Denmark	111 × Siemens SWT-3.6-120
BARD Offshore 1	400	Germany	80 × BARD 5.0MW
Global Tech I	400	Germany	80 × ArevaMultibrid M5000 5.0MW
West of Duddon Sands	389	United Kingdom	108 × Siemens SWT-3.6-120
Walney(Phases 1&2)	367.2	United Kingdom	102 × Siemens SWT-3.6-107
Thorntonbank(Phases 1–3)	325	Belgium	6 × Senvion 5MW,
Sheringham Shoal	315	United Kingdom	48 × Senvion 6.15MW
BorkumRiffgrund 1	312	Germany	88 × Siemens SWT-3.6-107
Thanet	300	United Kingdom	78 × Siemens SWT-4.0-120
Nordsee Ost	295	Germany	100 × Vestas V90-3.0MW
Amrumbank West	288	Germany	48 × Senvion 6.15MW
Butendiek	288	Germany	80 × Siemens SWT-3.6-120
DanTysk	288	Germany	80 × Siemens SWT-3.6-120
EnBW Baltic 2	288	Germany	80 × Siemens SWT-3.6-120
Meerwind Süd / Ost	288	Germany	80 × Siemens SWT-3.6-120
Lincs	270	United Kingdom	80 × Siemens SWT-3.6-120
Humber Gateway	219	United Kingdom	75 × Siemens SWT-3.6-120
Northwind	216	Belgium	73 × Vestas V112-3.0MW

Westermost Rough	210	United Kingdom	72 × Vestas V112-3.0MW
Horns Rev 2	209.3	Denmark	35 × Siemens SWT-6.0-154
Rødsand II	207	Denmark	91 × Siemens SWT-2.3-93

2.1.5.1 Anholt offshore wind farm denmark

This is the third largest offshore wind power installation in the world located between Djursland and Anholt Island in Kattegat. With a capacity of 400 MW, it has same capacity as the BARD offshore. Most of the diesel-powered energy supply along the island was replaced by a cable from the wind energy center (Danish Energy Agency, 2010). The first monopole foundation was placed by a heavy lift vessel on the 31st of December 2011 (Jan *et al.*, 2013). Figure 2.5 shows the Anholt offshore wind farm in Denmark.

Figure 2.4: Anholt offshore wind farm Denmark
(Source: baltictransportjornal.com)

2.1.5.2 Jiangsu Xiangshui offshore wind farm, china

Constructed in the outer waters of Xiangshui county in Jiangsu, Jiangsu Xiangshui offshore wind farm has a production capacity of 202 and it is China's first wind power project to convey power through an offshore transformer substation (China Daily, 2014). The wind farm's operational area has a water depth between 8 m and 12 m. The project includes wind turbines rated at 3 MW and 4 MW and based on a high-rise pile cap foundations of 146.5 m height. Each turbine has a hub height of 90m and rotor diameter of 113 m. Figure 2.7 shows Jiangsu Xiangshui offshore wind farm in Jiangsu, China

Figure 2.5: Jiangsu Xiangshui offshore wind farm China
(Source: energiasustentables.com.ar)

2.1.6 Considerations for offshore wind farm location

There are three major considerations for the location of an offshore wind farm which are:

2.1.6.1 Environmental considerations

Offshore wind energy developers have to consider a variety of environmental factors. A large scale development causes certain level of effect on the present environmental roles. Different from its non-renewable counterparts, offshore wind energy projects has very little effect on the environment as it generates power without the burning fuel and zero emission pollutant. Offshore wind power also has a less substantially offensive effect as compared to conventional forms of energy production that are accompanied with extensive bionetwork damage. Nonetheless, construction and operation of wind farms has some level of effect on the existing environment which must be considered and carefully assessed before commencing the project. Most of the important variables usually considered comprises of avian migration, marine mammal habitats, endangered species habitats and habitat areas of particular concern (UNC-CH 2009).

Owning to the fact that wind energy turbines used for the conversion of wind energy to electrical energy are fixed below the ocean surface and stands above hundreds of feet, there is delicacy in the ecological conditions of coastal environments. Turbines must be located in areas where they cannot disrupt the protected marine habitats as well as avian traveling paths. Wind farms can cover great areas of the water space, and stands to about 400 feet tall, therefore they stand as an impending hazard to traveling sea birds, bats, and butterflies.

2.1.6.2 Economic considerations

The economic feasibility of an offshore wind energy development is influenced by a variation of technical and marine use concerns. The physical ecological elements that impacts biodiversity goes a long way to determine the exact form of technology that needs to be adopted at specific locations and this affects the cost implication of the development of an offshore wind project. These ecological factors comprises of wind resources, geographical conditions, distance from shores, bathymetry, current industrial ocean usage must all be put into consideration when embarking on an offshore wind farm projects. The effect of offshore wind projects on existing ocean uses has to be as minimal as possible and cost effectiveness has to be put into play while considering the environmental conditions so as to support and preserve marketable scale wind energy development. Essential procedures must be taken to ensure that wind farms are situated in highly resourceful locations where there is minimum interference to already existing life activities.

Spatial features that affect the economic feasibility involved in offshore wind farm projects comprise of wind speed, bathymetry, and distance from region of settlement. The amount of energy that can be harnessed in a particular location correlates directly with the wind speed at the location reason be that the stronger and steadier winds blows, the higher the energy production possibility of the wind farm. The financial impact of the bathymetry and distance from energy facilities was described by samoteskul *et al.* (2014). In their work, it was stated that a depths below 60 m require a jacket foundation which costs around $6255 per metric ton and this is increases costs by 1.3 million dollars per meter of depth. Depth greater than 60 m calls for a floating type of foundation that cost around 9.6 million dollars for a generic 5MW turbine. In terms of distance from shores, a distance below 80 km from shore require HVAC cables which costs around $1,128,000 per km while 80 km and above requires HVDC cables which gives an increased cost of $2,150,000 per km.

2.1.6.3 Socio-political considerations

There are lots of complications in the socio-political nature of offshore wind planning, these levels of social pressure and political drive, or lack thereof, has undoubtedly had an effect on the development of offshore wind. Examples of these social-political factors that affects the offshore wind farm planning and site appropriateness are the availability of governmental financial incentives, governing framework, and communal awareness, however widely debated is the level of impact that each of these factors has. Offshore wind energy is lagging behind in most nations of the world, it is growing rapidly in other places like Europe where there is the social and political will to explore other forms renewable resources.

There is an overlap existing between the economic and socio-political consideration and this over-lap is the Political incentives, however the decision as to whether or not to initiate this kind of project is ultimately a political one and is outside the powers of the developers themselves. A look at the existing framework of offshore wind development in countries where it's been successful gives an additional investigation into what it takes to drive a fruitful offshore wind energy market.

2.1.7 Wind energy capacity in Nigeria

Faced with Africa is the growing challenge of generating additional power to counter the current and impending demand with over half a billion of Africa's population not having access to electricity. Africa is blessed with the highest reserves of renewable form of energy resources in the world, and the continent has enough renewable energy potential to meet its future power demands (World Energy Council, 2010).

One of the fastest rising technologies in terms of energy production presently is the wind energy. The rising worry about global warming and the unreliable and epileptic state of power supply in Nigeria ought to be something to worry about by all and should increase the nation's determination into strong demand for wind generation. Wind as a source of energy production has and is still progressively gaining relevance around the world, though supported by long history, wind energy technology is new compared to the solar; it is certainly available, still many countries are yet to clinch it. Wind energy today in Nigeria has been woefully under-utilized. A 10 MW capacity onshore wind farm is said by the government to have been almost completed and has at present started to function on experimental basis. Located in the northwestern part of Kastina, Kastina Onshore Wind farm is the first form of wind energy development in Nigeria and the largest in West Africa (Akinbami *et al.*, 2001). The wind farm has the capacity to provide power for over 2,200 going by industrial calculations. Located in Rimi Villages about 25 km south of Katsina City, the project is made up of 37 wind turbines, with an individual capacity of

275kilo-watt. The project was first thought of by the Kastina state government, later inspired by the high wind velocity in Katsina, the federal government keyed into the vision and gave their support.

About 80 million Nigeria's population don't have access to adequate electricity; this has contributed greatly to the slow rate of human and economic development in Africa's largest population and biggest economy. This has prompted the present leadership to initiate several measures to resolve the energy crises faced by the country. Among this measures are the liberalization of the energy industry to encourage public private partnership in the sector. Interest in the area of harnessing the nation's renewable energy resources has been growing impressively, most especially the area of solar energy. In the year 2016, Gigawatt Global (GWG), made public the development of a 100 MW PV station in the north. Also recently, MotirSeaspire a Unites States investment consortium signed a Memorandum of Understanding with the Nigerian government to provide up to 1,200 MW of solar-powered electricity in the country by 2017.

2.1.8 Multi-criteria decision analysis in renewable energy

A part of the discipline of operations research is the multiple-criteria decisions making (MCDM) that extensively appraises a multiple contradictory criteria in decision making (both in our daily lives and in other setups like business, government and medicine). Contradictory criteria are typical in evaluating options and cost or price is commonly one of these main criteria, and some measure of quality is typically another criterion, easily in conflict with the cost. In acquiring an automobile, price, luxury, protection, and fuel consumption may be some of the major criteria to put into consideration (Afshar *et al.*, 2011).

The technique for order of performance by similarity to ideal solution (TOPSIS) is one of the most adopted Multi-Criteria Decision Making techniques to solve issues related to diverse perspectives. The technique for order of performance by similarity to ideal solution method first came into use in it crisp form in the year 1981 with the concept of "Displaced Ideal separated away from the Ideal Solution the least" (Sachdeva et al., 2009). It has a basic assumption that the best solution should be that which is close to the positive ideal solution as possible and the farthest from negative ideal solution. This has been broadly applied by the researchers to solve problems with conflicting criteria in many fields (Parkan, and Wu, 1999), (Jee, and Kang, 2000).

In lots of decision-making situations, it is quite challenging to achieve precise numerical values for the criteria or attributes (Cai *et al.*, 2009; Li *et al.*, 2010). Therefore, several parameters will be difficult to be assessed precisely and the information of different subjective criteria and their weights are usually conveyed in linguistic terms by the decision maker (Kahraman and Kaya, 2010). To get past this uncertainty in human decision, fuzzy logic can be applied.

2.1.9 Analytic Hierarchy Process

The Analytic Hierarchy Process simply called the AHP is a systematized technique for organizing and evaluating compound choices, based on mathematics. These technique was established in the 1970s by Thomas L. Saaty and it has been broadly considered and refined since then. It has particular application in group decision making (Kao, 2010) and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, ship building (Kao, 2010) and education. Rather than suggesting a "precise" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements (Saaty, 2008).

Once a hierarchy is built in the Analytic Hierarchy Process, the decision makers systematically evaluate its various elements by comparing them to each other two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations (Pohekar and Ramachandran, 2004).

2.2 Review of Past Work

A work carried out by Ajayi (2010) on potential for wind energy in Nigeria talks about some of the problems of wind energy development and utilization in Nigeria. Surveyed were various government enterprises at evaluating the possibilities of wind for the production of electricity. Wind was reported to be strongest in hilly regions of the North, while the middle belt and northern fringes have high wind energy potential. In his work, $4.0 - 7.5$ m/s and $3.0 - 3.5$ m/s was found in the north and south respectively at about 10 m off ground level.

In Behzadian *et al.* (2012), state-of the-art survey was carried out on TOPSIS applications multi-criteria decision making (MCDM), these methods were said to have received lots of consideration from researchers and practitioners across various industries. Among various multi criteria decision making methods developed to solve real-world decision problems, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) remains the best across different application areas.

Site selection for wind farm installation by Biswal1 and Shukla (2015) stated that wind energy offers substantial possibility for near-term (2020) and long-term (2050) greenhouse gas (GHG) emissions reductions. This work developed an algorithm that was applied for the selection of a suitable location for the installation of wind turbines. Matlab software was used for the execution of the algorithm. Offshore wind farms were considered better over the onshore counterpart due to various regions as they have more wind potential and more consistent wind profile.

In Chinedum *et al.* (2001) a logistic analysis of Nigeria offshore wind farm sector that studied the appropriateness of the Nigeria's offshore region for offshore wind farms installation was carried out. Cost comparative valuations of the benefits of embracing this renewable energy option over fossil fuel and other energy alternatives was carried out. The offshore wind farm however costlier was found to hold abundant benefits not found in non-renewable energy alternatives.

Research on Wind Energy Potential in Nigeria by Felix *et al.* (2012) reported that one of the fastest growing technologies in energy generation nowadays is the wind energy. Their work showed that the erratic and epileptic state of power in this country and the concern about global warming should be a great concern for all and should drive us into strong demand for wind generation. The paper describes the wind energy potential in Nigeria and specifies the conditions to be met before the wind generator can be connected to the existing grid and how it can be connected.

Garba and Al-Amin (2014) carried out an Assessment of Wind Energy Alternative in Nigeria from the Lessons of the Katsina Wind Farm. Katsina wind farm is certainly a pride to Nigeria; if only some few details could be strengthening in order to ensure the sustainability of the project. They stated that it is imperative to state that there is an urgent need to have an energy mix of Solar, Wind and Hydro resources in the country. In order to meet the demand of over 170 million populace

A Decision Making Model for Selection of Wind Energy Production Farms Based on Fuzzy Analytic Hierarchy Process by Sagbas *et al.* (2011) was aimed at offering an evaluation model for the prioritizing of wind energy production sites namely, Mersin, Silifke and Anamur, located in Mediterranean Sea region of Turkey. For this purpose, a fuzzy analytical hierarchy decision making approach based on multi-criteria decision making framework including economic, technical, and environmental criteria was performed.

2.2.1 Research gap

A lot has been done on wind energy capacity around the globe as well as in Nigeria. Most of the Nigeria based research works related to this thesis has majorly been on onshore wind farms. This particular work looks at the possibility of utilizing the country's offshore wind potentials to improve the already existing sources of power supply in Nigeria.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The decision of the appropriate location for offshore wind farm installation depends on multiple criteria which must be fulfilled by the selected location. There are three major considerations for the selection of an appropriate offshore wind farm site(s) which are;

1. Economical Consideration
2. Socio-Political consideration
3. Environmental Consideration

Environmental consideration is further divided into two vital Multi-Criteria aspects. The first is a Multi-Criteria process concerned with the geographical nature of the selected location. A Geographical Information System (GIS) is majorly required to get all of the criteria need for analysis. It considers Aquatic Life, Soil Topography, Undersea Soil

Erosion and the Change in Water Level. The second aspect is considers the suitability of the selected location based on the immediate surroundings. This aspect is known to be the technical aspect of the Environmental Consideration. Attributes considered in this aspect are;

1. Average Wind Speed of the Offshore.
2. Distance from shore (Settlement)
3. Distance from Airport(s)
4. Distance from Local Electricity Distribution Companies
5. Proximity to high Power demand Areas
6. Interference with Bird flight
7. Interference with Undersea Cables and Gas lines
8. Interference with Existing Shipping Route
9. Interference with Telecommunication Installations.

This thesis is focused on the Technical aspect of the Environmental Consideration for the appropriate location for offshore wind farm in Nigeria.

3.1.1 Data collection

This thesis is limited to technical attribute of the environmental considerations. The required data are Average wind speed, Distance from shore (Settlement), Distance from Airport(s), Distance from Local Electricity Distribution Companies and proximity to high Power Demand Areas, Interference with Bird flight, Interference with Undersea Cables and Gas lines, Interference with Existing Shipping Route and Interference with Telecommunication Installations. These data were collected for the three states i.e. Lagos, Warri and Port-Harcourt, which are the alternatives for which their attributes were analysed.

The required Average Wind Speed was collected from the Nigerian Meteorological Agency(NIMET), while the quantitative attributes were sourced for and qualitative attributes were obtained using Questionnaires as shown in Appendix Four (A,B and C). Both public and government opinion on the subject were also gotten through the use of Questionnaires which was responded to by members of the community in view. The developed questionnaire was considered for three alternatives (Lagos, Warri and Port-Harcourt).

3.2 Methods

3.2.1 Mathematical model

Data collected were analysed using the fuzzy TOPSIS mathematical model. Technique for order performance by similarity to ideal solution is a convenient technique in resolving a multi-criteria problem (Deng et al. 2000). TOPSIS assists decision maker(s) organize the problems to be solved, it also helps to analyse, compare and rank alternatives. The Multi-Criteria Decision Process involves a series process as shown by the flow chat in Figure 3.1.

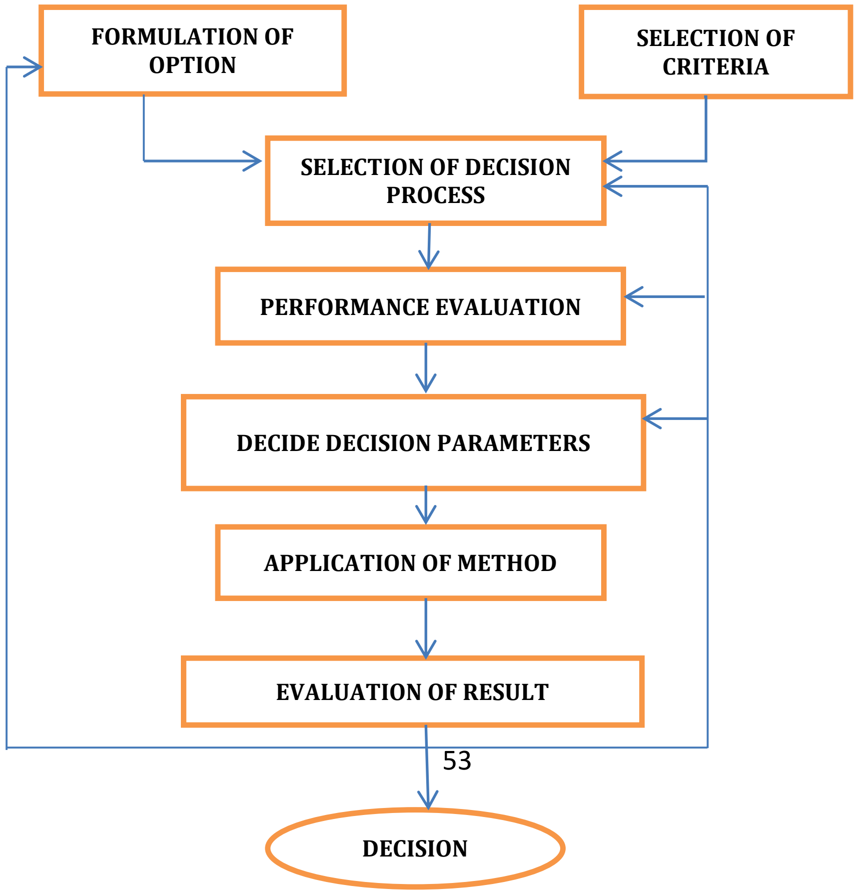


Figure 3.1: Multi-Criteria Decision Process

3.2.2 The analytical hierarchy process - AHP

Among several multi-criteria decision making methods, there is the Analytical Hierarchy Process developed by Saaty (1977). It offers measures of decision consistency, develops priorities among criteria and alternatives and makes simpler preference rankings among decision criteria using pair wise comparisons.

3.2.3 Mathematical process:

For a matrix of a pair-wise element;

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} \\ C_{21} & C_{22} & C_{23} & C_{24} \\ C_{31} & C_{32} & C_{33} & C_{34} \\ C_{41} & C_{42} & C_{43} & C_{44} \end{bmatrix}$$

1. Sum the values in each column of the pair-wise matrix.

$$C_{ij} = \sum_{i=1}^{n} c_{ij} \qquad (3.1)$$

2. Divide each element in the matrix by its column total to generate a normalized pair-wise matrix.

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} c_{ij}} \begin{bmatrix} x_{11} & x_{12} & . & x_{1m} \\ x_{21} & . & . & . \\ . & . & . & . \\ x_{n1} & . & . & x_{nm} \end{bmatrix} \qquad (3.2)$$

3. Consistency Vector is calculated by multiplying the pair-wise matrix by the weights vector

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} \\ C_{21} & C_{22} & C_{23} & C_{24} \\ C_{31} & C_{32} & C_{33} & C_{34} \\ C_{41} & C_{42} & C_{43} & C_{44} \end{bmatrix} \times \begin{bmatrix} W_{11} \\ W_{21} \\ W_{31} \\ W_{41} \end{bmatrix} = \begin{bmatrix} C_{V11} \\ C_{V21} \\ C_{V31} \\ C_{V41} \end{bmatrix} \qquad (3.3)$$

4. λ_{max} (Average) is calculated by averaging the value of the consistency vector.

$$\lambda = \sum_{i=1}^{n} Cv_{ij} \qquad (3.4)$$

$$CI = \frac{\lambda - n}{n-1} \qquad (3.5)$$

$$CR = \frac{CI}{RI} \qquad (3.6)$$

$$D^k = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} X_1 & X_2 & \dots & X_j & \dots & X_n \end{array} \\ \begin{pmatrix} x^k_{11} & x^k_{12} & \dots & x^k_{1j} & \dots & x^k_{1n} \\ x^k_{21} & x^k_{22} & \dots & x^k_{2j} & \dots & x^k_{2n} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ x^k_{i1} & x^k_{i2} & \dots & x^k_{ij} & \dots & x^k_{in} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ x^k_{m1} & x^k_{m2} & \dots & x^k_{mj} & \dots & x^k_{mn} \end{pmatrix} \end{array}$$ (Sachdeva *et al.*, 2009) (3.7)

Ai represents the alternative i, i = 1,...,m; $X_j$represents criterion j, j = 1,...,n; with both numerical and non-numerical data. x^k_{ij} indicates the performance rating of alternative A_i with respect to criterionX_j by decision maker k, k =1,..., K, and x^k_{ij} is the component ofD^k. Note that non-numerical data from each alternative can be assigned discrete values or linguistics values.

For easy combination of qualitative and quantitative attributes, Normalization is carried out on the data and this handles the disparity in both set of data.

Mathematically;

1. Take the average of the criteria values

$$Average(\mu) = \frac{\sum_{i=1}^{n} C_{ij}}{n} \tag{3.8}$$

2. Find the standard deviation based on samples (done with the Excel function **(=STDEV.S)**)

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(C_{ij} - \mu\right)^2} \tag{3.9}$$

Finally standardize the criteria values by using the Excel function (**=STANDARDIZE**)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Wind data

This work looks at multi-criteria evaluation of offshore wind farm locations of three locations in Nigeria. Which are Victoria Island (Lagos), Abonemma (Port Harcourt) and Koko (Warri). Appendix two (A, B and C) show the monthly average wind speed for Lagos, Warri and Port- Harcourt respectively.

Table 4.1 of Appendix (three) shows a Ten years average wind speed for the locations under consideration (Lagos, Port-Harcourt and Warri). From the table, Port-Harcourt has the highest average wind speed of 7.35 m/s followed by Warri with and average wind speed of 7.29 m/s and Lagos has 6.25 m/s. Using Table 4.1, Figure 4.1.1a, 4.1.1b and 4.1.1c is a bar chart of the yearly average for ten years of wind speed for Lagos, Warri and Port-Harcourt respectively. While Figure 4.1.1d is the combine bar chart for the three alternatives.

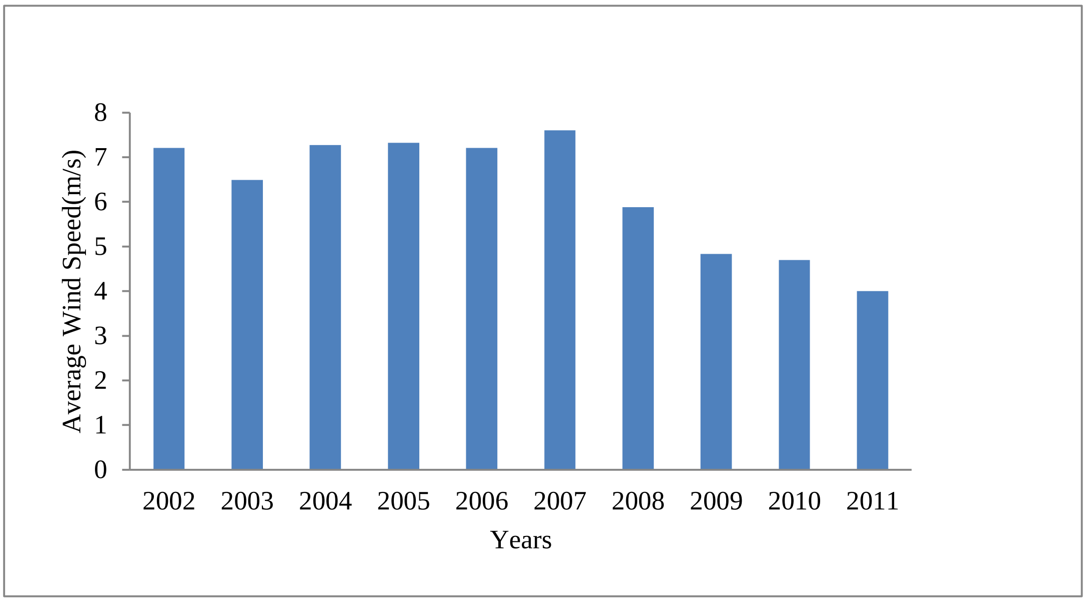


Figure 4.1a: Lagos average wind speed for ten years

Figure 4.1b: Warri average wind speed for ten years

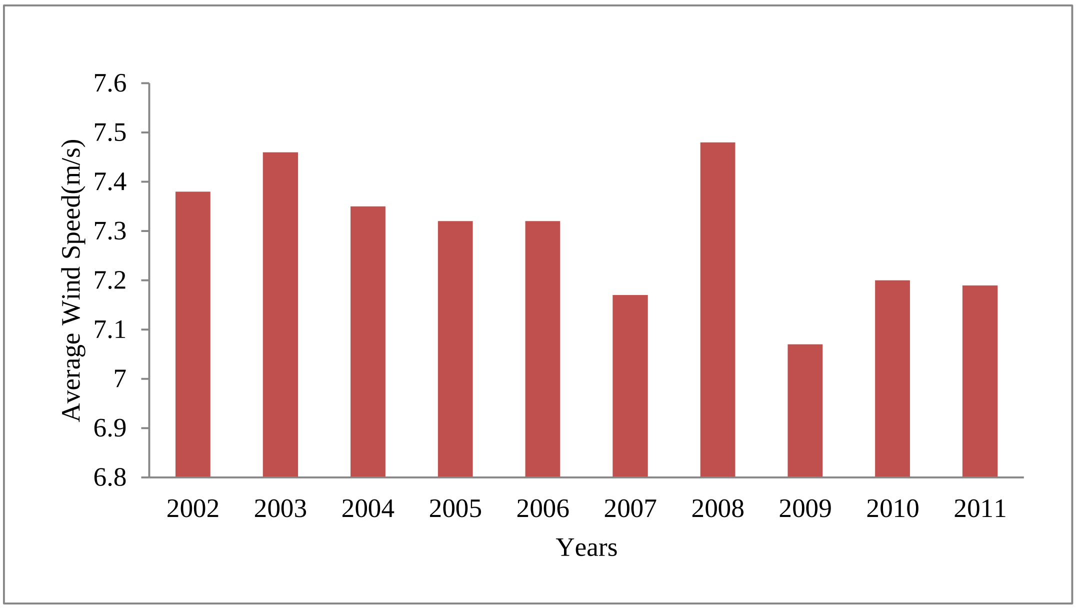
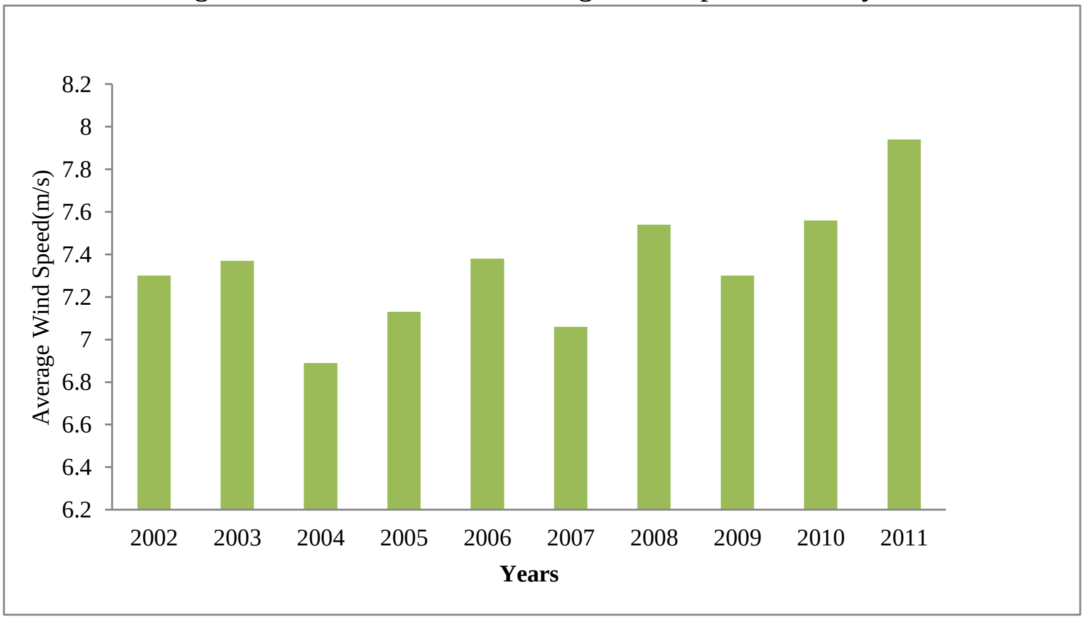


Figure 4.1c: Port-harcourt average wind speed for ten years



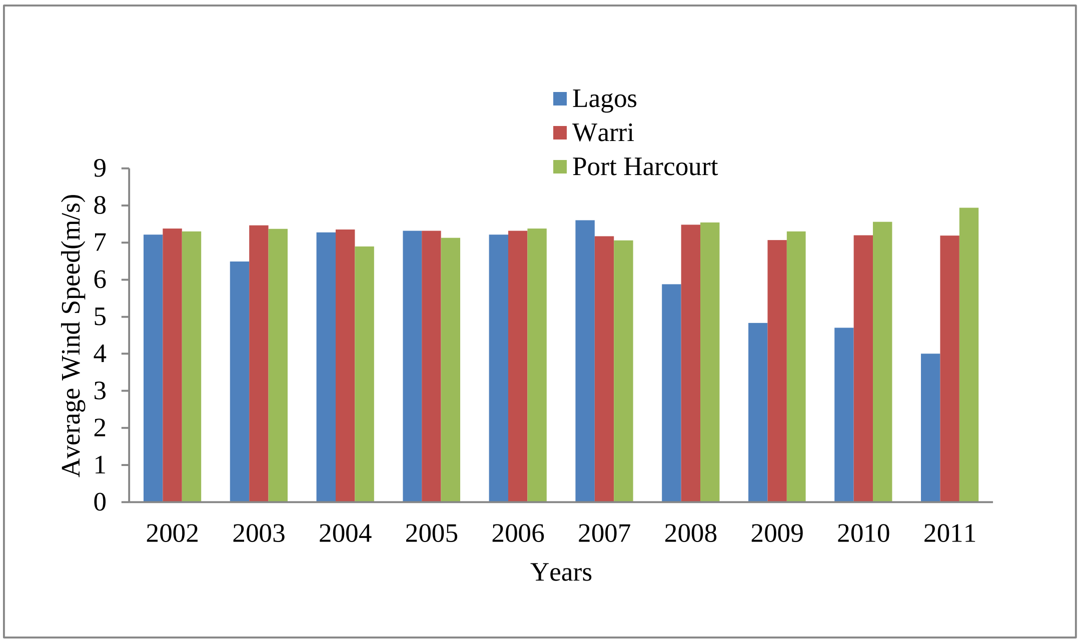


Figure 4.1d: Combined average wind speed for the three alternatives

From the combined bar chart, it is observed that Warri has a steadier wind speed for the ten years period followed by port-Harcourt while Lagos has a large variation in wind speed for the ten years period. Also, Warri has it lowest average wind speed in the year 2009 (7.07m/s) and highest in the year 2008 (7.48m/s), Port-Harcourt lowest average wind speed of 6.89m/s occurred in 2004 while the highest was in 2011 (7.94m/s). Lagos has 7.32m/s as its highest wind speed which was in 2005 and lowest of 4.0m/s occurring in 2011.

The average wind speed for the three alternatives Lagos (6.25 m/s), Warri (7.29 m/s) and Port-Harcourt (7.35 m/s), this implies that all of the alternatives have the required average wind speed required for installation of wind farm which is a minimum of 4.0 m/s as stated by Ajayi, 2012.

4.2 Technical aspects of the environmental attributes

Other required criteria for the proper evaluation of an offshore wind farm like distance from shore, distance from an airport, proximity to power demand and Local Power distribution companies were collected from the use of questionnaires which were served to professional individuals in the three locations. The samples collected were sorted and rearrange as shown in Table 4.2a, 4.2b and 4.2c in Appendix three for the three Alternatives. After which the average was taken for further analysis. The distance from shore was gotten from the NIMET stations in each of the locations. Lagos was found to be 500 km, Warri 350 km and Port-Harcourt was 400 km.

4.3 Analytic hierarchy process (AHP)

Haven collected all the required data, the weight function was computed on Microsoft Excel. The computation was based on the Analytic Hierarchy Process (AHP) principle. Weights were allotted to Attributes based on their relevance in the determination of the appropriate site location.

4.3.1 Mathematical evaluation

Table 4.3a in Appendix three shows the criterion weight score. Comparison of criteria were done and scored according to the rating on this table. When a particular criterion is compared to itself, it carries a judgment value of 1. And if two different criteria happen to have the same level of relevance, a judgment value of 1 is also assigned. When a criterion is less important than that which it is been compared to, the judgment value is taken from the right hand side of Table 4.3a and an inverse of that value is recorded but when a criterion is more important than that which it is been compared to, the judgment value is taken from the right hand side of Table 4.3a and the actual value is recorded. Table 4.3b in Appendix three shows the comparison matrix of order nine (9) where 9 criteria C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8 and C_9 are compared against each other.

4.3.2 Normalization

Having completed the comparison matrix next is to normalize the matrix. Using Equation (1), the sum of the pair-wise criteria matrix column was calculated and shown on Table 4.4a contained in Appendix three. Using Equation (2), each element in the column was divided by the column sum to return its normalized value. Summation of each column of the normalized matrix was 1 which conforms to Satty's claim that if the column sum of a normalized comparison must be equal to 1. Table 4.4b of Appendix three shows the normalized form of the comparison matrix.

4.3.3 Consistency analysis

Consistency analysis involves the calculation of the Consistency Ratio (CR), Consistency Index (CI) while the Random Index has already been generated by Satty, 1980 as shown below.

Table 4.5: Random inconsistency indices for *n* = 10 (Saaty, 1980)

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Notes: n = order of Matrix

Equations (3), (4), (5) and (6) were used to calculate the consistency Vector, Consistency Measure, Consistency Index and Consistency Ratio respectively. To calculate the CI and CR the Matrix Multiplication Function was calculated using the EXCEL (**=MMULT()**) function. Table 4.6 in Appendix three shows the result for this process.

4.3.4 Criterion weight (C_w)

From Table 4.8a, the average of the column total is multiplied by the Consistency Ratio (CR) to get the required Criteria Weight (C_w) for the fuzzy TOPSIS analysis. The result of this process is shown on Table 4.10.

Table 4.7: Analytic Hierarchy Process (AHP) Distribution of Weight

Criteria	Criteria Weight (C_w)
C_1	0.14590609
C_2	0.276207251
C_3	0.229392462
C_4	0.204424575
C_5	0.330824504
C_6	0.0994034
C_7	0.062731816
C_8	0.035512361
C_9	0.035512361

4.4 Decision matrix

Haven computing the weight function, the Attribute/Alternative Matrix is form as shown below:

		Lagos	Warri	Port Harcourt	Criteria Weight
C_1	Power Demand	4.5	3.875	4.375	0.14590609
C_2	Distance from Airport	533	438.5	448.23	0.276207251
C_3	Average Wind Speed	6.25	7.29	7.35	0.229392462
C_4	Shipping Route	1.75	3.875	4.375	0.204424575
C_5	Undersea Gas Line	2.375	4.5	4.875	0.330824504
C_6	Distance from Shore	500	350	400	0.0994034
C_7	Distance from Disco	531.125	431.85	426.875	0.062731816
C_8	Bird Flight Interference	2.25	2.5	3.25	0.035512361
C_9	Telecom Interference	3.25	4.625	4.125	0.035512361

Due to great disparity in the type of data, the matrix is resolved into two separate parts using Microsoft Excel. Table 4.8a shows the quantitative attribute value for the three alternatives and Figure 4.2a shows the Bar chart representation of the quantitative attributes. While Table 4.8b and Figure4.2b shows the qualitative attributes and bar chart representation respectively.

Table 4.8a: Quantitative attributes value for three alternatives

Quantitative Attribute	Lagos	Alternatives Warri	Port-Harcourt
Distance from Shore (km)	49.70	34.79	39.76
Distance from Airport (km)	147.22	121.12	123.80
Distance from DISCO (km)	33.32	27.09	26.78

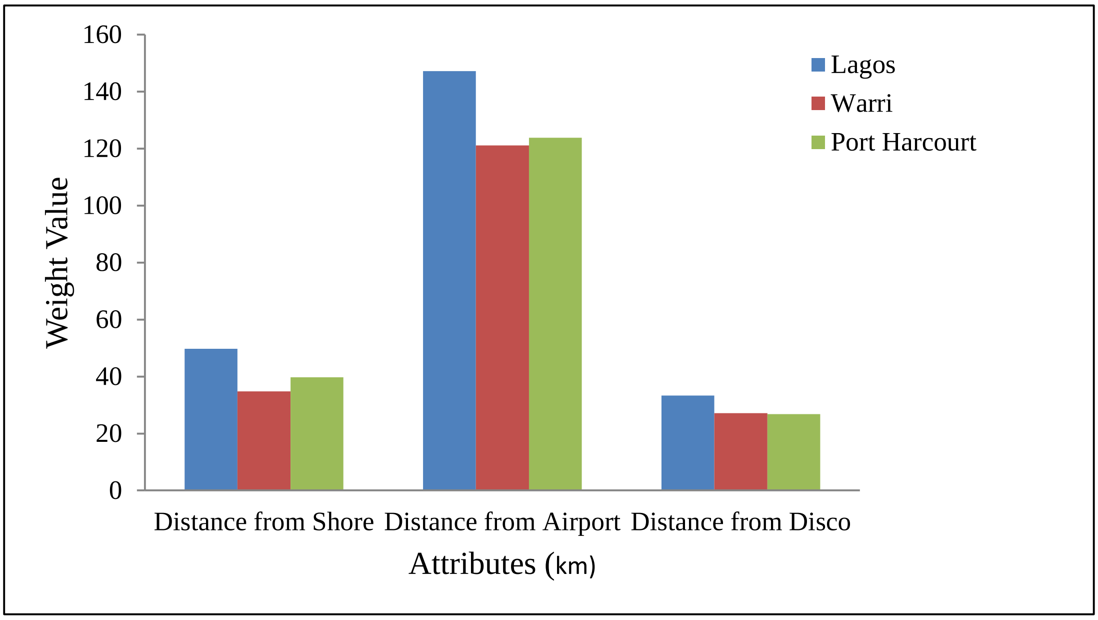


Figure 4.2a: Quantitative attributes value for three alternatives

From the bar chart above, Lagos has the highest distance from shore and that brings it close to the Ideal Positive Solution as offshore wind farms are expected to be at least 50km away from shores for impaired visibility and noise. Warri and Port-Harcourt are far from the Ideal Positive Solution and that shows they are closer to the Ideal Negative solution.

In terms of distance from airport, the Ideal Positive Solution will be the location with the farthest distance from airports so as to avoid flight interference. From the bar chart, Lagos is also found to be the closest to an ideal positive solution while the other alternatives are on the side of the Ideal Negative Solution.

But, looking at the distance from Distribution Company; Lagos though with the highest value, is not close to the Ideal Positive Solution rather it is close to the Ideal Negative Solution as the Positive Solution in this case will be a location closest to a Distribution Company so as to easily connect to the national grid. Therefore, Warri is the closest to the Ideal Positive Solution followed closely by Port-Harcourt.

Table 4.8b: Qualitative attributes value for three alternatives

Qualitative Attribute	Alternatives Lagos	Warri	Port-Harcourt
Power Demand	0.656577	0.565386	0.638339144
Average Wind Speed	1.433703	1.672271	1.686034596
Shipping Route	0.357743	0.792145	0.894357516
Undersea Gas Line	0.785708	1.48871	1.612769457
Bird Flight Interference	0.079903	0.088781	0.115415173
Telecommunication Interference	0.115415	0.164245	0.146488489

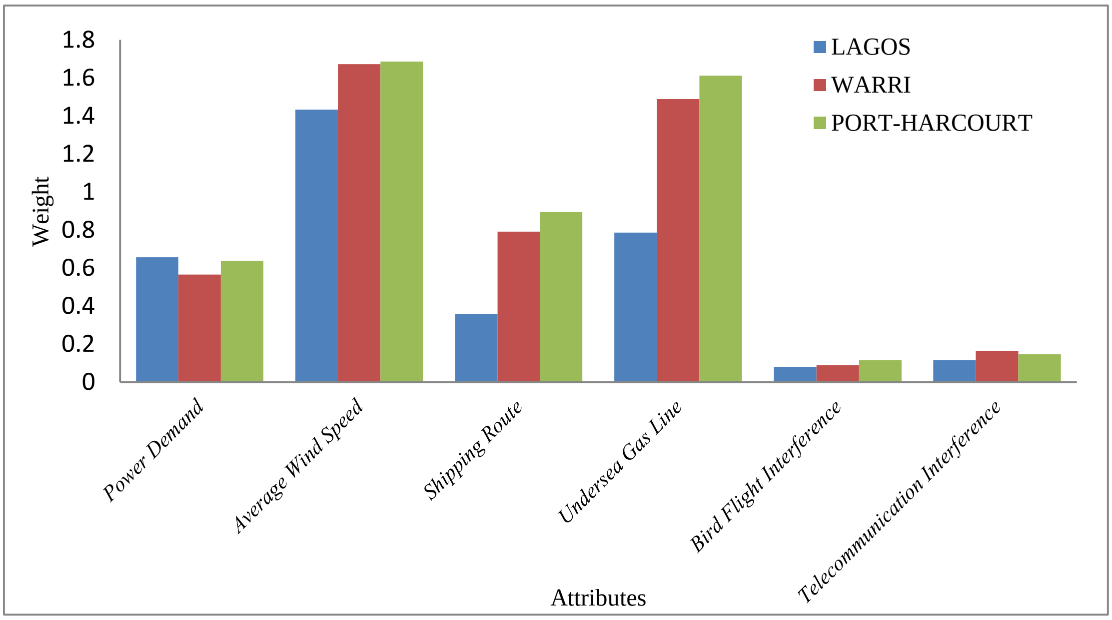


Figure 4.2b: Qualitative Attributes Value for three Alternatives

Results for qualitative analysis displayed on Figure 4.2b Shows that Lagos has the highest demand for electricity; followed closely by Port-Harcourt while Warri is behind interms of electricity demand. This result can be attributed to some factors which are; the level of industrialization, the land mass area of the location and its relative population and the diversity in occupation.

Bird flight was found to be very minimal in Lagos followed by Warri and highest in Port-Harcourt. Though from literature (Michal et al, 2014) much attention is not paid to interference with bird flight because, in place where offshore wind farms have been installed, bird mortality was recorded and after sometimes the birds were observed to have moved from locations where wind farms a situated. But high value of bird flight is a negative Ideal Situation therefore Lagos is the Ideal Positive Solution for this attribute. High value for Shipping Route indicates an Ideal Negative Solution and from the result presented on the bar chart, Port-Harcourt was found the closest to the Ideal Negative Solution while Lagos is the closest to the Ideal Positive Solution.

Port-Harcourt was also found to have the highest value for undersea gas and cable lines followed by Warri while Lagos has the least. The Ideal Positive Solution for this attribute will be a location with the least value as this enables easy construction of wind farm turbine foundations. Therefore, Lagos is the closest to the ideal positive solution. Lastly, Telecommunication Installations in the three alternatives; a low value here indicates a Positive Ideal Solution and Lagos has the least value and this implies that it’s the closest to the positive ideal situation.

4.5 Normalized Data

Finally, the qualitative and quantitative attributes can be combined by normalizing the data. The normalization process takes care of the disparity in data. This was done using Equations (8) and (9). The Normalization was done as well on Microsoft Excel using equations and a combined result is shown in Table 4.9 with a corresponding Normalized Bar chart.

Table 4.9: Normalized Attribute Values for the three Alternatives

Attributes	Alternatives		
	Lagos	Warri	Port-Harcourt
Power Demand	-0.51669886	-0.50940128	-0.515217729
Distance from Airport	2.475748931	2.515977327	2.495524571
Average Wind Speed	-0.50083179	-0.48162274	-0.489607252
Shipping Route	-0.52280035	-0.50371051	-0.508959467
Undersea Gas Line	-0.51406231	-0.48622941	-0.491398187
Distance from Shore	0.48468654	0.349534551	0.441128166
Distance from Disco	0.150179123	0.156282669	0.123771098
Bird Flight Interference	-0.52847318	-0.52136223	-0.528000387
Telecommunication Interference	-0.52774811	-0.51946838	-0.527240813

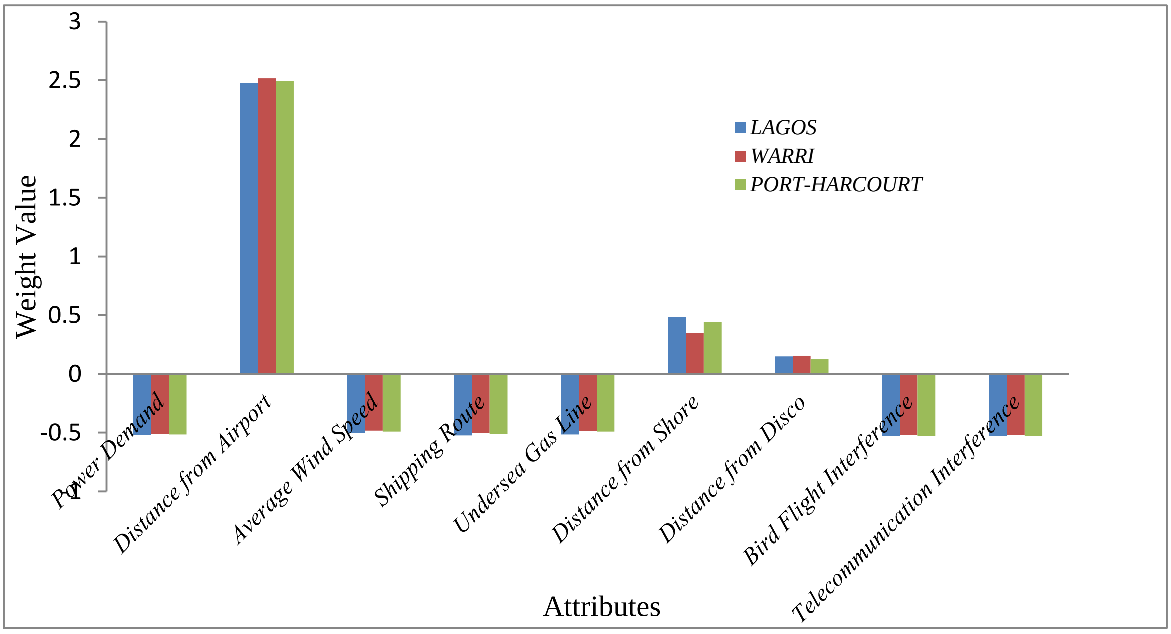


Figure 4.3: Normalized Attributes Value for three Alternatives

Due to the disparity in data, results were first grouped into quantitative and qualitative attributes for easy representation. But Figure 4.3 shows the combined bar chart for the considered attributes of the three locations.

To make a final selection of which alternative amongst the three analyzed is best for consideration for the installation of offshore wind farm, cumulative of all the attributes value were calculated for the three alternatives. The cumulative value is shown on Table 4.10 while Figure 4.4 gives the pictorial representation.

Table 4.10: Alternatives Cumulative Result

Alternatives	Lagos	Warri	Port Harcourt
Cumulative	233.67	187.77	195.44

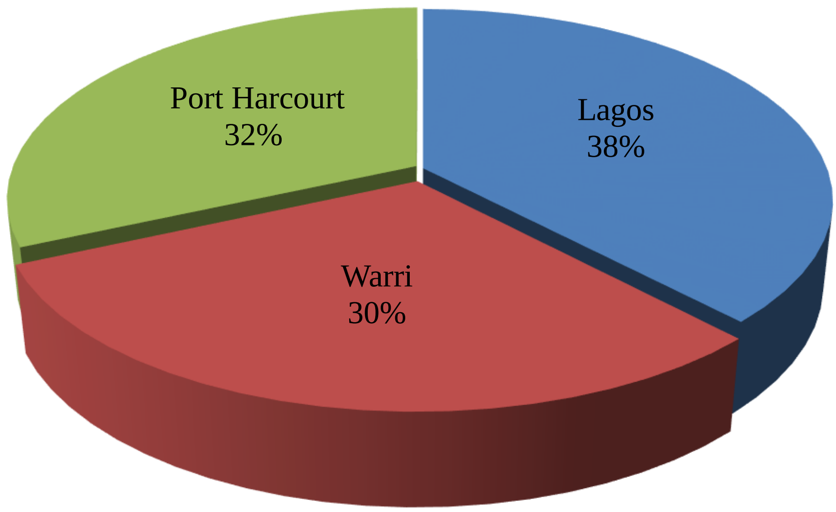


Figure 4.4: Cumulate Decision Pie Chart

The above chart shows that Lagos has the highest consideration rate of 38% followed by Port-Harcourt with 32% and lastly Warri with 30%.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This work is focused at the Multi-Criteria Assessment of the appropriate offshore wind farm location in Nigeria. In this study, offshore wind farm location attributes for Victoria Island (Lagos), Koko (Warri) and Abonnema (Port-Harcourt) have been evaluated using fuzzy TOPSIS multi-criteria tool.

The most significant results of this study can be summarized as:

The collected wind farm siting attributes revealed that the three alternatives showed a good wind speed characteristic. This was shown by the 10 years average wind speeds which are 6.25 m/s, 7.29 m/s and 7.347 m/s for Victoria Island, Koko and Abonnema respectively.

The application of AHP process gave a Normalized Column total of 1, Consistency Index of 0.1230 and Consistency Ratio of 0.0843 which are within the expected range as stated by (Satty, 2008).

From the fuzzy TOPSIS analysis, Victoria Island showed a 38% consideration rate which is the highest amongst the three alternatives that was considered.

Based on (3) above, it was concluded that Victoria Island is the best site for the setting up of offshore wind farm facilities.

5.2 Recommendations

1. For a more efficient finding, a Geographical Information System (GIS) analysis should be carried out on Nigeria offshore regions case study of Victoria Island offshore region for proper insight on the soil structure of the offshore region.
2. Based on the recommendation above, different types of offshore wind turbine structure should be analyzed so as to know the kind of structure to be considered for offshore wind farm installations.
3. A work should also be done on the appropriate foundation system to be considered for Nigeria offshore region with focus on Victoria Island offshore region.

5.3 Limitation of the Research

This thesis has been limited by the following factor:

1. There are very little Nigeria based literature available for review.
2. Non availability of Geographical Information System (GIS) analysis has also limited the work as factors under this were not put into consideration for the purpose of this thesis.

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APPENDIX ONE

A: LIST OF OFFSHORE WIND FARMS AROUND THE WORLD

WIND FARM	CAPACITY (MW)	COUNTRY	STATE/ PROVINCE
Alta Wind Energy Center	1,320	USA	California
BayannurWulanyiligeng Wind Farm	300	China	Inner Mongolia
Biglow Canyon Wind Farm	450	USA	Oregon
Buffalo Gap Wind Farm	523.3	USA	Texas
Capricorn Ridge Wind Farm	662.5	USA	Texas
Cedar Creek Wind Farm	551	USA	Colorado
Clyde Wind Farm	350	UK	South Lanarkshire, Scotland
Collgar Wind Farm	206	Australia	Merredin Shire, Western Australia
Crystal Lake Wind Farm	416	USA	Iowa
Dabancheng Wind Farm	500	China	Xinjiang
Eurus Wind Farm	250.5	Mexico	Oaxaca
Fântânele-Cogealac Wind Farm	600	Romania	Fântânele&Cogealac
Fowler Ridge Wind Farm	599.8	USA	Indiana
Fubei Wind Farm	450	China	Liaoning
Gansu Wind Farm	6,000	China	Gansu
Gulf Wind Farm	283.2	USA	Texas
Hallett Wind Farm	298	Australia	South Australia

Hopkins Ridge Wind Farm	385	USA	Washington
Horse Hollow Wind Energy Center	735.5	USA	Texas
Jaisalmer Wind Park	1,064	India	Rajasthan
King Mountain Wind Farm	281.2	USA	Texas
Klondike Wind Farm	399	USA	Oregon
Lake Bonney Wind Farm	279	Australia	South Australia
Liaoning Fuxin Wind Farm	300	China	Liaoning
Lone Star Wind Farm	400	USA	Texas
LongyuanHuitengliang Wind Farm	300	China	Inner Mongolia
Macarthur Wind Farm	420	Australia	Victoria
Maple Ridge Wind Farm	321.8	USA	New York
Meadow Lake Wind Farm	500	USA	Indiana
Mount Storm Wind Farm	264	USA	West Virginia
Panther Creek Wind Farm	458	USA	Texas
Papalote Creek Wind Farm	380	USA	Texas
Peetz Wind Farm	430	USA	Colorado
Peñascal Wind Power Project	404	USA	Texas
Pioneer Prairie Wind Farm	300.3	USA	Iowa
Roscoe Wind Farm	781.5	USA	Texas

Shepherds Flat Wind Farm	845	USA	Oregon
Shiloh Wind Farm	300	USA	California
Smoky Hills Wind Farm	250	USA	Kansas
Snowtown Wind Farm	370	Australia	South Australia
Stateline Wind Farm	300	USA	Oregon & Washington
Story County Wind Farm	300	USA	Iowa
Streator Cayuga Ridge South	300	USA	Illinois
Sweetwater Wind Farm	585.3	USA	Texas

APPENDIX TWO

A: Summary of monthly average wind speeds and standard deviations in Lagos (VI), 2002-2011

Month	Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Whole Year
January	Vm	6.09	5.55	4.965	5.787	7.18	4.406	5.66	4.34	3.44	2.93	5.033
February	Vm	7.99	7.43	7.13	8.214	8.7	8.696	6.9	5.2	5.22	4.07	6.955
March	Vm	8.6	8.28	8.165	8.468	8.36	9.226	9.26	6.76	4.59	4.68	7.637
April	Vm	7.61	6.65	7.927	8.567	9	9.86	8.08	6.58	5.46	4.5	7.424
May	Vm	6.47	7.98	7.023	7.145	6.13	6.823	6.35	5.98	4.34	3.9	6.214
June	Vm	6.93	7.05	7.453	6.537	6.06	7.737	5.87	4.48	3.84	3.74	5.97
July	Vm	8.02	9.43	10.17	8.406	8.75	9.768	5.11	4.45	6.47	6.01	7.657
August	Vm	9.68	8.88	9.903	10.27	9.75	10.52	6.58	5.68	6.78	7.5	8.554

September	Vm	8.3	6.52	6.33	8.15	7.95	7.567	4.83	4.2	5.52	3.74	6.311
October	Vm	5.89	4.04	6.145	5.371	5.57	5.71	4.19	3.68	4.07	3.31	4.797
November	Vm	5.16	3.18	5.66	5.48	4.18	5.943	3.92	3.47	3.71	2.61	4.332
December	Vm	5.76	2.86	6.335	5.448	4.92	4.965	3.78	3.21	3	0.99	4.126
Yearly	Vm	7.21	6.49	7.267	7.32	7.21	7.602	5.88	4.84	4.7	4	6.251

B: Summary of monthly average wind speeds and standard deviations in Warri (Koko), 2002-2011

Month	Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Whole Year
January	Vm	7.28	7.32	7.239	7.303	7.15	7.3	7.45	7.32	6.85	6.67	7.188
February	Vm	7.52	7.29	7.375	7.229	7.08	7.457	7.65	7.28	6.95	7.06	7.289
March	Vm	7.37	7.2	7.468	7.229	7.14	7.287	7.64	7.17	7.04	7	7.253

April	Vm	7.46	7.39	7.127	7.3	7.67	7.571	7.78	7.11	6.9	6.98	7.328
May	Vm	6.94	7.44	7.468	7.632	7.43	7.565	7.47	7.03	7.46	7.25	7.368
June	Vm	7.22	7.55	7.483	7.59	7.38	7.477	7.68	6.81	7.54	7.22	7.396
July	Vm	7.11	7.19	7.661	7.603	7.64	7.603	7.82	6.84	7.07	7.3	7.384
August	Vm	7.1	7.26	7.848	7.877	7.58	7.355	7.34	6.82	7.27	7.03	7.347
September	Vm	7.66	7.83	7.103	7.037	7.14	6.567	7.2	7.18	7.42	7.34	7.248
October	Vm	7.43	7.54	7.265	6.945	7.07	6.7	7.06	7.09	7.28	7.43	7.18
November	Vm	7.76	7.73	7.08	6.96	7.17	6.537	7.07	7.17	7.31	7.59	7.237
December	Vm	7.67	7.76	7.103	7.123	7.37	6.626	7.62	7.02	7.32	7.4	7.3
Yearly	Vm	7.38	7.46	7.352	7.319	7.32	7.17	7.48	7.07	7.2	7.19	7.293

C: Summary of monthly average wind speeds and standard deviations in Port Harcourt (Abonemma), 2002-2011

Month	Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Whole Year
January	Vm	6.59	7.56	7.69	6.316	7.57	7.19	8.01	7.07	7.29	7.73	7.301
February	Vm	6.81	7.19	7.15	7.086	7.36	6.659	7.76	7.37	7.3	7.53	7.222
March	Vm	7.04	7.64	7.277	7.532	6.98	6.787	7.75	6.99	7.22	7.09	7.229
April	Vm	6.84	7.44	6.683	7.463	7.3	6.857	7.63	7.2	7.7	7.5	7.264
May	Vm	6.9	7.47	6.506	7.119	7.07	7.035	7.35	7.29	7.4	7.84	7.198
June	Vm	7	7.56	6.347	7.24	7.7	6.97	7.32	7.52	7.76	7.96	7.336
July	Vm	6.8	7.54	7.274	7.671	7.41	7.167	7.14	7.55	7.77	7.63	7.395
August	Vm	6.88	7.56	7.045	7.368	7.69	7.116	7.33	7.03	8.09	7.98	7.409
September	Vm	7.06	7.01	6.257	6.9	7.53	7.52	7.59	7.51	7.43	8.7	7.35

October	Vm	7.11	6.99	6.726	7.135	7.47	7.306	7.42	7.41	7.17	8.59	7.334
November	Vm	7.85	7.25	6.993	7.527	7.21	7.257	7.8	7.44	7.55	8.52	7.54
December	Vm	7.51	7.23	6.768	6.229	7.23	6.89	7.39	7.29	8.05	8.27	7.268
Yearly	Vm	7.03	7.37	6.893	7.132	7.38	7.063	7.54	7.3	7.56	7.94	7.322

APPENDIX THREE

Table 4.1: Ten Years Average Wind Speed for Lagos, Warri and Port-Harcourt

ALTERNATIVES	YEARS										AVERAGE
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
Lagos	7.21	6.49	7.27	7.32	7.21	7.6	5.88	4.83	4.7	4	6.25
Warri	7.38	7.46	7.35	7.32	7.32	7.17	7.48	7.07	7.2	7.19	7.29
Port Harcourt	7.3	7.37	6.89	7.13	7.38	7.06	7.54	7.3	7.56	7.94	7.35

Table 4.2a: Summary of Attribute Data Collected for Lagos

Attributes	Samples								Average
	1	2	3	4	5	6	7	8	
Distance from Airport (m)	534	530	535	533	535	529	533	535	533
Distance from DISCO (m)	532	533	533	530	529	528	531	529	531.13
Power Demand	4	5	5	5	5	4	4	4	4.5
Bird Flight Interference	3	2	2	2	3	2	2	2	2.25
Shipping Route	2	2	2	1	3	1	2	1	1.75
Undersea Gas Line	2	2	3	4	3	2	2	1	2.38
Telecommunication Interference	3	4	1	4	4	4	3	3	3.25

Table 4.2b: Summary of Attribute Data Collected for Warri

Attributes	Samples								Average
	1	2	3	4	5	6	7	8	
Distance from Airport (m)	437	430	440	437	435	445	437	447	438.5
Distance from DISCO (m)	433.3	430	435.5	425	432	437	431	431	431.85
Power Demand	5	5	4	3	4	4	3	3	3.88
Bird Flight Interference	2	2	3	1	4	2	3	3	2.5
Shipping Route	4	4	4	5	4	4	3	3	3.88
Undersea Gas Line	5	5	4	4	5	5	4	4	4.5
Telecommunication Interference	4	5	5	4	5	4	5	5	4.63

Table 4.2c: Summary of Attribute Data Collected for Port-Harcourt

Attributes	Samples								Average
	1	2	3	4	5	6	7	8	
Distance from Airport (m)	449	450	450	449	448	445	445.5	448.5	448.23
Distance from DISCO (m)	427.4	426	428.1	425.3	427	428.8	427.4	425	426.88
Power Demand	4	4	4	5	4	4	5	5	4.38
Bird Flight Interference	3	4	3	3	4	3	3	3	3.25
Shipping Route	5	4	4	5	5	5	3	4	4.38
Undersea Gas Line	4	5	5	5	5	5	5	5	4.88
Telecommunication Interference	5	4	4	4	3	4	4	5	4.13

Table 4.3a: Effective Criteria and Pair Wise Comparison

Factor	Factor weighting Score											Factor
	More Important than					Equal	Less Important than					
C_1	1	2	3	4	5	1	1	2	3	4	5	C_2
C_2	1	2	3	4	5	1	1	2	3	4	5	C_3
C_3	1	2	3	4	5	1	1	2	3	4	5	C_4
C_4	1	2	3	4	5	1	1	2	3	4	5	C_5
C_5	1	2	3	4	5	1	1	2	3	4	5	C_6
C_6	1	2	3	4	5	1	1	2	3	4	5	C_7
C_7	1	2	3	4	5	1	1	2	3	4	5	C_8
C_8	1	2	3	4	5	1	1	2	3	4	5	C_9
C_9	1	2	3	4	5	1	1	2	3	4	5	C_1

Table 4.3b: Pair Wise Input Comparison Matrix

Factor	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
C_1	1	3	2	2	4	0.5	0.3333	0.25	0.25
C_2	0.3333	1	0.5	0.5	2	0.25	0.2	0.1667	0.1667
C_3	0.5	2	1	1	0.3333	0.3333	0.25	0.2	0.2
C_4	0.5	2	1	1	3	0.3333	0.25	0.2	0.2
C_5	0.25	0.5	3	0.3333	1	0.2	0.1667	0.1429	0.1429
C_6	2	4	3	3	5	1	0.5	0.3333	0.3333
C_7	3	5	4	4	6	2	1	0.5	0.5
C_8	4	6	5	5	7	3	2	1	1
C_9	4	6	5	5	7	3	2	1	1

Table 4.4a: Column Total of the Pair Wise Input Comparison Matrix

Factor	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
C_1	1	3	2	2	4	0.5	0.3333	0.25	0.25
C_2	0.3333	1	0.5	0.5	2	0.25	0.2	0.1667	0.1667
C_3	0.5	2	1	1	0.3333	0.3333	0.25	0.2	0.2
C_4	0.5	2	1	1	3	0.3333	0.25	0.2	0.2
C_5	0.25	0.5	3	0.3333	1	0.2	0.1667	0.1429	0.1429
C_6	2	4	3	3	5	1	0.5	0.3333	0.3333
C_7	3	5	4	4	6	2	1	0.5	0.5
C_8	4	6	5	5	7	3	2	1	1
C_9	4	6	5	5	7	3	2	1	1
Total	15.5833	29.5	24.5	21.8333	35.3333	10.6167	6.7	3.7929	3.7929

Table 4.4b: Normalized Comparison Comparison Matrix

Factor	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Total	Average
C_1	0.0641	0.1017	0.0816	0.0916	0.1132	0.0471	0.0498	0.0659	0.0659	0.681	0.0756648
C_2	0.0214	0.0339	0.0204	0.0229	0.0566	0.0236	0.0299	0.0439	0.0439	0.297	0.0329427
C_3	0.0321	0.0678	0.0408	0.0458	0.0094	0.0314	0.0373	0.0527	0.0527	0.370	0.0411229
C_4	0.0321	0.0678	0.0408	0.0458	0.0849	0.0314	0.0373	0.0527	0.0527	0.446	0.0495086
C_5	0.0160	0.0170	0.1225	0.0153	0.0283	0.0188	0.0249	0.0377	0.0377	0.318	0.0353393
C_6	0.1283	0.1356	0.1225	0.1374	0.1415	0.0942	0.0746	0.0879	0.0879	1.010	0.1122095
C_7	0.1925	0.1695	0.1633	0.1832	0.1698	0.1884	0.1493	0.1318	0.1318	1.480	0.1643975
C_8	0.2567	0.2034	0.2041	0.2290	0.1981	0.2826	0.2985	0.2637	0.2637	2.200	0.2444073
C_9	0.2567	0.2034	0.2041	0.2290	0.1981	0.2826	0.2985	0.2637	0.2637	2.200	0.2444073
Total	1	1	1	1	1	1	1	1	1		

Table 4.6: Result of Consistency Analysis showing CR, C

	C1	**C2**	**.**	**.**	**.**	**.**	**C7**	**C8**	**C9**	Total	Average	(MMULT)	N	Consistency Measure
C1	0.06417	.	.	.	.	.	.	.	.	0.68098	0.07566	0.869379118	9	9.869379118
C2	0.02139	.	.				.	.	.	0.29648	0.03294	1.084848531	9	10.08484853
C3	0.03209	.	.				.	.	.	0.37011	0.04112	1.079044658	9	10.07904466
C4	0.03209	.	.				.	.	.	0.44558	0.04951	0.950148397	9	9.950148397
C5	0.01604	.	.				.	.	.	0.31805	0.03534	0.938845846	9	9.938845846
C6	0.12834	.	.				.	.	.	1.00989	0.11221	0.862793802	9	9.862793802
C7	0.19251	.	.				.	.	.	1.47958	0.1644	0.924888443	9	9.924888443
C8	0.25668	.	.	.	.	.	.	.	.	2.19967	0.24441	1.074079089	9	10.07407909
C9	0.25668	.	.	.	.	.	.	.	.	2.19967	0.24441	1.074079089	9	10.07407909
Total	1	1					1	1	1			CI		0.123029264
												RI		1.46
												CR (CI/RI)		0.084266619

APPENDIX FOUR

A. THESIS QUESTIONNAIRE FOR LAGOS

MULTI-CRITERIA EVALUTION OF THE APPROPRIATE OFFSHORE WIND FARM LOCATION IN NIGERIA.

Dear Respondent,

I am a postgraduate student in the Department of Mechanical engineering, Federal University of Technology Minna. I am carrying out a research on Multi-criteria Evaluation of the Appropriate Offshore Wind Farm Location in Nigeria. The research is strictly for academic purposes and all information collected would be treated with strict confidentiality. I therefore solicit your support and co-operation in responding to the questionnaire. Thanks for your co-operation.

QUESTIONNAIRE IDENTIFICATION

Questionnaire no: …………………… State: …………….…………….

Location: ……………………...………. Date: …………..…………………

SECTION A

PERSONAL DATA

Please tick as appropriate [√]

1. Age at last Birthday ………………………………..
2. Sex: (a). Male [ ] (b). Female [ ]
3. State of Origin: …………………………………….
4. Education level: (a). No formal education [ ] (b). Primary education [ ](c). Secondary education [ ] (d). Tertiary education [ ]

5. Occupation: (a). Artisan [ ](b). Trader [ ] (c). Civil servant [ ] (d). Student [ ] (e).Others (Specify)…………………………………………………………………

6. Source of electricity: (a). Personal generator [ ](b). Solar energy [ ](c). PHCN [ ](d). None [ ](e).Others (Specify)…………………………..…………………

SECTION B

1. Do you know about wind farm?

   YES [ ] NO [ ]

2. How many forms of wind farm do you know of? ....

   Name them…………………...…………………………………………………

3. Do you know what an offshore is

   YES [ ] NO [ ]

4. Do you know about offshore wind farm

   YES [ ] NO [ ]

5. How would you rate electricity demand in Lagos?

   VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

6. Does Lagos have any electricity distribution company?

   YES [ ] NO [ ]

   Where is itlocated……………………………….………………...……………..

   Approximate Distance from Victoria Island…………………….………………..

7. Does Lagos have a local or an international Airport?

   YES [ ] NO [ ]

Where is it located……………………………………………………………..……

Approximate Distance from Victoria Island……………………………………..

8. Is there a chance of existing shipping and other sea activities in Victoria Island Offshore?

YES [ ] NO [ ]

If YES, How would you rate this possibility?

VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

9. How would you rate bird flight around victoria Island

VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

10. Is there a chance of existing undersea cables and Gas line in Victoria Island Offshore?

YES [ ] NO [ ]

If YES, How would you rate this possibility?

VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

11. How would you rate Telecommunication Installations around victoriaIsland

VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

SECTION C

1. Do you think that an offshore wind in Lagos will improve power availability?

YES [ ] NO [ ]

2. Do you have any fear what so ever regarding the installation of offshore wind farm in Victoria Island Offshore

   YES [ ]   NO [ ]

   If YES, state it/them:

   ………………………………………………………………………………………

   ………………………………………………………………………………………

   ………………………………………………………………………………………

   ………………………………………………………………………

3. Who do you suggest should embark on the project of Installation of offshore wind farm installations?

   State Government [ ]   Federal Government [ ]   Private Investors [ ]

B. THESIS QUESTIONNAIRE FOR WARRI

MULTI-CRITERIA EVALUTION OF THE APPROPRIATE OFFSHORE WIND FARM LOCATION IN NIGERIA.

Dear Respondent,

I am a postgraduate student in the Department of Mechanical engineering, Federal University of Technology Minna. I am carrying out a research on Multi-criteria Evaluation of the Appropriate Offshore Wind Farm Location in Nigeria. The research is strictly for academic purposes and all information collected would be treated with strict confidentiality. I therefore solicit your support and co-operation in responding to the questionnaire. Thanks for your co-operation.

QUESTIONNAIRE IDENTIFICATION

Questionnaire no: …………………… State: …………….…………….

Location: ……………………...………. Date: …………...……………….

SECTION A

PERSONAL DATA

Please tick as appropriate [√]

7. Age at last Birthday ………………………………..
8. Sex: (a). Male [ ] (b). Female [ ]
9. State of Origin: …………………………………….
10. Education level: (a). No formal education [ ] (b). Primary education [ ](c). Secondary education [ ] (d). Tertiary education [ ]
11. Occupation: (a). Artisan [ ](b). Trader [ ] (c). Civil servant [ ] (d). Student [ ] (e).Others (Specify)……………………………………………………………
12. Source of electricity: (a). Personal generator [ ](b). Solar energy [ ](c). PHCN [ ](d). None [ ](e).Others (Specify)……………………….…………………

SECTION B

1. Do you know about wind farm?

   YES [ ] NO [ ]

2. How many forms of wind farm do you know of? ....

   Name them…………………...……………………………………………………

3. Do you know what an offshore is

YES [ ] NO [ ]

4. Do you know about offshore wind farm

YES [ ] NO [ ]

5. How would you rate electricity demand in Warri?

VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

6. Does Warri have any electricity distribution company?

YES [ ] NO [ ]

Where is it located……………………………….……………...……………..

Approximate Distance from Koko…………………….………………..

7. Does Warri have a local or an international Airport?

YES [ ] NO [ ]

Where is it located………………………………………………………..……

Approximate Distance from Koko……………………………………..

8. Is there a chance of existing shipping and other sea activities in Koko Offshore?

YES [ ] NO [ ]

If YES, How would you rate this possibility?

VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

9. How would you rate bird flight around Koko

VERY HIGH [ ] HIGH [ ] MEDIUM [ ] LOW [ ] VERY LOW [ ]

10. Is there a chance of existing undersea cables and Gas line in Koko Offshore?

YES [ ]   NO [ ]

If YES, How would you rate this possibility?

VERY HIGH [ ]   HIGH [ ]   MEDIUM [ ]   LOW [ ]   VERY LOW [ ]

11. How would you rate Telecommunication Installations around Koko

VERY HIGH [ ]   HIGH [ ]   MEDIUM [ ]   LOW [ ]   VERY LOW [ ]

SECTION C

1. Do you think that an offshore wind in Warri will improve power availability?

   YES [ ]   NO [ ]

2. Do you have any fear what so ever regarding the installation of offshore wind farm in Koko Offshore

   YES [ ]   NO [ ]

   If YES, state it/them:

   …………………………………………………………………………………………

   …………………………………………………………………………………………

   …………………………………………………………………………………………

   ……………………………………………………………………………

3. Who do you suggest should embark on the project of Installation of offshore wind farm installations?

State Government [ ] Federal Government [ ] Private Investors [ ]

C. THESIS QUESTIONNAIRE FOR PORT-HARCOURT

MULTI-CRITERIA EVALUTION OF THE APPROPRIATE OFFSHORE WIND FARM LOCATION IN NIGERIA.

Dear Respondent,

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QUESTIONNAIRE IDENTIFICATION

Questionnaire no: …………………… State: …………….…………….

Location: ……………………...………. Date: …………..……………….

SECTION A

PERSONAL DATA

Please tick as appropriate [√]

4. Age at last Birthday ………………………………..
5. Sex: (a). Male [ ] (b). Female [ ]
6. State of Origin: …………………………………….

7. Education level: (a). No formal education [ ] (b). Primary education [ ](c). Secondary education [ ] (d). Tertiary education [ ]
8. Occupation: (a). Artisan [ ](b). Trader [ ] (c). Civil servant [ ] (d). Student [ ] (e).Others (Specify)……………………………………………………………
9. Source of electricity: (a). Personal generator [ ](b). Solar energy [ ](c). PHCN [ ](d). None [ ](e).Others (Specify)……………………….…………………

SECTION B

1. Do you know about wind farm?

   YES [ ]   NO [ ]

2. How many forms of wind farm do you know of? ....

   Name them…………………...…………………………………………………

3. Do you know what an offshore is

   YES [ ]   NO [ ]

4. Do you know about offshore wind farm

   YES [ ]   NO [ ]

5. How would you rate electricity demand in Port-Harcourt?

   VERY HIGH [ ]   HIGH [ ]   MEDIUM [ ]   LOW [ ]   VERY LOW [ ]

6. Does Port-Harcourt have any electricity distribution company?

   YES [ ]   NO [ ]

   Where is it located……………………………….……………...……………..

   Approximate Distance from Abonnema……………………….………………..

7. Does Port-Harcourt have a local or an international Airport?

YES [ ]   NO [ ]

Where is it located…………………………………………………………..……

Approximate Distance from Abonnema……………………………………..

8. Is there a chance of existing shipping and other sea activities in Abonnema Offshore?

YES [ ]   NO [ ]

If YES, How would you rate this possibility?

VERY HIGH [ ]   HIGH [ ]   MEDIUM [ ]   LOW [ ]   VERY LOW [ ]

9. How would you rate bird flight around Abonnema

VERY HIGH [ ]   HIGH [ ]   MEDIUM [ ]   LOW [ ]   VERY LOW [ ]

10. Is there a chance of existing undersea cables and Gas line in Abonnema Offshore?

YES [ ]   NO [ ]

If YES, How would you rate this possibility?

VERY HIGH [ ]   HIGH [ ]   MEDIUM [ ]   LOW [ ]   VERY LOW [ ]

11. How would you rate Telecommunication Installations around Abonnema

VERY HIGH [ ]   HIGH [ ]   MEDIUM [ ]   LOW [ ]   VERY LOW [ ]

SECTION C

1. Do you think that an offshore wind in Port-Harcourt will improve power availability?

YES [ ]   NO [ ]

2. Do you have any fear what so ever regarding the installation of offshore wind farm in Abonnema Offshore

YES [ ] NO [ ]

If YES, state it/them:

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………

3. Who do you suggest should embark on the project of Installation of offshore wind farm installations?

State Government [ ] Federal Government [ ] Private Investors [ ]