THE ESTIMATION AND PROJECTION OF THE ELECTRIC POWER GENERATION FROM CORN RESIDUES IN NIGERIA BASED ON LINEAR REGRESSION ANALYSIS

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To

My parents:

Mohammed and Munirat

My lovely and heartwarming families:

Amina and Hajara

The coolness of my eyes:

Saifullah, Fazlullah and Bushra

For your unalloyed love, fortitude, support and lustrous wishes

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ABSTRACT

A global desire for sustainable energy development to combat greenhouse gases (GHGs) emissions from energy sector has incited research endeavours on the exploitation of various kinds of renewable energy. However, presence of biomass resources in nearly every part of the world coupled with their ability to decarbonise electric power sector when used for electricity generation has attracted a very important attention for their exploitation. Thus, estimation and projection of the potential capability of different kinds of biomass resources for power generation is imperative. In the estimation and projection of electric power potential of a bio-residue, a standard formulation involving only two parameters is commonly employed by researchers. The parameters are the calorific value of residue and residue conversion factor. The estimations were made in country case study without taking into account another factor where some quantity of residues is diverted for contending applications. Therefore, this research presents a new mathematical technique called a Modified Nominal Bio-Power Capacity (MNBPC) by introducing the concept of residue availability factor. The new formulation is used for estimating the nominal power capacity of three corn residues (cob, straw and stalk) in Nigeria as a case study. A period of 15 years (1996-2010) is chosen for the estimation using corn production quantity obtained from United Nations Food and Agriculture Organisation while the calorific values of the sample residues are obtained experimentally. The computation is also based on the average of different gasification efficiency of 31% adopted from literature. A projection of 10 years (2011-2020) based on the new formulation was performed using linear regression which is in line with the plan of action to integrate bioelectricity into the nation's power sector by the year 2020. The least squares technique is considered to be superior for the projection because of its ability to correlate production quantity with time in a long forecasting scenario compared to other techniques. Based on the 70% collection rate (availability factor) of the residue surveyed in the country case study, computational findings estimated 2,570 MW (2.57 GW) nominal power capacity in the year 2010. This potential is approximately 33% of the total current installed capacity of 7,876 MW and 25.7% of the national electric power demand of 10,000 MW. The projection result shows that by the year 2020, a total capacity of 3,200 MW (3.2 GW) could be achieved with corn stalk residue exhibiting the highest potential of 73.1% of the total. This is based on 61% coefficients of determination between the residues' production trend with respect to time variation as evaluated using Pearson's Product Moment Correlation Coefficient. Finally, the estimated and projected potential in this study has shown a significant contribution from the corn residues to the proposed biomass power generation in the country.

ABSTRAK

Satu keinginan global bagi pembangunan tenaga mampan untuk mengurangkan pelepasan gas rumah hijau (GHG) daripada sektor tenaga telah mencetuskan usaha penyelidikan mengenai eksploitasi pelbagai jenis tenaga boleh diperbaharui. Walau bagaimanapun, kehadiran sumber biomas di hampir setiap pelusuk dunia ditambah dengan keupayaan untuk 'nyah-karbon' sektor kuasa elektrik apabila digunakan untuk penjanaan elektrik telah menarik perhatian yang sangat penting untuk dieksploitasi. Oleh itu, anggaran dan unjuran keupayaan potensi pelbagai jenis sumber biojisim untuk penjanaan kuasa adalah penting. Dalam anggaran dan unjuran potensi kuasa elektrik bio-sisa, penggubalan standard yang melibatkan hanya dua parameter biasanya digunakan oleh penyelidik. Parameter adalah nilai kalori sisa dan sisa-sisa faktor penukaran. Anggaran yang telah dibuat dalam kajian kes negara tanpa mengambil kira faktor lain yang mana beberapa kuantiti sisa dialihkan untuk aplikasi yang berbagai. Oleh itu, kajian ini membentangkan teknik baru matematik dipanggil "Modified Nominal Bio-Power Capacity" (MNBPC) dengan memperkenalkan konsep faktor ketersediaan sisa. Formulasi baru digunakan untuk menganggar kapasiti kuasa nominal tiga sisa jagung (Tongkol, jerami dan tangkai) di Nigeria sebagai kajian kes. Tempoh 15 tahun (1996-2010) dipilih untuk anggaran menggunakan jagung kuantiti pengeluaran yang diperolehi daripada Pertubuhan Makanan dan Pertanian Pertubuhan Bangsa-Bangsa Bersatu manakala nilai kalori sisa sampel diperoleh dari ujikaji. Pengiraan juga berdasarkan kepada purata kecekapan pengegasan berbeza sebanyak 31% diambil daripada kajian literatur. Satu unjuran 10 tahun (2011-2020) berdasarkan penggubalan baru telah dilakukan menggunakan regresi linear yang selaras dengan pelan tindakan untuk mengintegrasikan bioelektrik ke dalam sektor tenaga negara menjelang tahun 2020. Teknik kuasa dua terkecil dianggap yang terbaik untuk unjuran kerana keupayaan untuk mengaitkan kuantiti pengeluaran dengan masa dalam senario ramalan yang panjang berbanding dengan teknik-teknik lain. Berdasarkan kadar kutipan 70% (faktor ketersediaan) sisa yang ditinjau dalam kajian kes negara, penemuan pengiraan menganggarkan 2,570 MW (2.57 GW) kapasiti kuasa nominal pada tahun 2010. Potensi ini adalah kira-kira 33% daripada jumlah kapasiti semasa sebanyak 7876 MW dan 25.7% daripada 10,000 MW permintaan kuasa elektrik kebangsaan. Hasil unjuran menunjukkan bahawa menjelang tahun 2020, jumlah kapasiti sebanyak 3,200 MW (3.2 GW) boleh dicapai dengan sisa tangkai jagung mempamerkan potensi tertinggi sebanyak 73.1% daripada jumlah keseluruhan. Ini berdasarkan kepada 61% pekali penentuan diantara halatuju pengeluaran sisa berbanding kepada perubahan masa sebagaimana dinilai menggunakan Momen Pekali Korelasi Product Pearson. Akhir sekali, potensi yang dianggarkan dan diunjurkan dalam kajian ini telah menunjukkan sumbangan yang ketara daripada sisa jagung untuk penjanaan kuasa biojisim yang dicadangkan di negara ini.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
ACI	-	Acute Cardiovascular Infection
CCCC	-	Copenhagen Climate Change Conference
CDM	-	Clean Development Mechanism
CH_4	-	Methane
CHP	-	Combined Heat and Power
CO	-	Carbon dioxide
CO_2	-	Carbon dioxide
DC	-	Direct current
DRERs	-	Distributed Renewable Energy Resources
DG	-	Distributed Generation
EFGT	-	Externally Fired Gas Turbines
EIA	-	Environmental Impact Assessment
EPSR	-	Electric Power Sector Reform
FCT	-	Federal Capital Territory
g	-	Grammes
GE	-	Grid Extension
GEP	-	Green Energy Programme
GHGs	-	Greenhouse gases
GIS	-	Geographical Information System
GJ	-	Gigajoules
GW	-	Gigawatts
GWh	-	Gigawatt-hour
GWP	-	Global Warming Potential
ha	-	Hectares

HHV	-	Higher Heating Value
ICEs	-	Internal Combustion Engines
IPCC	-	Intergovernmental Panel on Climate Change
J/g	-	Joule per Gramme
J/K	-	Joule per Kelvin
K	-	Kelvin
LCA	-	Life Cycle assessment
LPG	-	Liquefied Petroleum Gas
LSTS	-	Least Squares Time Series
MJ/kg	-	Megajoule per Kilogramme
MNBPC	-	Modified Nominal Bio-Power Capacity
MSW	-	Municipal Solid Waste
MTE	-	Microturbine Engines
MW	-	Megawatts
NDA	-	Niger Dam Authority
NEP	-	National Energy Policy
NEPA	-	National Electric power Authority
NERC	-	Nigerian Electricity Regulatory Commission
NO_X	-	Nitrogen oxides
NRCS	-	National Resources Conservation Service
PHCN	-	Power Holding Company of Nigeria
PIFA	-	Prospect for Implementation Flowchart Analysis
PPMCC	-	Pearson’s Product Moment Correlation Coefficient
RE	-	Renewable Energy
REP	-	Rural Electrification Projects
RES	-	Renewable Energy Sources
RESD	-	Renewable Energy for Sustainable Development
R&D	-	Research and Development
SE	-	Stirling Engines
SO_x	-	Sulphur oxides
SP	-	Small Power
SSA	-	Sub-Sahara Africa
UNDP	-	United Nations Development Projects

UNFCCC	-	United Nations Framework Convention on Climate Change
UTM	-	Universiti Teknologi Malaysia
VSP	-	Very Small Power
WEC	-	World Energy Congress

LIST OF SYMBOLS

$Aaep_{c,j}$	-	Annual average energy potentialof c residue fron j crop
$Aep_{c,j}$	-	Available energy potential of *c* residue from *j* crop
a_j	-	Available j crop for power generation purpose
$CV_{c,j}$	-	Calorific Value of c residue from j crop
$\sum_{i=1}^{n} D_{ji}$	-	Total sum of diverted (loss) quantity of *j* crop due to *i* number of contending applications in a base-year
n	-	Number of observation
P_c	-	Quantity of c residue
$P_{c,j}$	-	Quantity of residue c from j crop production
$\overline{P_c}$	-	Mean value of the quantity of c residue
P_j	-	Production quantity of j crop
r_{cob}	-	Correlation coefficient for cob residue
r_{straw}	-	Correlation coefficient for straw residue
r_{stalk}	-	Correlation coefficient for stalk residue
$R_c^{\ 2}$	-	Coefficient of determination of c residue
T	-	Trend line parameter
T_{cob}	-	Trend line parameter for cob
T_{straw}	-	Trend line parameter for straw
T_{stalk}	-	Trend line parameter for stalk
γ	-	Intercept component of the model
β	-	Coefficient of the linear relationship

t_i	-	Time code for different years
ψ	-	Sum of squared deviation for the multiple linear equation
σ	-	Sum of squared deviation for the simple linear equation
$\sum$	-	Algebraic summation
$\tau_{c,j}$	-	Conversion factor of residue c from j crop
τ_{cob}	-	Corn cob conversion factor (crop to residue ratio)
τ_{straw}	-	Corn straw conversion factor (crop to residue ratio)
τ_{stalk}	-	Corn stalk conversion factor (crop to residue ratio)
ξ	-	Residue availability factor
$Npc_{c,j(gasif.)}$	-	efficiency of the plant using bio-residues for power generation via the route of gasification
$Npc_{c,j(comb.)}$	-	efficiency of the plant using bio-residues for power generation via the route of combustion

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Off-grid and grid connected renewable and distributed power generation using biomass residues is rapidly becoming a highly forward-thinking option to rural energy predicament in many developing countries. However, large-scale electricity supply from fossil related energy resources have been a commonly associated electricity supply structure for urban neighborhoods. Nonetheless, autonomous renewable and distributed power generation structures are making interesting incursion into the global electric power supply systems in both developed and developing countries.

Globalization of modern economy, technologies and other human related endeavors can undisputedly be attributed to the dynamic and sophisticated nature of modern electricity supply structures. The rapidly changing outlook of these concepts is responsible for the remarkable increase in global energy demand. There have been rigorous efforts to meet the global energy demand challenges but relying on the traditional fossil power generation alone is synonymous in taking a risk of backward trend in modern developmental strategies. The main reason behind this affirmation is that fossil electricity and other conventional energy generation sources are not only limited but their global reserves is declining as each day meet its end. On this focus, renewable energy development is gradually becoming one among the unavoidable prospect in the history of mankind.

Excessive combustion of fossil-based has great contribution to disobliging environmental consequences such as global warming. Recent industrial transformations experienced in advanced countries of the world have enormously altered the global environmental purity and sustainability. This is because the progress of industrial activities highly depends on modern energy consumption which is critically obtainable in large quantity from the combustion of fossil fuels and other conventional energy resources. To a greater extent, global fossil energy consumption has immensely increases the level of anthropogenic greenhouse gases (GHGs) emissions which is one of the major causes of persistence increase in global warming potential (GWP). Global warming has serious negative consequences on the sustainability of human health and the serenity of biodiversity in general. In respect to this consequential development, global summits like Kyoto Protocol under the tutelage of United Nations Framework Convention on Climate Change (UNFCCC), Copenhagen Climate Change Conference (CCCC), World Energy Congress (WEC), and Intergovernmental Panel on Climate Change (IPCC) strongly advocated for the use of policies to control and reduce emissions from power consumption and other energy related activities. This quest has spurred the infiltration of several globally recognized renewable energy programmes such as Clean Development Mechanism (CDM), Green Energy Programme (GEP) and Renewable Energy for Sustainable Development (RESD).

Regarding this point of view, renewable energy has attracted global curiosity being the only viable option available to mankind for providing solution to environmental constraints in generating power using conventional sources. Development of renewable energy from biomass is one of the major promising alternative energy resources because of its presence in almost every part of the world. Hamzeh *et al*, [1] acknowledged that about 10% of global energy supply is generated from biomass with the remaining 90% obtainable from fossil fuels and other conventional energy resources. This development is a clear index that the entire world is vulnerable to serious environmental peril if actions are not initiated to counter the trend.

Biomass is one of the sustainable Distributed Renewable Energy Resources (DRERs) for electric power generation in the world today. Considering the impediment of fuel importation to rural and remote areas where bio-energy resources are available, then biomass is preferably the best option for energy production. The most productive energy structure for biomass power application in such rural and remotes areas in any part of the world is distributed generation facilities. Biomass for distributed generation of electricity has proved its environmental and socio-economic benefits in recent years.

Distributed generation (DG) is the oldest channel of power supply to domestic consumers of electricity. Electric current was first produced in dc then followed by ac and the voltage profile was so low to be transported over long distances to serve large consumers, therefore the generating system was located close to the consumers in the pattern of present day DG system. Also looking beyond this fact, the rate at which renewable energy DG systems are penetrating the power industries at present is an indication of the tactical importance of DG technologies.

Biomass is obtained from varieties of sources as shown in Figure 1.1. The craving effect of this research study is to critically explore the potential of some selected biomass residues for DG of electricity considering Nigeria as a case study. The phenomenon of biomass for electricity is also known as bio-power or bioelectricity. In the context of renewable distributed generation of power, local renewable energy resources such as wind power, solar power, mini and micro hydropower and bio-power have been used successfully in many rural and remote areas with difficult access to electricity from centralized power system. At another level, grid connected bioelectricity have been seen in power industries of developed nations. Though, this development is not limited to developed countries as it has also been demonstrated in some developing countries like India, China and Thailand.

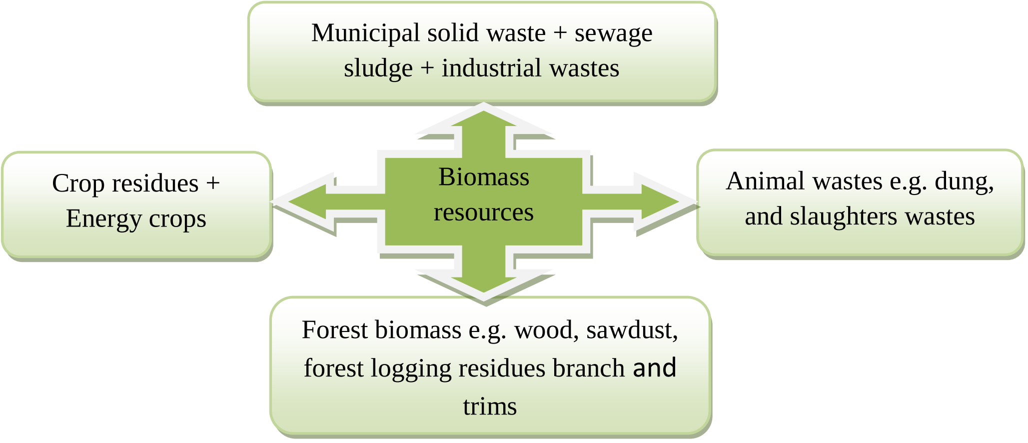

Figure 1.1: Main composition of biomass resource

As the price of energy from fossil fuels continued to manifest upwards adjustment based on economic issues and socio-political resolutions, the structure of energy supply based on distributed generation is swiftly becoming more noteworthy in the scheme of future power supply. Within the fold of the expected changes, renewable system distributed generation have a very significant role to play as shown in Figure 1.2. In this technology, the necessity for building bulk transmission system is usual case in traditional energy supply scenario is totally void and the possibility of distribution network upgrading may be ignored. Distributed generation is a viable alternative pattern for power generation [2] especially in regions with little or no access to energy from central grid system.

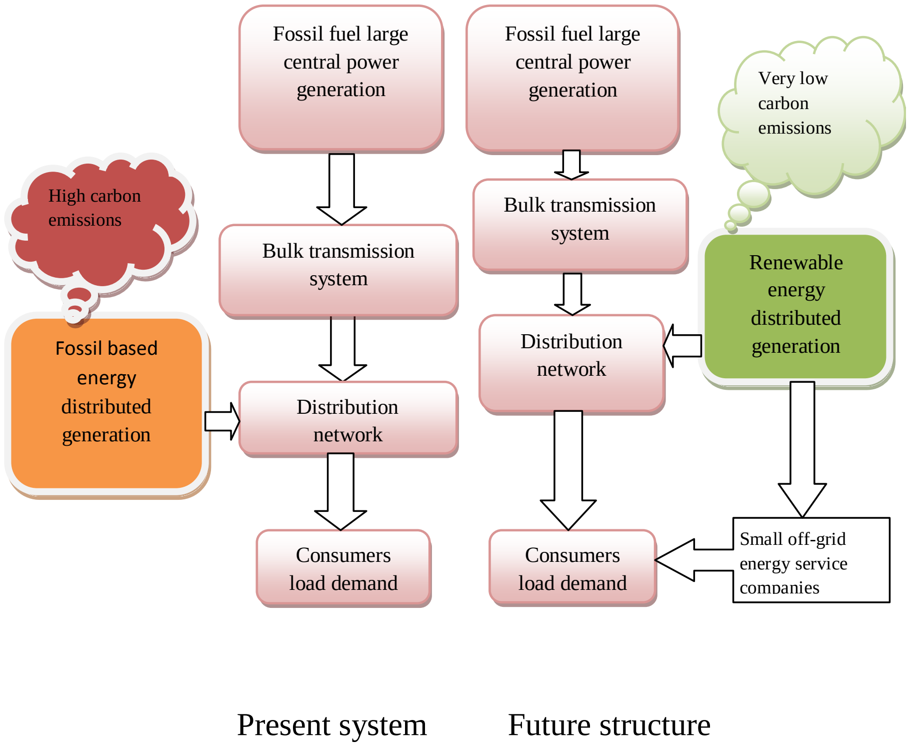

Figure 1.2: Comparison between the present and future electricity supply structure

Developed and developing countries are under persistence great effort to make provision for indispensable services to their citizens' especially electrical energy which is a pivot to all other developments. Human standard of living cannot be justified in absence of electrical energy services and environmental protection. With keen observation, wide ranges of disparity have been observed in the supply of electricity between developed and developing countries. This is also the prevailing circumstances between urban and rural communities of developing countries most especially in sub-Sahara Africa (SSA) countries. Inequality in the development of countries can simply be attributed to poor access to electricity which differs from county to country located in same or different regions.

1.1.1 History of the Nation's Power Sector

The Nigerian power sector started in 1962 as Electricity Corporation of Nigeria (ECN). Niger Dam Authority (NDA) was created later to harness the country's hydropower resources. The name of the power sector was afterwards changed to National Electric Power Authority (NEPA) resulting from the unification of NDA and ECN in 1972. Operating under the name of NEPA, the power sector was monopolistically entrusted with generation, transmission and distribution of electric power in the country. As a result of general low performance manifestation of NEPA, a major reform in the sector known as Electric Power Sector Reform (EPSR) Act was carried-out in 2005 to disintegrate the vertically operating scenario in that sector of the economy.

The foremost objective of the reform was to liberate the marketing policy in the sector by breaking the long-time monopoly being enjoyed by the NEPA. The reform led to the establishment of a statutory regulatory commission, Nigerian Electricity Regulatory Commission (NERC) entrusted with the mandate to monitor all power generation, transmission and distribution related activities in the nation's power sector. Independent Power Producer (IPP) participation was supported as part of the new investment strategy in the power sector. The reform also endeavors to segregate the entire power system operations into three independent companies comprising six generation, one transmission and eleven distributions which came into effect in 2007. The collection of these independent companies is now called Power Holding Company of Nigeria (PHCN).

Currently, there are 14 power generating stations in the country; Egbin (thermal power station-1320MW), Egbin AES (thermal power station-270MW), Sapele (thermal power station-1020MW), Okapi (thermal power station-480M), Afam (thermal power station-702MW), Delta (thermal power station-840MW), Omoku (thermal power station-150MW), Ajaokuta (thermal power station-110MW), Geregu (thermal power station-414MW), Omotosho (thermal power station-335MW), Olorunsogo (thermal power station-335MW), Kainji (hydropower station-760MW), Jebba (hydropower station-540MW) and Shiroro (hydropower station-600MW). The total installed capacity is 7,876MW while the estimated power demand of the country is about 15000MW. The demand had remained unmet for the following reasons;

i. With total installed capacity of 7,876MW from hydro and thermal gas power plants, the available capacity is generally below 4000MW throughout the history of the power sector due to the problem of system infrastructures.
ii. Inadequate diversification of energy resources.
iii. Inconsistence policy issues and lack of reforms implementation.

Table 1.1 illustrates the comparative analysis of the electricity consumption strength in Nigeria and some other selected countries in the world. Libya with population of 5.5million as shown in the Table 1.1 has generation potential of 4600MW with per capita consumption of 1.015kW while Nigeria is providing 0.03kW at the same time period despite the huge energy resources in the country. The democratically elected civilians government of Nigeria from 1999 to 2007 has invested more than $5billion into the power sector, yet every effort to meet the national power demand remain practically unworkable. This can be attributed to several cases of endemic financial mismanagement in the sector.

Table 1.1: Comparative analysis of electricity generation in some selected countries [3]

Country	Population (million)	Power generation (MW)	Per capita consumption (kW)
United States	250.00	813,000	3.200
Cuba	10.54	4,000	0.380
UK	57.00	76,000	1.330
Ukraine	49.00	54,000	1.330
Iraq	23.60	10,000	0.420
South Korea	47.00	52,000	1.090
South Africa	44.00	45,000	1.015
Libya	5.50	4,600	1.015
Egypt	67.90	18,000	0.265
Nigeria	**140.00**	**4,000**	**0.030**

1.1.2 Energy Demand Situation

Household and commercially supplied electrical energy had decreased over the years in the country. This has accentuated the economic conditions of the country with characteristic social poverty and insufficient chances for development. Nigeria is a developing country where the majority of human populations are farmers but the agricultural sector is highly underdeveloped with characteristic subsistence structure. Food importation especially rice and wheat is often considered used to support the sufficient domestic production. Household energy demand predominate other energy consuming sectors. The household energy demand is mainly for cooking, heating, lighting and services of household appliances. Due to energy crisis situation in the country, there are varieties of energy resources used to meet the energy needs.

Liquefied petroleum gas (LPG), firewood, wood charcoal, agricultural residues, kerosene and electricity are the main are the various energy carriers used in urban, semi-urban and rural areas. As earlier stated, majority of households rely on excessively on firewood and charcoal to meet large share of their domestic energy consumption. The general low income level in SSA is one of the factors affecting limiting the potential of many homes from gaining access to electricity especially in urban areas where the service of electricity exist. Households are allowed to decide on whether or not to have access to electricity in their homes [4]. Many in developing countries are more favored by charcoal as a source of cooking energy because it can be procured on the neighborhood market and used in cheap stoves [5] due to high billing tariffs and cost of purchasing cooking appliances [6-7] relying on electricity for operation. As human population continues to grow by natural disposition with persistent struggle for development, electricity demand trend is also expected to increase proportionally.

1.1.3 Categories of Biomass in Nigeria

Biomass has been a traditional source of energy well identified in Sub-Sahara Africa countries though largely on traditional method of application. In Nigeria, nearly about 98% of rural dwellers and more than 50% of urban households depends directly on bio-energy resources of various kinds for domestic heat energy needs. In most applications, firewood are carbonized into charcoal and used in locally made charcoal stoves for improved burning efficiency and fuel savings. Preference of charcoal over firewood and other sources of traditional energy resources are also due to its high energy density and easiness to be transported over some distance. Firewood application is commonly used in an open space three stone arrangement for cooking. This set up for heat energy generation is one of the major sources of indoor air pollution which affect mostly women and children in the form of acute cardiovascular infection (ACI).

Nigeria is an agrarian country. A substantial part of the country is high cultivable as shown in Figure 1.3 (satellite image of the country). Although, the country's agricultural activities is predominantly subsistence as majority of farmers rely on human labor and other traditional methods of farming. Capital investment and application of mechanized agricultural inputs is limited because the government focuses more on revenues generation from crude oil and natural gas. Crops growing in Nigeria are mostly on rain fed system. In Northern part of Nigeria where the draught season is more prolong, irrigation system is adopted by some medium and large-scale farmers. In this case the irrigation facilities are usually powered by diesel or petrol based generators.

Figure 1.3: Satellite image of Nigeria showing the cultivable part of the country [8]

Through in the various efforts of the farmers to feed the rapidly increasing population, lot of biomass resources are generated. The resources are distributed across the country in line with regional vegetative structures and agricultural activities. Energy demand in the country has continued to increase at a significant pace due to rapid change in population and socio-economic activities. Also, most modern farming activities need electricity for operation. Nigerian farmers are scattered in rural villages with little or no access to electricity. Large shares of their agricultural jobs are done by human and animal power application because electrification pace of rural areas in the country has very low record of just 2% access [9].

1.1.4 Major Biomass Residues and Production Quantity in Nigeria

Biomass resources in Nigeria can be grouped into four major categories as illustrated in Table 1.2. Availability of agricultural biomass in the country depends upon some important factors such as population, agricultural activities and natural vegetation (amalgamation of climate, humidity and rainfall) which are also applicable to purposely grown energy crops. Ideally, forest biomass availability depends on natural vegetation but can be influenced by human activities such as bush burning, wood logging and overgrazing. Municipal solid waste (MSW) generations depend mainly on social life of the people, availability of different functional institutions and economic activities of the region. The most important biomass residues in Nigeria are crop residues such as rice straw, rice husk, corn stalk, corn straw, corn cob, sorghum stover, and sugarcane bagasse. Others observed with considerable production quantity are groundnut hull, Egusi melonseed shell, sorghum threshed heads and wheat straw. In Nigeria, majority of the biomass crop residues were always disposed off deliberately either by burning close to human residence or remain in the farms as onsite waste being that technologies for handling the residues to produce energy are not yet available in the country. It can also be said that farmers have little knowledge about the use of the residues for onsite or commercial energy production being that Nigeria is a developing country with low diffusion of technological orientation.

Table 1.2: Summary of different categories of biomass resources in Nigeria.

Categories	Examples
Agricultural biomass	Food crops: rice, corn, beans, cowpea, sorghum, yam, cassava, potatoes, millet and wheat Cash crops: sugar cane, groundnut, soyabeans, cocoa, oil palm and egusi melon Orcard crops: oranges, mangoes, cashew, pawpaw, walnut, cola nut, banana and pineapple Animal manure from cow, donkey, horse, pig, goat, sheep, camel and poultry birds
Forest biomass	Forest wood, mill residues, forest thinning residues and logging slash
Municipal solid waste	Printed papers, green wastes such as vegetables, kitchen waste, slaughter waste, landfill gas, dead animals, textile waste, rags, sweeping refuse, afro-processing waste, cardboard, packaging and wood waste
Purposely grown energy crops	Jatropha, castor seed and sunflower

Biomass residues are agro-based waste raw materials generated from post farming activities. Annual production quantity of different crops in Nigeria varies significantly from crop to crop. It signifies that the quantity of residue produced by different crops also varies. The production quantity of the main crops grown in the country is given in Figure 1.4 with year 2010 considered as base period. From the data presented, it is obvious that corn has the highest production quantity and as well it generates three different residues compare to some of the crops. This is the major reason why corn residue is considered suitable for this research study.

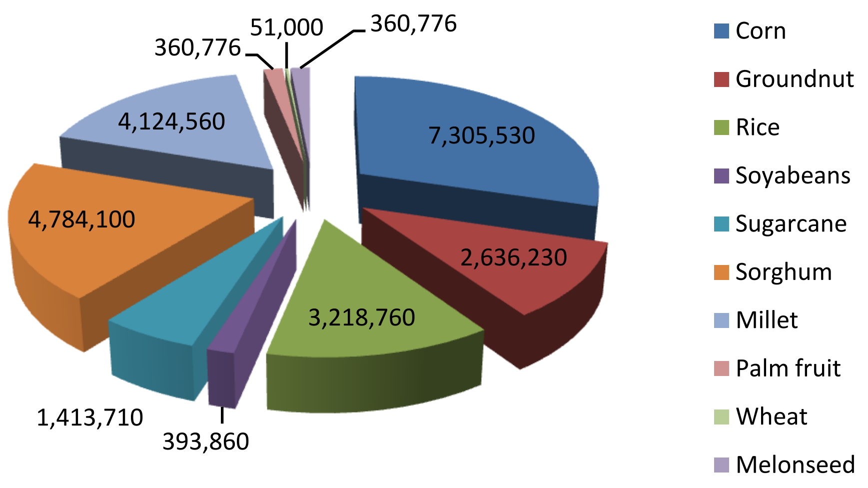

Figure 1.4: Production quantity of main crops with bio-residues in tonnes [10]

Moreover, application of the residues for animal livestock feeding or for other competing purposes is not very significant in the country because livestock rearing practice in Nigeria is intensively on nomadic bases. Domesticated animals in the country are also not well monitored in regard to feeding. In most cases they are freely allowed to feed from the surrounding vegetations. At present no rural energy arrangement in existence for utilization of these residues and the resources are usually very much available at the end of every harvesting seasons. Since availability of residues is the main factor to be considered before evaluating their potential for energy generation [11], therefore, this study address the contribution to electricity from some selected biomass crop residues as energy feedstock in Nigeria.

1.2 Statement of the Problem

Global stride to reduce the level of emissions of GHGs in the atmosphere and enthusiasm to bridge the socio-economic gap between rural and urban settlements are among the vital needs for bio-power generation. Spectacular change in the population of the country from time to time adjudges the country's corresponding increase in energy demand. The widespread revolting situation in the nation's power sector revealed that more than half of the people living in Nigeria especially in rural areas lack access to electrical energy. Approximately 40% of households in the country have access connection to the nationwide grid [12]. Development of clean and renewable energy source like biomass has not been reckoned with even though its logical role in the country's current state of affairs is productive. However, there are many barriers affecting RE development in the country including potential estimation of the available resources and inadequate funding mechanism.

The situation of energy crisis and sporadic power failures in Nigeria is very disturbing situation to the public consumers of electrical energy because of its effects on the general quality of life. Electricity provisioning has very great influence in modern civilization as well as urban and rural socio-economic development. Many developing counties have not only explored their biomass resources potential but they have invested wisely on the growing technology for constructive growths. Therefore, the priority of this study is to provide a platform for some selected biomass residues for bioelectricity application in Nigeria.

Survey on available literatures hinging on bio-power potential evaluation so far disclosed that researchers have neglected the need to tackle lost of residues to other activities competing applications with bio-residue use for power generation. Realistically, it is practically impossible to use 100% of residues produce for power generation purpose being that there are some competing applications where some of these residues may be used. This fact was also acknowledged by Yang [13], based on the recommendation of National Resources Conservation Service (NRCS) of the United States Development Agency (USDA) that for power generation using crop residue some quantity is diverted for other applications. With respect to this challenge, this research tends to establish mathematical formulation to accommodate the loss in quantity of residues produced by modification of standard computational technique while introducing what is known as modified nominal bio-power potential (MNBPC) evaluation function. It also aims at long term forecasting using regression analysis in line with the country's plan of action to integrate bioelectricity into the power sector by year 2020.

1.3 Objectives of the Study

Government efforts for rural electrification by grid expansion (GE) cannot be relied upon as the Rural Electrification Project (REP) of the country has well-known history of failure. It is financially expensive to provide electricity to sparsely populated areas in developing countries like Nigeria because government interest is to focus on GE. Insufficient fund, financial irregularities in the nation's power sector couple with some technical constraints may further compound the problem of electricity supply to rural communities. There is consensus opinion among renewable energy experts that bio-energy if well tapped can offer a better alternative to rural energy scarcity. The problem of intermittent national energy and economic crisis, environmental and health related menace from fossil fuels consumption is a serious concern. There is speculation that backward trend in energy provision in the country may remain for ages if the syndrome of grid extension mission triumph. Electricity provision by GE has to be followed by a corresponding increase in the national power generation capacity.

Modern agricultural practices seek to transform farming processes into a mechanized type to support the ever growing population and energy demand. Energy provision is the only agent that can drive the envisage development in agricultural sector. Establishment of independent distributed power generation systems in rural areas can reduce the problems in the national energy supply matrix. Investment in biomass and other green energy technologies can give Nigeria the capacity to overcome energy shortage and reposition the country's investment capacity before year 2020. Hence, the precise objectives of this research study are:

i. To estimate the potential for power generation of the residues using modified bio-power nominal capacity assessment formulation.
ii. To apply regression analysis to project the nominal power capacity for a period of 10 years and as well investigates the trend relationship between the residues production quantity and the future time variation based on forecasting technique from 2011 to 2020.

1.4 Significance of the Study

At present biomass for energy application is gaining a serious momentum around the world. It is in the coordinated efforts of the giants and emerging economies of the world to reduce the drift of atmospheric pollution from burning of fossil fuels. They also acknowledge the needs to continued socio-economic development to improve standard of livings of the entire humankind. All these ideologies prompted the searches for clean and sustainable energy which is an inevitable endeavor for every sovereign country. Major and minors feedstock bio-energy are now coming to the limelight as the search for renewable bio-energy resources continued. It is this zeal that glint interest on this study to investigate the potential of the biomass residues for distributed generation as a contribution to the energy needs of the country.

Although, Nigeria is not an industrialized nation but the economic and environmental demand to rearrange the portfolio to exploit sustainable energy resource in the country is pragmatic. In order to confront the problems of energy shortage while simultaneously seeking to counter environmental constraint from fossil fuel consumption, bio-energy development is seen as a strategic option. In addition, utilization of biomass for energy can foster economic development, improve the living conditions of rural dwellers, encourage new sense of social integration, promote national interest and set a pace for physical development. Therefore, this research intent to provide a road map for sustainable bioelectric power generation from the selected biomass residues through distributed generation technology in Nigeria. The ploy to exploit the benefits of CDM in line with Kyoto Protocol is another significance of this research. Also, it will be structured to support as a noteworthy information provider to key energy bodies in the country like Energy Commission of Nigeria (ECN), Power Holding Companies of Nigeria (PHCN), Independent Power Producers (IPPs) and international bodies that may have vested interest to promote renewable energy development in Nigeria.

1.5 Scope of the Study

Studying the potential of any raw material for alternative energy production is a very essential task. Several studies have explained some tactical importance of RE resources in the upwards and downwards of energy application. Efforts have not been harnessed for exploring the potential of biomass corn residues for power generation in the country. Based upon this, the study aimed at determining the nominal power potential of all the three main residues from corn; cob, stalk and straw.

1.6 Research Contribution

This research intends to contribute to a growing centre of bio-power generation knowledge which is one of the global spotlights towards embracing alternative energy production. The strategic contributions of the research involve mathematical modification of nominal power potential evaluation function to accommodate losses in the quantity of residues utilization for power generation. It also forecasts the potential availability of residues for power generation using time series.

1.7 Thesis Outline

This thesis is structured into fivefold chapter. Chapter one centre on the general introduction to the concept of renewable energy using biomass for distributed power generation. Also covers key areas of case study country's description, current situation of the nation's power sector, electricity demand portfolio of the country as well as biomass resources available in the country. In the later sections of the chapter, problem statement, objectives, significance, scope and the research contribution were discussed.

Chapter two mainly reviewed on the related literatures starting with the definition of biomass in relation to energy production. It then follows by the review of related literature on biomass for power generation in various case study countries. Within the fold of this chapter, it also highlights weaknesses of many other projection techniques as they are not productive for long term forecasting. The benefit of biomass for power generation in developing countries is also discussed. The chapter was concluded with discussions on various technological pathways of biomass residues conversion for power generation.

In chapter three, the research methodologies were intensively discussed. Starting with the prologue using flowchart, this research work explores three different methodologies. After the review of past literature then followed mathematical formulation, and laboratory experiment using the selected research samples (corn cob, corn straw and corn stalk). It was followed by the collection of secondary data on the crop residues production over some period of time (15 years). Microsoft Excel based computational procedure was employed then analysis and discussion of results.

Chapter four dwells on the research result, analysis and discussion of findings. The result of the experiment with that of the corn production data are used for the computation of the nominal power capacity of each residue. It also utilizes the time series data for trend line forecasting equation.

Chapter five which is the last segment of the thesis discusses on the conclusion and future work. It pin-points the conclusion base on the findings of the research work and also endeavors to concludes based on the future research work. It was advocated that future work shall give directives on how to expand the frontier of energy consumption using the biomass resources for renewable power generation.

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