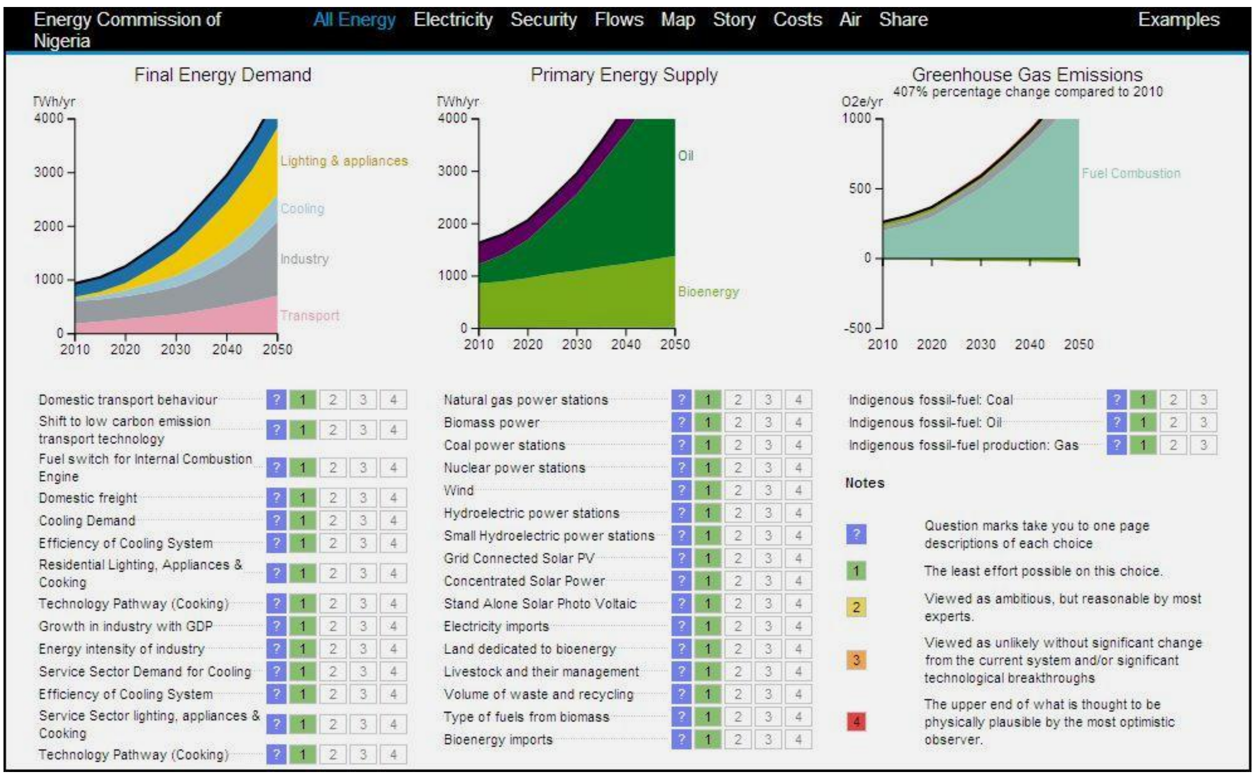
NIGERIA ENERGY CALCULATOR 2050 (NECAL2050)

Website: www.nigeria-energy-calculator.org

REPORT



March 2015

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ACKNOWLEDGEMENT

The Nigeria Energy Calculator 2050 (NECAL2050) was conducted under the 2014 capital budget of the Commission titled "Sustainable Energy Project Development – Energy Modelling" with the No. STEC 30004661. NECAL2050, a Web-based energy planning instrument, reveals interactively the various energy demand and supply pathways over long term periods and their consequent emissions. It was developed by the Energy Commission of Nigeria with technical and part financial support from the UK Department of Energy and Climate Change (DECC) and the British High Commission (BHC) in Nigeria.

The Energy Commission of Nigeria wishes to seize this opportunity to express its profound gratitude to the UK-DECC and the BHC for their tangible support. Our gratitude also goes to the Honourable Minister of Science and Technology for his support, as well as our numerous stakeholders, who worked with us to make the project a success. The diligence of staff of Energy Commission of Nigeria, who worked tirelessly in the project, is highly appreciated.

The Director General / Chief Executive Officer
Energy Commission of Nigeria

PREFACE

Sustainable patterns of energy production, distribution and use are essential to achieving the interrelated economic, social and environmental aims of sustainable human development. Current patterns of energy production, distribution and use worldwide are generally unsustainable and therefore changes need to be made. In Nigeria, up to 55% of the population does not have access to modern energy (electricity and fuels); they rely on traditional energy sources for their cooking and production activities thereby compromising their social and economic development conditions. Moreover, there is need to supply more energy services to support continued development.

Fortunately for Nigeria, the energy infrastructure is still evolving and it is essential that the infrastructure be developed in ways that avoid retracing the wasteful and destructive stages that characterized industrialization in the past. Our energy future will largely depend on the choices we make while developing the energy infrastructure. Future energy choices are commonly formulated by stakeholders in complex decision making processes involving government, the private sector and the public.

The ECN is charged with the responsibility for the strategic planning and coordination of national policies on energy in all its ramifications towards achieving a balanced development of the Nigerian energy sector. In doing so, the ECN is always in search of policies, tools and methodologies that will help in the effective discharge of the functions. The societal significance of our future energy choices prompted the ECN to embrace the UK2050 Calculator when it was introduced to us.

The Nigeria energy calculator is built on the modeling framework of the UK 2050 pathways Calculator. It is intended to be used as a practical tool for energy demand and supply analyses by policy makers, the academia, the business sector and the general public to explore the various options on how Nigeria can develop its energy sector in a sustainable manner. Some other countries have also developed their own versions of the calculator, using the modeling framework of the UK 2050 pathways Calculator. The countries include China, Japan, India, South Africa, Belgium, Taiwan, etc. The Calculator story began in the UK in 2009, when the UK Government's Department of Energy and Climate Change (UK-DECC) was tasked with coming up with a plan to meet the world's first legally binding emissions target (an 80% reduction by 2050 based on a 1990 baseline). Because there was so much uncertainty about what technologies would be available in the future, the team decided to build a new tool to explore all the options available, rather than using existing models that determine an optimum pathway. This was called the 2050 Pathways Calculator. The calculator is a simulation tool for energy demand and supply scenarios that aim at tracking emissions from energy consumption and supply with a long-term perspective up to 2050.

Vast arrays of considerations impinge on the energy decisions and choices people make. The decisions and choices that people, businesses and government make determine the overall size and configuration of the resultant energy system. In Nigeria, future energy systems will be decided by considerations such as: the population of the country; the distance an individual travels per year within the country; the proportion of the distance an individual travels by road, personal car, public transport or trekking; the type of fuel a household uses or prefers to use for cooking; the number, characteristics and utilization of energy consuming devices in a home; how much cooling energy an individual or an organization requires to achieve thermal comfort; growth rate of industry and industrial energy intensity; energy resources of the country; cost-benefit analysis, public safety, public opinion, diverse stakeholder groups and organizations, etc.

We are not faced with choosing a single energy source, but rather we must agree on the best combination of choices of energy. In general, it can be assumed that no single individual or organization has sufficient information about or understands the full range of issues associated with a complex technical, social, economic, political and environmental problem which the energy system represents. The NECAL2050 provides a way of harnessing the collective intelligence of the wide range of stakeholders in the energy sector and the general public. The structured nature of the NECAL2050 also shows how to positively guide large stakeholders' network to more informed decisions. This tool expands the capability to make informed decisions about the Nigerian energy sector planning from small to large stakeholder groups.

The web-based Decision Support System is equipped with feedback mechanism through which the virtual stakeholder audience can post their choices and suggestions for the energy sector development. The managers of the system will continually collect collate and analyze the postings to derive insights and perspectives that will be applied in the energy sector planning.

We believe that the NECAL2050, supported by its transparent data set and user-friendly interface for presenting the result, can be a useful tool for engaging in consultations and dialogues with the wide range of stakeholders in the energy debates. We commend it (www.nigeria-energy-calculator.org) to the use of the general public, experts and non-experts alike. We also invite and welcome your choices and suggestions which will help us refine the NECAL2050 system and recommend more informed energy policies for Nigeria.

The Honourable Minister
Federal Ministry of Science and Technology

ACRONYMS

ABU	Ahmadu Bello University
ARCN	Agricultural Research Council of Nigeria
AUMTCO	Abuja Urban Mass Transport Company
BOI	Bank of Industry
CFL	Compact Fluorescent Lamp
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CSP	Concentrated Solar Power
E10	10% Ethanol
ECN	Energy Commission of Nigeria
EIS	Energy Information System
EMTMD	Energy Management Training & Manpower Development
EPA	Energy Planning & Analysis
EV	Electric Vehicle
F	Fluorine
FAAN	Federal Airport Authority of Nigeria
FMA&RD	Federal Ministry of Agriculture & Rural Development
FMITI	Federal Ministry of Industry Trade & Investment
FMST	Federal Ministry of Science & Technology
FUT	Federal University of Technology
GHG	Green House Gases
HEV	Hybrid Electric Vehicle
HGV	Heavy Good Vehicle
ICE	Internal Combustion Engine
LAMATA	Lagos Metropolitan Area Transport Authority
LDC	Low Developing Countries
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas

M.O.U	Memorandum of Understanding
MAED	Model for Energy Demand
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impacts
MOD	Ministry of Defence
MSW	Municipal Solid Waste
NACCIMA	Nigerian Association of Chambers of Commerce Industry Mines & Agriculture
NBS	National Bureau for Statistics
NCEE	National Centre for Energy & Environment
NCERD	National Centre for Energy Research & Development
NCHRD	National Centre for Hydropower Research & Development
NESREA	National Environmental Standard Regulatory and Enforcement Agency
NGC	Nigerian Gas Company
NITT	National Institute of Transport Technology
NNPC	Nigerian National Petroleum Corporation
NST	Nuclear Science Technology
O_2	Oxygen
PHEV	Plug Hybrid Electric Vehicle
PPP	Public Private Partnership
PV	Photovoltaic
RE	Renewable Energy
SERC	Sokoto Energy Research Centre
UK – DECC	United Kingdom Department of Energy and Climate Change
UNDP	United Nations Development Programme
WASP	Wien Automatic System Planning Package

Units of Measurement

Bcf	Billion Cubic Feet
Boe	Barrel of Oil Equivalent
GW	Giga Watts
kCal	Kilocalorie
M^3	Cubic Metre
MHa	Million Hectares
Mtoe	Million Tonnes of Oil Equivalent
TCE	Tonne of Coal Equivalent
Tcf	Trillion Cubic Feet
TWh	Tera Watts Hour

CHAPTER ONE

INTRODUCTION

After an extensive communication between the ECN and UK-DECC and an introduction to the UK 2050 Calculator by the UK – DECC experts in Abuja, Nigeria, a Memorandum of Understanding (M.O.U) was signed between the UK – DECC, ECN and the British High Commission on Friday 22nd November 2013 at the British High Commission in Abuja. The M.O.U. stipulates the roles and responsibilities of each party in the tripartite agreement to jointly support the development of a Nigerian version of the UK 2050 Calculator. The M.O.U. also outlined the action plan for the implementation of the project aimed at producing a Nigeria Energy Calculator (NECAL2050).

NECAL2050 is an integrated model of energy, emissions and land use in Nigeria and aims to identify energy secure pathways for supply and demand of energy between now and 2050. The objectives of the NECAL2050 exercise are summarized as follows:

- It will offer a platform to facilitate academic and policy debate about the possible future pathways for the Nigerian energy sector and enable prioritizing some potential policy interventions for deeper analysis.
- It will help users (individuals, businesses and government) understand the wide range of possible energy pathways available to the country from highly pessimistic to highly optimistic scenarios.
- For each scenario in this range of possibilities, it will provide indicative numbers for demand and supply, and potential implications on issues such as import dependence, cost and land requirement.

By default, the UK-DECC developed the calculator to assist in the design of a carbon free energy future. The motivation for the Energy Commission of Nigeria are: (i) to develop a useful tool for engaging Nigeria energy experts and non-experts alike in debate about policy-making towards a more secure, sustainable and affordable energy future for the country, and (ii) to strengthen the capacity of ECN staff to carry out energy systems analyses which will improve energy policy assessment and formulation and energy planning for the country. Nigeria is not bound by the Kyoto Protocol to reduce its GHG emissions, being an Annex III member country. However, it is obvious that Nigeria cannot develop its energy infrastructure, still evolving, along the same pattern that caused emissions of large quantities of GHG into the atmosphere which are implicated in the climate change challenge. The project is intended to develop a tool that will enable experts and non-experts to contribute to the debate of achieving a sustainable energy infrastructure for the country.

What can it do?

The calculator allows users to experiment with different energy scenarios for the future and calculates aggregate costs, security of supply, environmental footprint and provides an energy flow diagram and a map showing the proportion of the land area of the country that is devoted for the cultivation of energy crops.

As a pathways simulation tool, the calculator can help policy makers as well as energy producers and consumers (including the public) to understand the energy and emissions related choices they are making. It allows users to develop their own pathway combinations to achieve emissions reduction and ensure energy security based on available resources, technologies and behavioural changes. It is not possible to predict the future and none of the pathways that this analysis produces or describes is an optimal or preferred route. The aim of this 2050 pathways analysis is to demonstrate the scale of the changes that will be required and the choices and trade-offs which are likely to be available to us as a society [1].

Like the UK 2050 Pathways Calculator, the Nigeria Energy Calculator 2050 sets out a range of four trajectories for the types of changes that might occur. These trajectories are intended to reflect the whole range of potential future scenarios that might be seen in that particular sector. In the energy supply sectors these trajectories represent a potential roll-out of energy infrastructure taking cognizant of resources and rate of development. For the energy demand sectors, the trajectories represent the behavioral and technological changes. In general, these trajectories are described as "levels" indicate either scale of changes or choices.

Unlike some other approaches (e.g. WASP and MESSAGE adopt cost optimization), the 2050 pathways analysis does not adopt a cost optimization approach – i.e. the calculator does not identify the least cost way of meeting the 2050 target. The aim is to look at what might be practically and physically deliverable in each sector over the study period (2010 – 2050) under different assumptions. The calculator then allows users of the tool to explore their own choices.

Cost is of course one critical dimension when making such a choice, and the cost implications for large scale electricity generation in different pathways will be discussed in future editions of the calculator. Other criteria such as public acceptability, land use impacts, wider environmental impacts, practical deliverability, technological risk, international dependency, business investment behavior and fiscal regimes, competitive and socio-economic and welfare impacts would also be important in understanding which of the potential pathways to 2050 is most desirable and most deliverable [1,2].

In exploring pathways, it is important to bear in mind that the 'Level 4' sectoral trajectories represent heroic levels of effort or change, and as a result it might be expected that the trade-offs associated with a pathway containing Level 4 ambition in one or more sectors would be particularly difficult.

Although this analysis takes a detailed look at what might be possible to achieve over the next 40 years, it does not set out what policy decisions would be required to deliver such a future. A detailed policy roadmap covering such a long timeframe would be neither possible nor plausible. Instead, we have described the shape of trajectories as they might be experienced on the ground under the assumptions of the associated levels.

This transparent and handy tool can help answer the fundamental questions of how the energy system can evolve in the future and its impact on GHG emissions, energy security, energy mix for electricity generation and related costs. It can provide a platform for engaging in dialogues on the challenges and opportunities of the future energy system and the responses to climate change by addressing such critical issues as:

1. If the entire population is to be supplied with electricity at all times, how can this be achieved?
2. Provide a wide range of options regarding how we can supply our energy and what available technologies can be introduced to reduce energy consumption and emissions, etc.
3. Provides the results immediately with good visualization.
4. Provide a handy interface for use by both experts and non-experts.
5. Help provide scenarios supported by different stakeholders.

The Nigeria Energy Calculator (NECAL2050) is an integrated model of energy, emissions and land use in Nigeria to identify energy secure pathways for supply and demand of energy between now and 2050.

Nigeria is one of the fastest growing developing countries (DC) with unique challenges for the development of the energy infrastructure. Demand for convenient forms of energy is set to grow due to steady economic growth, in a context of dwindling domestic reserves of conventional fuels. It is imperative to better understand the impact of today's energy choices on future energy security, economic and sustainable development, and in particular the links with food production, if bioenergy is chosen as a route to energy independence.

The NECAL2050 is open source energy and emissions model of Nigeria. It allows the user to explore all high-level energy, economy and emission pathway options the country faces. For each possible pathways the user can further investigate impacts on land-use, electricity, energy security, food production and intake.

How is different from other models used by ECN for modeling Nigeria energy systems?

The ECN has applied WASP, MAED, MESSAGE, etc. in modeling Nigeria's energy system in the past. ECN is still actively applying MAED & MESSAGE for the modeling of Nigeria's energy system. NECAL2050 is an addition to the suits of energy modeling tools which provide insights into the possible future development of the Nigeria's energy system. The major similarities and differences between MAED, MESSAGE and NECAL2050 are summarized in Table 1.

Table 1: Similarities and Differences between MAED, MESSAGE and NECAL2050

S/No.	MAED	MESSAGE	NECAL2050
1.	Excel-based energy demand modeling framework or modeling tool.	Energy supply modeling framework based on dynamic linear programming.	Integrated energy demand and supply model; Excel –based and Web-based.
2.	Simulation modeling framework.	Optimization model	Both demand and supply modes are simulation models
3.	MAED does not calculate emissions.	Calculates up to maximum of five user defined emission types on the supply side based on input demand.	Calculates the emissions on the demand side for fuels (e.g. gas, petrol, fuelwood, etc.); calculates emissions from electricity at the supply side on the supply.
4.	Takes a very long time to run a single scenario.	Takes a very long time to run a single scenario.	Can run several scenarios within a very short time.

What does the Nigeria energy calculator 2050 look like?

Two versions of the Nigeria Energy Calculator 2050 were developed which are the Excel version and the Web Tool version (see www.nigeria-energy-calculator.org). The excel spreadsheet model provides the fundamental model, information and analysis based on which the Web Tool was developed.

The NECAL2050 platform does not ‘recommend’ or ‘prefer’ any one scenario or pathway over the others. It merely provides the user a way to understand the realm of possible scenarios and their implications and post their preferences and choices as a contribution to the debate on sustainable energy development for Nigeria.

CHAPTER TWO

NIGERIA ENERGY CALCULATOR 2050 METHODOLOGY

Long-horizon modelling of energy infrastructure and their interactions with other domains such as socio-economic and technical aspects of a country is complex and challenging. It is difficult to forecast the evolution of a particular country and its constituent sectors (e.g. economy), 25 or 50 years into the future [3]. The difficulty in modelling arises from the uncertainty inherent in the interactions between in-country and external factors that affect model choices and underpinning assumptions. Scenario-based models based on plausible and acceptable descriptions of the future are often employed in such cases to study the effect of an evolving system. Outputs from scenario-based models give a probable range, rather than a deterministic one. NECAL2050 is scenario-based and the methodology for the calculations is described below:

The energy system must be continuously balanced to match supply and demand. NECAL2050 is an accounting framework algorithmically equipped with a mechanism to balance the energy numbers arising out of various combinations of demand and supply choices. A range of existing and future technologies are provided to ensure that the energy system can operate securely to meet demand and changing energy requirements. The Calculator in the Excel version algorithmically balances the demand with supply on a five yearly interval up to year 2050. The demand is summed up as per the user choice (out of four choices) in each of the demand sectors. Thereafter, the user has to choose as to how he would supply the energy. Once the user has exercised his choices, the calculator compares the demand and the supply figures.

For fossil fuels, if the balance is positive, that is, supply is higher than the demand, then domestic production and resources are sufficient to meet demand. If the balance is negative, then domestic production and resources are insufficient to meet demand and the calculator draws up imported supplies of fossil energy. For electricity, any imbalance that results from the selected demand and supply choices will be balanced by the increase or decrease of self-generation.

Above description may be summarized mathematically as follows:

Define,

D_i = sum of energy demand by sector in year i; **Eq. 1**

S_i = sum of energy supplies by energy form in year i; **Eq. 2**

L_i = sum of energy conversion and distribution losses, and energy use by energy facilities in year i;

Supply less losses is:

$$\boldsymbol{X_i = S_i - L_i} \quad \textbf{Eq. 3}$$

Then,

$$\boldsymbol{B_i = D_i - X_i} \quad \textbf{Eq. 4}$$

Where B_i is the difference between energy demand and supply that will have to be balanced through recourse to import or otherwise for fuels and by self-generation for electricity.

The energy flow diagram ((Sankey diagram) in the webtool is the key to viewing the energy balance in the NECAL2050. It guides the user as to how the demanded energy is being supplied – source wise, and whether there is surplus or deficit. The Sankey diagram can help the user to calibrate his choices to either change his demand choices to reduce import of reduce dependency on self-generation. Hence, this tool is very amenable to use as an energy security enhancement tool. Once the balancing numbers are generated by the balancing algorithm, the user can make his choices as to how to reduce import dependency or self-generation by re-calibrating the demand or supply or both of them.

Energy Demand Calculation Procedures

Residential Sector (X.a)

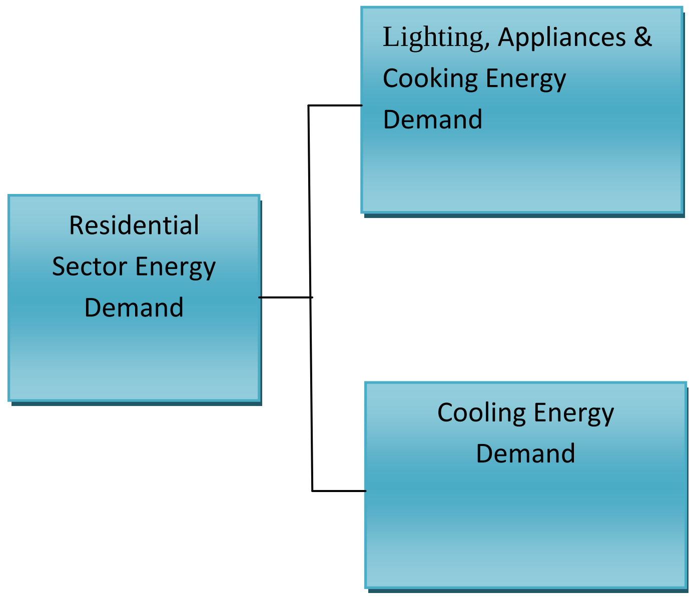


Figure 1: Framework for analysis of energy demand in residential sector

Trajectory Choice:

Residential sector energy demand consists of two modules: (i) lighting, appliances and cooking energy demand, and (ii) cooling energy demand, as demonstrated in Fig. 1. Each of the two energy demand drivers has two other drivers (components). Energy Demand and Technology Pathway are the components for lighting, appliances and cooking module while Cooling Energy Demand per Household and Efficiency of Cooling system are the ones for cooling energy demand. Each of the trajectories has four levels of choices.

Energy Vectors:

Cooling demand and Lighting & appliances demand has only one energy vector which is electricity while cooking has four vectors which are electricity (delivered to end user), liquid hydrocarbon (e.g. kerosene), gaseous hydrocarbon (e.g LPG) and traditional fuel (fuelwood, charcoal, crop residue, etc.).

***Calculation Procedure**:*

The procedure for the calculation of energy demand is listed below:

I. Compute energy demand by vector (e.g electricity, LPG, etc.);
II. Compute total energy demand by vector;
III. Compute emissions by energy vectors;
IV. Compute total emissions.

Lighting and Appliances energy demand (LAED)

$$\boldsymbol{LAED = \frac{LAED}{HH} * HH_n} \qquad \textbf{Eq. 5}$$

Where:

LAED/HH = lighting and appliances energy demand per household

HH_n= number of households

Cooking energy demand (C_kED)

$$\boldsymbol{C_kED = \frac{C_kED}{HH} * HH_n} \qquad \textbf{Eq. 6}$$

Where:

C_k *ED/HH* = Cooking energy demand per household

HH_n= number of households

Total Energy Demand by vector for Lighting, Appliances and Cooking ($TED_{LA\&C}$)

$$\boldsymbol{TED_{LA\&C} = LAED + C_kED} \qquad \textbf{Eq. 7}$$

Emissions [X]

$$[\boldsymbol{X}] = \boldsymbol{TED_{LA\&C} * EF} \qquad \textbf{Eq. 8}$$

Where:

X = Gas emissions (e.g CO_2, CH_4, N_2O, …)

EF = Emission factor of the energy vector

Cooling energy demand (CED)

$$\boldsymbol{CED = \frac{CED}{HH} * HH_n} \qquad \textbf{Eq. 9}$$

Where:

CED/HH = cooling energy demand per household.

Total Energy Demand by vector in a residential sector (TED)

$$\boldsymbol{TED = TED_{LA\&C} + CED} \qquad \textbf{Eq. 10}$$

<u>Services Sector (X.b)</u>

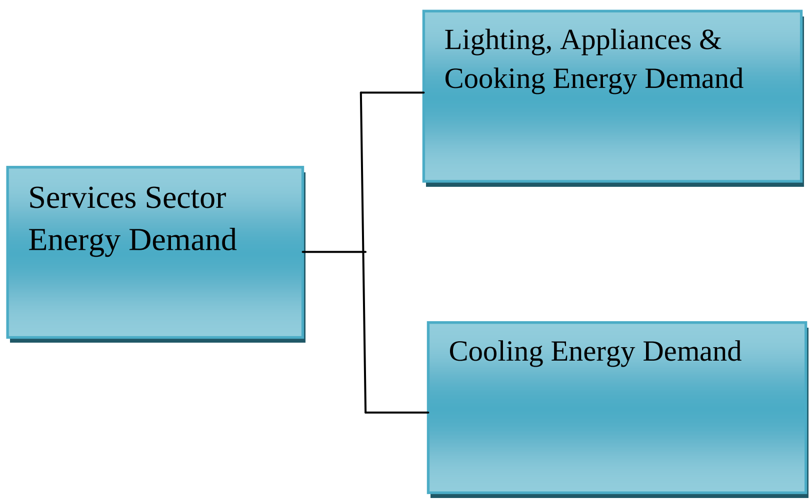


Figure 2: Framework for Analysis of Energy Demand in Services Sector

Trajectory Choice:

Services sector energy demand consists of two modules:

(i) Lighting, appliances & cooking, and

(ii) Cooling energy demand, as demonstrated in Fig. 2 above.

The modules have two different components. Energy Demand and Technology Pathway are the components for lighting, appliances and cooking module while cooling demand and efficiency of cooling system are the one for cooling energy demand. Each of the components of the modules has four choices.

Energy Vectors:

Cooling demand and Lighting & appliances demand has only one energy vector which is electricity while cooking have four vectors which are electricity (delivered to end user), liquid hydrocarbon (e.g kerosene), gaseous hydrocarbon (e.g LPG) and traditional fuel (fuelwood, charcoal, crop residue, e.t.c.)

Calculation Procedure:

The procedure for the calculation of energy demand is listed below:

I. Compute energy demand by vector (e.g electricity, LPG, e.t.c)
II. Compute total energy demand by vector
III. Compute emissions by energy vectors
IV. Compute total emissions

Lighting and Appliances energy demand (LAED)

$$\boldsymbol{LAED = \frac{LAED}{HH} * HH_n} \qquad \textbf{Eq. 11}$$

Where:

LAED/HH = lighting and appliances energy demand per household

Cooking energy demand (C_kED)

$$\boldsymbol{C_kED = \frac{C_kED}{HH} * HH_n} \qquad \textbf{Eq. 12}$$

Where:

C_k *ED/HH* = Cooking energy demand per household

Total Energy Demand by vector for Lighting, Appliances and Cooking ($TED_{LA\&C}$)

$$TED_{LA\&C} = LAED + C_k ED \quad \textbf{Eq. 13}$$

Emissions [X]

$$[X] = TED_{LA\&C} * EF \quad \textbf{Eq. 14}$$

Where: X = Gas emission (e.g CO_2, CH_4, N_2O, …)

EF = Emission factor of the vector

Cooling Energy Demand (CED)

$$CED = \frac{CED}{HH} * HH_n \quad \textbf{Eq. 15}$$

Where: *CED/HH* = cooling energy demand per household,

Total Energy Demand by vector in a residential sector (TED)

$$TED = TED_{LA\&C} + CED \quad \textbf{Eq. 16}$$

<u>Industrial Sector (XI.a)</u>

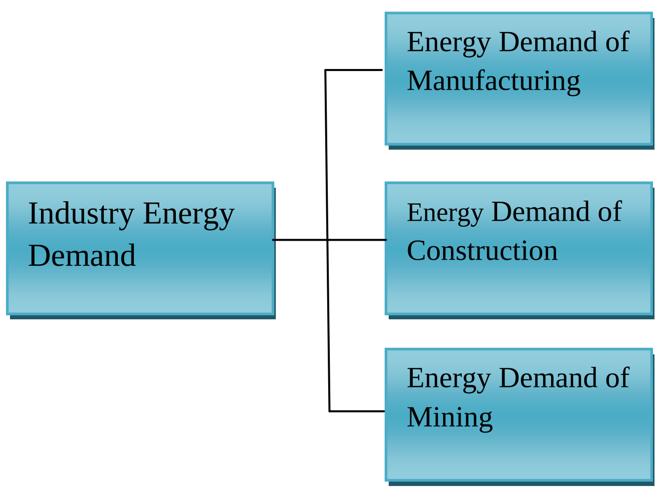


Figure 3: Framework for Analysis of Energy Demand on Industrial Sector

Industrial sector energy demand is modeled as the sum of energy demand in three industrial subsectors (i.e. manufacturing, construction and mining) as shown in Fig.3 above. Industrial process has two components of trajectory which are growth in industry with GDP and energy intensity. Each of the components of the trajectory has four choices.

***Energy Vectors*:**

I. Electricity (delivered to end user)
II. Solid hydrocarbon (e.g. coal)
III. Liquid hydrocarbon (e.g. fuel oil)
IV. Gaseous hydrocarbon (e.g. natural gas)
V. Traditional fuel (fuel wood)

Compensational process/ methodology:

I. Compute energy demand by vector by industry class/ category and sum up.
II. Compute process emission by energy vector by industry category and sum up.
III. Compute combustion emissions by energy vector by industry category and sum up.

Total energy demand (TED)

$$\boldsymbol{TED = ED_{Man} + ED_C + ED_M} \quad \textbf{Eq. 17}$$

Where:

ED_{Man} = energy demand in manufacturing

ED_C = energy demand in construction

ED_M = energy demand in mining

Energy demand by subsector (ED)

$$\boldsymbol{ED = OI * K} \quad \textbf{Eq. 18}$$

Where:

OI = Output index

K = energy demand multiplier

Demand by vector (ED_V)

$$ED_V = TED * L \qquad \textbf{Eq. 19}$$

Where:

L = split (share) by vector

Process emission for a particular GHG

$$GHG = PEG * N \qquad \textbf{Eq. 20}$$

Where:

PEG = process emission growth

N = baseline GHG emission

Combustion Emission (CE)

$$CE = ED_V * EF \qquad \textbf{Eq. 21}$$

Where,

EF = emission factor

The process emissions are emissions through the industrial production process; and the emissions considered in the industrial sector are: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, PM_{10}, NO_x, SO_2 and NMVOC. However, it is CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 that are treated as GHG and reflected in the emission chart of the webtool while NO_x, SO_2 and NMVOC are emissions that affect air quality only.

Combustion emissions are gases released during the combustion of fuels used in providing energy for the industrial processes. CO_2, CH_4 and N_2O are considered in the analysis.

The global warming potentials of the GHG employed in the model are presented in Table 2.

Table 2 : Global Warming Potentials of Greenhouse Gases

Greenhouse Gas	Global Warming Potential
Carbon Dioxide, CO_2	1
Methane, CH_4	21
Nitrous Oxide, N_2O	310
Hydrofluorocarbons, HFCs	140 – 11,700
Perfluorocarbons, PFCs	6,500 – 9,200
Sulfur hexafluoride, SF_6	23,900

Source: Ref. 4

Transport Sector

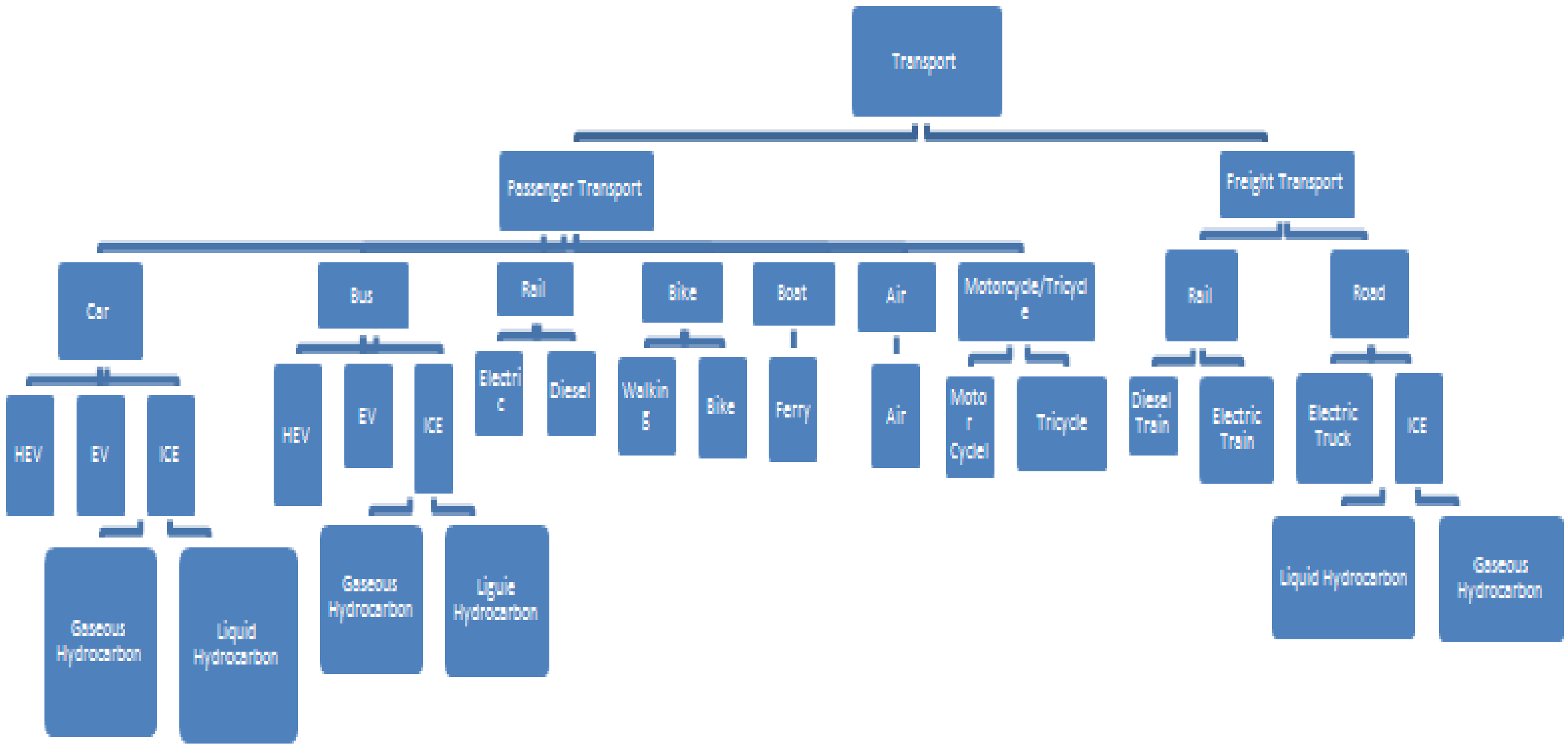


Figure 4: Structure of Transport Sector

Passenger Travel

Mode of Transport/Technologies

- Car
  - Internal Combustion Engine – Liquid Hydrocarbon (ICE-LH)
  - Internal Combustion Engine-Gaseous Hydrocarbon (ICE-GH)
  - Electric Vehicle (EV)
  - Hybrid Electric Vehicle (HEV)
- Bus
  - Internal Combustion Engine – Liquid Hydrocarbon (ICE-LH)
  - Internal Combustion Engine-Gaseous Hydrocarbon (ICE-GH)
  - Electric Vehicle (EV)
  - Hybrid Electric Vehicle (HEV)
- Bike
  - Bike
- Motor Cycle/Tricycle
  - Motor Cycle
  - Tricycle
- Train
  - Diesel
  - Electric
- Air
  - Air
- Boat
  - Ferry

Computation of total Passenger-km by mode

$$Totaldistancetravel = distancetravelperperson * population$$

$$\boldsymbol{Mode\ Share = \frac{distance\ travelled\ by\ mode}{Total\ distance\ travelled} * 100}$$ **Eq. 22**

Computation of Passenger-km by mode /Technology

$$\boldsymbol{Ownership = {}^{number\ of\ vehicles}/_{Population}}$$ **Eq. 23**

$$Occupancy = {number\ of\ person}/_{vehicle} \quad \textbf{Eq. 24}$$

$$Technology\ Penetration = \frac{Technology}{\sum Technology\ in\ mode} * 100 \quad \textbf{Eq. 25}$$

Computation of Energy Used by Mode & Vector

$$Energy\ Demand = \sum Distance\ travellled\ by\ mode\ and\ technology * efficiency\ of\ techn\ ology$$

Eq. 26

$$Efficiency\ of\ technology = {petrol\ used\ (litre)}/_{Distance\ Travelled\ (km)} \quad \textbf{Eq. 27}$$

Computation of Emission by Mode

$$Emission = \sum Distance\ travelled\ by\ technology * emission\ factor \quad \textbf{Eq. 28}$$

$$Emission\ factor = {CO2\ (kg)}/_{Distance\ Travelled\ (km)} \quad \textbf{Eq. 29}$$

Freight Transport

Mode/Technology of Transport

- Rail
  - Diesel Train
  - Electric Train
- Road
  - Diesel
  - Gas
  - Electric

Computation of Energy Used diesel

$$Energy\ Demand = \sum Dist\ travel\ by\ mode\ and\ technology * efficiency\ of\ technology \quad \textbf{Eq. 30}$$

$$Efficiency\ of\ technology = {petrol\ used\ (litre)}/_{Distance\ Travelled\ (km)} \quad \textbf{Eq. 31}$$

Computation of Emission by Mode

$$\boldsymbol{Emission = \sum Distance\ travel\ by\ technology * emission\ factor} \quad \textbf{Eq. 32}$$

$$\boldsymbol{Emission\ factor = {CO2\ (kg)}/{Distance\ Travelled\ (km)}} \quad \textbf{Eq. 33}$$

Energy Supply Calculation Procedures

The procedures applied for the calculation of the electricity supply is explained as follow:

- Gas Power Plant
- Self Generation (Oil)
- Coal Power Plant
- Biomass Power Plant
- Nuclear Power Plant (for nuclear plants, capacity factor is used in place of load factor to calculate available generation)

$$\boldsymbol{Available\ Generation = Available\ Capacity * Load\ Factor} \quad \textbf{Eq. 34}$$

$$\boldsymbol{Total\ Generation = Available\ Generation + Plant's\ Own\ Requirement} \quad \textbf{Eq. 35}$$

$$\boldsymbol{Resources\ Requirment = {Total\ Generation}/{Thermal\ Efficiency\ of\ Plant}} \quad \textbf{Eq. 36}$$

$$\boldsymbol{GHG\ Emission = Resource\ Requirement * Emission\ Factor} \quad \textbf{Eq. 37}$$

Renewable (Wind, Solar PV and CSP, Hydro) Power Plants

$$\boldsymbol{Available\ Generation = Available\ Capacity * Load\ Factor} \quad \textbf{Eq. 38}$$

$$Total\ Generation = Available\ Generation + Plant's\ Own\ Requirement \quad \textbf{Eq. 39}$$

$$Resources\ Requirment = {Total\ Generation}/{Thermal\ Efficiency\ of\ Plant} \quad \textbf{Eq. 40}$$

The Process of Developing the Nigeria Energy Calculator 2050

The Nigeria Energy Calculator 2050was developed following the general model structure of the UK 2050 Pathways calculator. The objectives set out at the beginning of the project by the Nigerian Team are: (i) to develop an interactive user-friendly tool that allows experts non-experts to develop their own combination of levels of change in different technologies and sectors of the economy to explore different energy and emissions scenarios out to 2050 [1], and (ii) to build in-house capacity to develop the tool. To achieve the objectives, the ECN developed the organogram, the procedure and processes for the implementation of the project under the guidance of the UK-DECC. We also made several fundamental changes to accommodate the actual situation in Nigeria. These include:

- Nigeria-specific data on scenario setting, technology specifications, and social and economic indicators are used based on extensive literature review and expert consultation
- Sectoral coverage is set to reflect Nigeria's priority sectors for energy demand and supply
- Four scenarios for 2050 reflecting future macro-economic and social indicators are set at the top level of the model structure which is link with relevant sectoral scenarios for the supply and demand sides
- For energy supply sectors, four levels of options are set to reflect the level of efforts ranging from no efforts (Level One) i.e., business as usual, medium (Level Two), high (Level Three) and extreme efforts (Level Four) representing the physical limits of energy resources or technical potential for the supply sectors
- Technology options are provided based on Nigeria's situation
- In the Nigeria Energy Calculator 2050, energy supply is set to match energy demand by adjusting the gap between the grid electricity supply and demand with the self-generation by small to large generators. Energy deficiency is automatically filled by self generation.
- In the current version, the levels of cost are not included.

We consulted hundreds of experts in the development of the model. This is to ensure that we use the best data, include the most accurate assumptions, and take into account the full range of opinions when we look into what is possible in the future. We also held one stakeholders meeting which allowed experts in the different sectors included in the model to discuss issues in detail. The tool was then launched in draft form with a call for evidence on 18thMarch 2015 during the National Energy Summit held between 17-18 March, 2015 in Abuja so that we could receive more feedback on a working prototype. On this page you can see information on our workshops. The organogram (Fig. 5) and other specific steps taken for the implementation of the project are presented below.

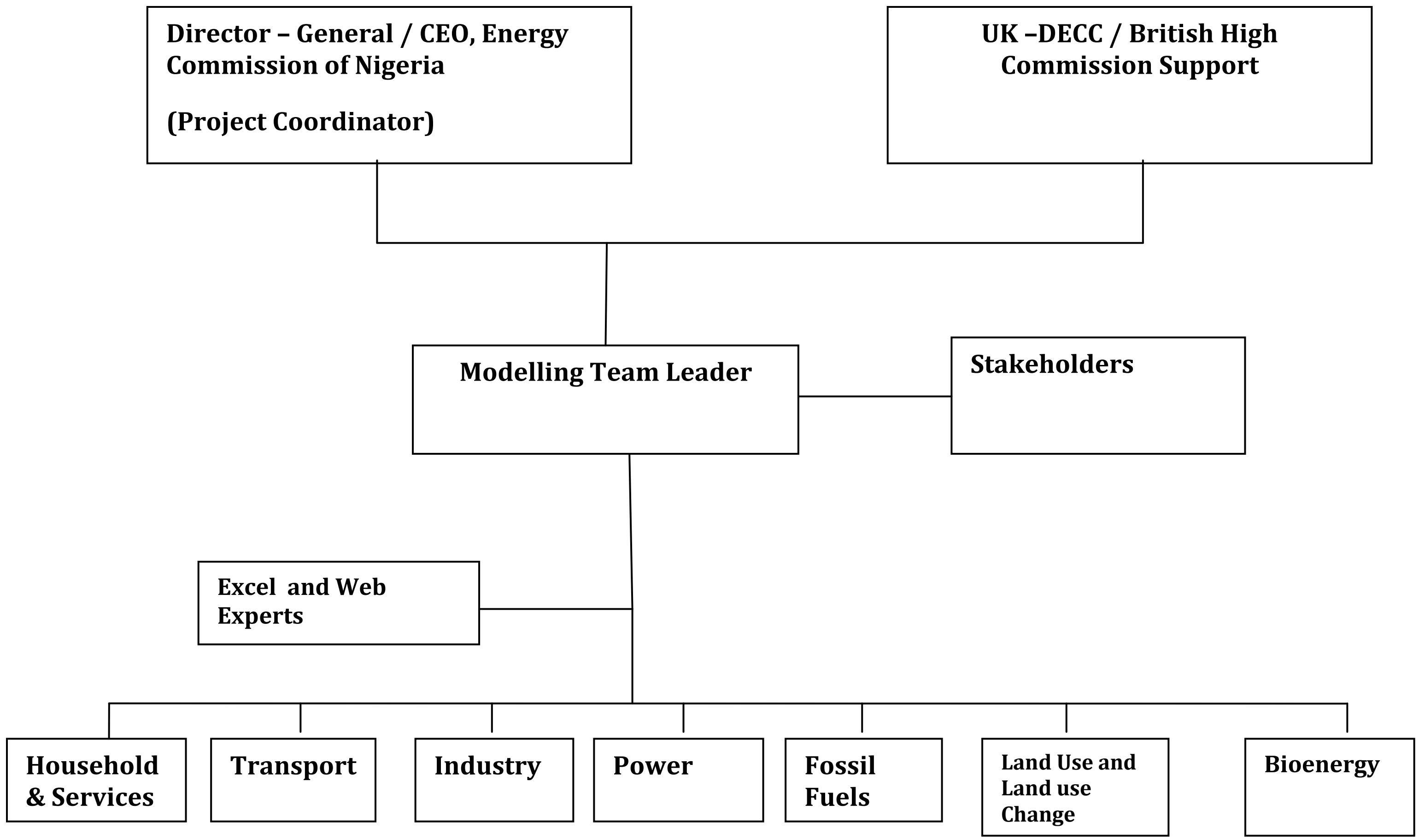


Figure 5: Structure for the Implementation of Nigeria Energy Calculator

The specific steps involved in the development of NECAL2050 are:

- Officials of UK-DECC introduced the Nigerian to the he calculator over a period of one week (18th – 22nd November, 2013);
- The UK-DECC, British High Commission in Nigeria and the Energy Commission of Nigeria signed Memorandum of Understanding on Friday 22nd November 2013;
- Thereafter, the Nigerian was set up and began developing the 1-pagers (scenarios);
- Sent drafts of 1-pagers to UK-DECC by email, which they reviewed and advised further;
- Regular meetings by telephone to discuss updates, challenges and way forward;
- One-day (21st August 2014) stakeholders workshop in Abuja to discuss 1-pagers and receive input from energy and environment experts stakeholders to improve scenarios;
- Nigerian Team visited UK-DECC over the period 15th – 27th September 2014 to get training on excel; version, improvements of the 1-pagers and structure of the energy system;
- Nigerian Team returned home to continue working on the excel version;
- Team and UK-DECC continued to exchange emails and have telephone meetings to discuss progress, challenges and way forward;
- UK-DECC officials visited Team in Abuja from 17th – 21st November, 2014 to help improve excel work;
- Finally we got the excel work completed and ready for connection to the website;
- Adapted UK 2050 Calculator for the Nigeria Energy Calculator (NECAL2050);
- Participation in the International Conference on 2050 Calculator held in Taipei, Taiwan from 10th to 12th February 2015;
- Launching of calculator.

CHAPTER THREE

STRUCTURE OF THE CALCULATOR

The subsectors under energy demand, energy supply and non-energy sectors are shown in Table 3.

Table 3: Sectoral Coverage

Energy Demand Sectors	Energy Supply Sectors	Non-energy sectors
Residential *Cocking, lighting and appliances* *Cooling*	**Bio-energy**	**Volume of waste & recycle**
Service *Cocking, lighting and appliances* *Cooling*	**Nuclear**	**Agriculture and land use**
Transport *Passenger Transport* *Freight Transport*	**Coal**	**Types of fuels for biomass**
Industry	**Gas**	
	Wind	
	Solar Photo Voltaic *Grid Connected* *Stand Alone*	
	Concentrated Solar Power	
	Hydroelectric Power *Large* *Small*	

Levels Setting under the Nigeria Energy Calculator 2050

For each sector, the Nigeria Energy Calculator sets out a range of four trajectories for types of changes that may occur. These trajectories are intended to reflect the whole range of potential future scenarios that might be seen in that particular sector. In the energy supply sectors these trajectories represent a potential roll-out of energy generation infrastructure. For the energy demand sectors, the trajectories represent the behavioral and technological changes. In general, these trajectories are described as “levels” as they indicate scale of change. However, for certain sectors such as transportation, the changes indicate choices rather than scales, and therefore are described as “trajectories” or “options”.

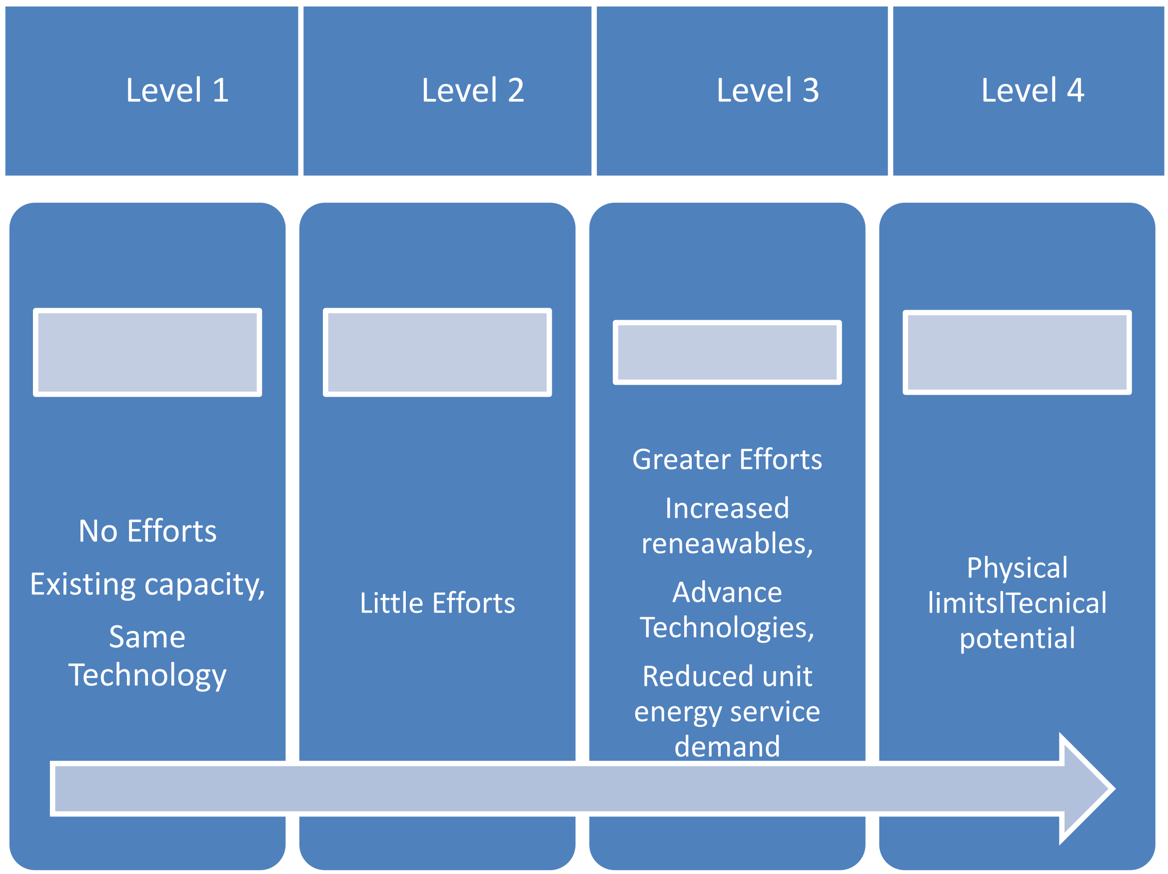


Figure 6: Levels /Trajectories Setting

The levels/trajectories have been set up on the basis of progressively higher efforts towards meeting energy demand and minimizing GHG emission. For example, Level 1 represents low effort and continuation of existing capacity, technology and no change in consumption behaviour. Whereas Level 4 represents greatest effort leading towards increased use of renewable energy, advanced technology, reduction of energy service demand and physical limits or technical potential of energy supply from that particular energy source.

Global Assumptions

Macro-economic framework

The level of GDP growth is a fixed at an average of 7% per annum over the study period within the model. The assumption is based on the observation that the average GDP growth rate per annum between 2007 and 2011is 7.09% [4]. Moreover, in a study conducted earlier by the Energy Commission of Nigeria, a reference scenario of 7% GDP growth rate per annum was assumed over the period 2009 to 2030 [6]. Table 4 shows the GDP, GDP growth rates and GDP per capita used in the model. The implication is that in those sectors where the level of change is understood to be influenced by GDP, such as transport demand, the trajectories were developed to reflect that assumption. The model does not capture potential positive and negative feedback impacts on the economy from the levels of effort implied by the pathways.

Table 4: GDP, GDP growth rates and GDP per Capita

Year	GDP (Billion Naira)	GDP growth rate per annum (%)	GDP per capita (Naira)
2007			
2009	269.06	6.40	1,915.95
2010	286.28	6.34	1,975.34
2015	395.93	6.70	2,485.60
2020	551.42	6.85	3,010.90
2025	773.40	7.00	3,732.49
2030	1097.47	7.25	4,681.31
2035	1557.32	7.25	5,871.31
2040	2209.86	7.25	7,363.80
2045	3135.83	7.25	9,464.28
2050	4449.78	7.00	12,163.91

Source: Ref. 5

Population growth framework

Population is a major factor which determines energy demand in a country. Nigeria's population is projected to grow from 140431790 in 2006 to 403,893,047 in 2050.

Table 5: **GDP, GDP growth rates and GDP per Capita**

Year	Population	Persons / Household	Number of Households
2006	140,431,790	5.2	27,006,113
2007	144,926,639	5.2	27,870,508
2010	159,289,560	5.2	30,632,608
2015	183,141,384	5.6	32,703,819
2020	207,207,666	5.4	38,371,790
2025	234,436,455	5.2	45,083,934
2030	265,243,331	5.0	53,048,666
2035	300,098,483	5.0	60,019,697
2040	331,332,974	5.0	66,266,595
2045	365,818,376	5.0	73,163,675
2050	403,893,047	5.0	80,778,609

Source: Ref. 6

Calculation Procedure

The Nigeria Energy Calculator follows a six step calculation procedure. Using Excel Spreadsheet model as an example, the calculation procedures is explained as follows:

Step One

The users select their 2050 scenarios and sectoral trajectories for both supply and demand sectors as shown in Fig. 7 to form one pathway.

Trajectory selection

Supply			YOUR CHOICE	LIMIT	One page note
Nigeria Electricity Generation	I.a	Natural gas power stations	4	4	0.pdf
	I.b	Biomass power	4	4	1.pdf
	I.c	Coal power stations	4	4	2.pdf
	II.a	Nuclear power stations	4	4	3.pdf
	III.a.1	Wind	4	4	4.pdf
	III.b.1	Hydroelectric power stations	4	4	5.pdf
	III.b.2	Small Hydroelectric power stations	4	4	6.pdf
	III.f	Grid Connected Solar PV	4	4	7.pdf
	III.g	Concentrated Solar Power	4	4	8.pdf
	IV.a	Stand Alone Solar Photo Voltaic	4	4	9.pdf

Figure 7: Trajectory Selection

Step Two

Sectoral sheets then calculate the outputs based on user trajectory selections as shown in Fig. 8 below.

Lighting, Appliances & Cooking

Residential Lighting, Appliances, and Cooking

Trajectory choice

Component	Trajectory
(i) Demand	1
(ii) Technology pathway	1

Trajectory assumptions

Lighting and appliances, demand per household [1] TWh

Trajectory	Comment	Notes	2010	2015	2020	2025	2030	2035	2040	2045	2050
1	Lighting and appliances		7.19E-07	1.37E-06	2.59E-06	5.03E-06	7.03E-06	8.98E-06	1.08E-05	1.24E-05	1.39E-05
2	Lighting and appliances		7.19E-07	1.03E-06	1.94E-06	3.78E-06	5.27E-06	6.74E-06	8.11E-06	9.33E-06	1.04E-05
3	Lighting and appliances		7.19E-07	9.57E-07	1.81E-06	3.52E-06	4.92E-06	6.29E-06	7.57E-06	8.71E-06	9.72E-06
4	Lighting and appliances		7.19E-07	8.21E-07	1.55E-06	3.02E-06	4.22E-06	5.39E-06	6.49E-06	7.47E-06	8.33E-06

Cooking, demand per household TWh

Trajectory	Comment	Notes	2010	2015	2020	2025	2030	2035	2040	2045	2050
1	Cooking		7.6E-06	7.5E-06	7.5E-06	7.4E-06	7.3E-06	7.2E-06	7.1E-06	7.0E-06	7.0E-06
2	Cooking		7.6E-06	7.3E-06	7.0E-06	6.7E-06	6.4E-06	6.1E-06	5.8E-06	5.5E-06	5.2E-06
3	Cooking		7.6E-06	7.1E-06	6.6E-06	6.1E-06	5.6E-06	5.0E-06	4.5E-06	4.0E-06	3.5E-06
4	Cooking		7.6E-06	6.9E-06	6.2E-06	5.4E-06	4.7E-06	3.9E-06	3.2E-06	2.5E-06	1.7E-06

Figure 8: Typical Sectoral Sheet

Step Three

Energy balance sheets for each defined years (2010, 2015, 2020, 2025, 2030, 2035, 2040 and 2050) are generated based on sectoral outputs as shown in Fig. 9.

	2010										
	TWh	**Uses**									
	Sector	Cooling H.01	Lighting & appliances L.01	Cooking L.02	Industry I.01	Road transport T.01	Rail transport T.02	Domestic aviation T.03	Berge T.04	Pipeline T.07	**Total uses**
	Consumption										
IX.a	Residential Cooling	37.6	-	-	-	-	-	-	-	-	37.6
	Total Domestic	37.6	-	-	-	-	-	-	-	-	37.6
IX.c	Service Sector Cooling	7.6	-	-	-	-	-	-	-	-	7.6
	Total Commercial	7.6	-	-	-	-	-	-	-	-	7.6
IX	**Cooling**	45.2	-	-	-	-	-	-	-	-	45.2
											-
X.a	Residential Lighting, Appliances, and Cooking	-	20.6	218.8	-	-	-	-	-	-	239.5
X.b	Service Sector Lighting, Appliances, and Cooking	-	10.1	20.5	-	-	-	-	-	-	30.7
X	**Lighting, Appliances & Cooking**	-	30.8	239.4	-	-	-	-	-	-	270.1
											-

Figure 9: Typical Year sheet

Step Four

A summary sheet is compiled by compiling all yearly energy balance sheets as shown in Fig. 10 below.

Energy source /use Charts										
2050 Calculator calculations										
	TWh / year	2010	2015	2020	2025	2030	2035	2040	2045	2050
Use										
T.01	Road transport	160.8	205.1	246.4	285.6	321.5	384.0	445.1	513.3	587.3
T.02	Rail transport	50.9	62.6	74.6	87.8	102.0	117.2	130.1	142.9	155.4
T.03	Domestic aviation	43.9	54.0	64.6	76.5	89.8	104.6	118.3	133.1	149.1
T.04	Berge	-	-	-	-	-	-	-	-	-
T.07	Pipeline	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7	5.2
	Transport	256.7	323.3	387.7	452.4	516.3	609.5	697.6	794.0	897.0
I.01	Industry	419.3	409.3	421.5	457.1	514.0	611.4	768.7	1,014.8	1,392.5
H.01	Cooling	45.2	72.4	101.1	131.4	163.5	197.5	233.5	271.6	312.1
L.01	Lighting & appliances	30.8	61.5	114.7	217.2	315.7	421.9	516.9	611.5	712.6
L.02	Cooking	239.4	251.1	263.2	275.6	288.4	301.5	315.0	328.8	343.0
	Total	**991.4**	**1,117.8**	**1,288.2**	**1,533.8**	**1,798.0**	**2,141.8**	**2,531.7**	**3,020.7**	**3,657.1**

Figure 10: **Intermediate Output sheet**

Step Five

Results are presented in charts based on the summary sheet for energy for primary energy supply, total final energy consumption, energy mix for electricity generation, emissions and total additional costs as shown in Figures 11 and 12.

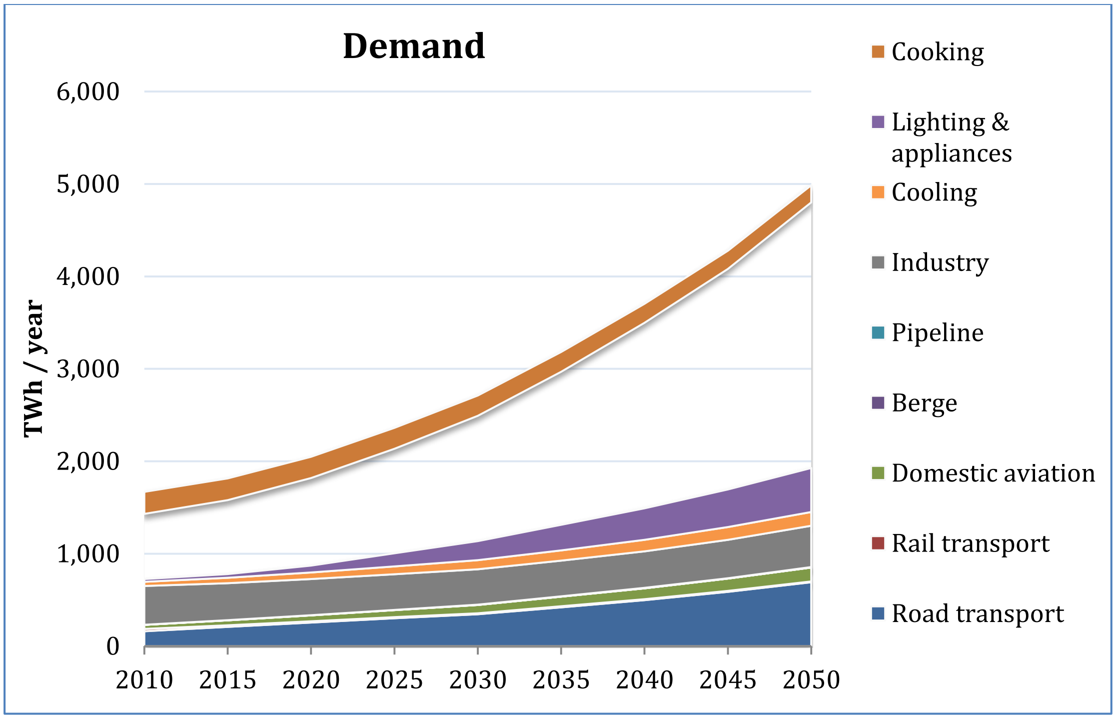


Figure 11: Energy Demand output

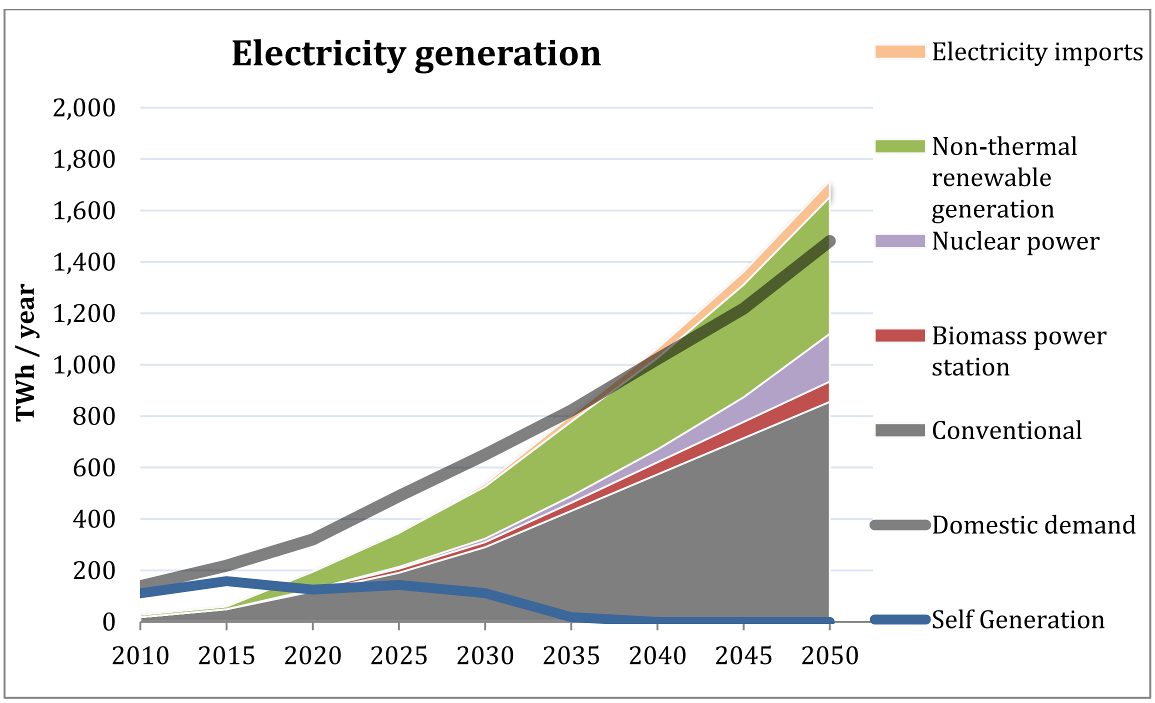


Figure 12: Electricity Generation

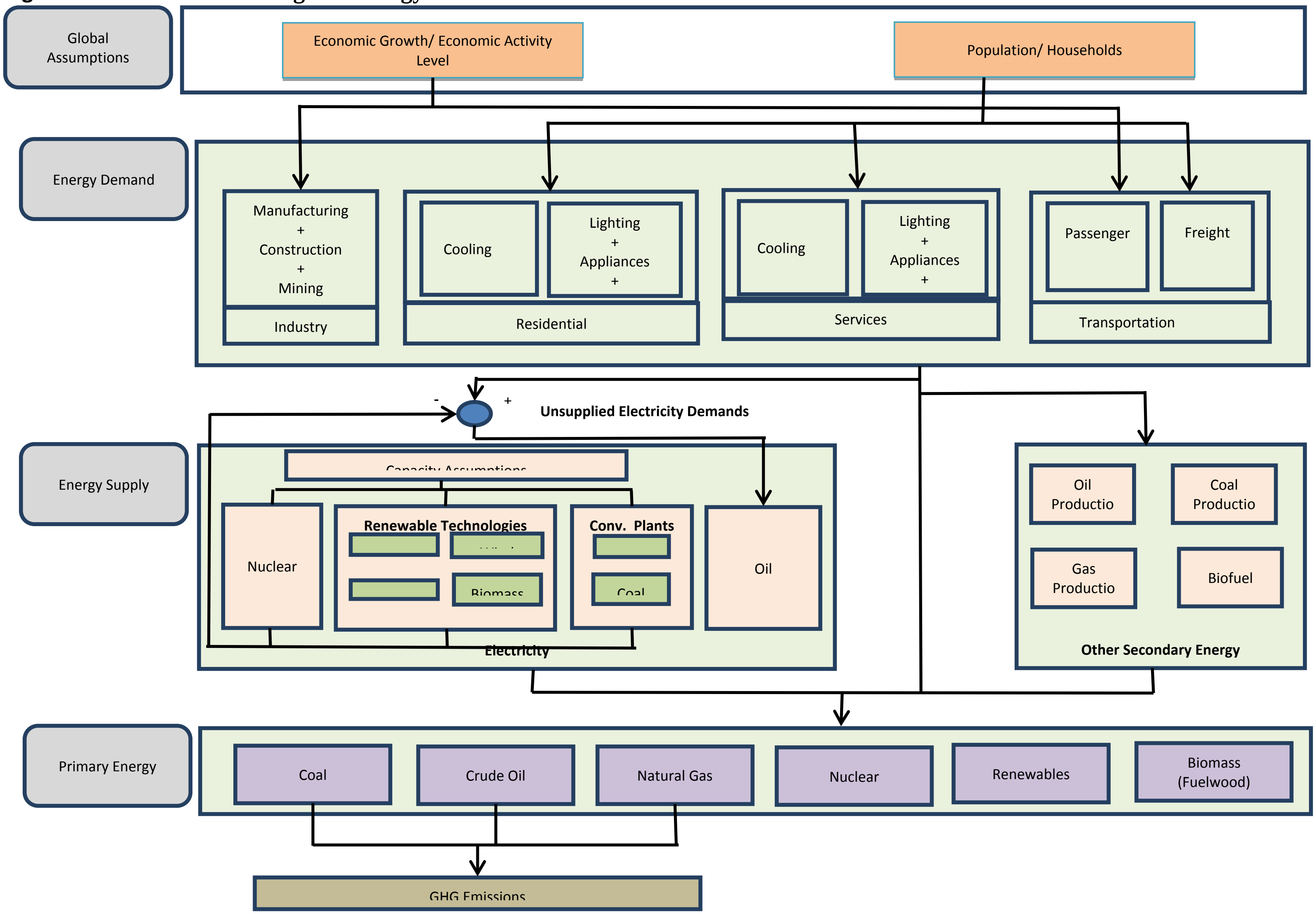
Step Six

The users modify their trajectory selections to simulate choosing pathway

Structure of the Nigeria Energy Calculator2050

The structure of the model is shown in Figure 13 which is adapted from [7].

Figure 13: Structure of the Nigeria Energy Calculator 2050



Scenario

All the top sectoral trajectory setting are the four scenarios based on which economic indicators in terms of GDP growth and sectoral output levels and social indicators in terms of population size and number of households, etc., are determined. The scenarios setting have impact on energy demand sectors. In particular, the GDP growth and sectoral output levels are linked with industrial sectors, freight transport sector and service sectors, while the population size and number of households are linked with residential sectors and passenger transport sector.

Energy Demand

Four categories of energy end users are considered, industry, residential, service and transport sectors. The activity levels of each sector are consumption; behaviours, technology penetration (technology options) and energy efficiency advancement will influence the sectoral outputs in terms of energy demand, GHG emission levels and corresponding additional costs per person.

Energy Supply

Secondary energy supply include electricity generation other secondary energies are included in the model. Electricity is generated from conventional power plants using fossil fuels, biomass, nuclear power plant and renewable energy. Other secondary energies include biofuels and refinery products

Primary Energy

Primary energy resources include hydrocarbon energy carriers (coal, crude oil and natural gas) nuclear energy, renewable energy and biomass. Both primary and secondary energies transformed will be provided to satisfy energy demand. Emissions are generated from fossil fuel combustion influenced by way energy supply and demand levels.

HOW TO INSTALL AND START UP THE EXCEL SPREADSHEET MODEL

i. If installing from the internet (available at www.nigeria-energy-calculator.org) find "Excel Spreadsheet version" click the icon of the Excel Spreadsheet model, download the excel file and save on your PC
ii. Open the Excel file
iii. Find the "control" sheet, click and open

iv. On the "control" sheet you can select your choices for the trajectory setting of the scenarios and for each sector of the demand side and supply side:
   a. Columns A-D: Given definition of technology, energy efficiency and beahavioural drivers influencing sectoral trajectory setting;
   b. Column E: Levels of efforts which require the users to input;
   c. Column F: The upper limits (most are 4) set for corresponding selection in Column E;
   d. Column H-L: Explanations on the level setting for Column E;
   e. Column N-U: Example Pathways;
   f. Column X-AH: Calculation results of energy supply and demand including three figures;
   g. Column AJ-AT: Calculation results of electricity supply to end-user
   h. Column AV-BF: Calculation results of emissions

v. You can select one among several options provided in Columns H-L and then input the value of selection (e.g. 2) into the corresponding cell in Column E.

vi. Upon completion of all selections required for Column E, press F9 on the keyboard or calculate from the excel spreadsheet. The Nigeria Energy Calculator 2050will calculate based on your selection.

HOW TO ACCESS AND USE THE WEB TOOL

i. Connect to internet

ii. Type in the website address: www.nigeria-energy-calculator.org

iii. Select between 1-4 for the scenario setting on the top

iv. Switch to different pages on Energy, Electricity, Security and Flows by share clicking on the bar under scenario selection

v. On the lower part of each page, you can select your own sectoral choices from Level One to Level Four. On the left side are energy demand-related levers and on the right side are energy-supply related levers. Upon the completion of selection, the results calculated based on your unique sectoral selections will be presented immediately on the upper part of the webpage.

CAVEATS FOR USING THE NIGERIA ENERGY CALCULATOR2050

The Nigeria Energy Calculator 2050 demonstrates the scales that are likely to be required for Nigeria to make transition to a low carbon economy, as well as the choices available for clean modern energy access for all. The Calculator is helpful in exploring a range of available pathways; none of these generated pathways should be prejudged as optimal.

The Calculator does not adopt a cost-optimization approach. Instead it focuses on identifying the least-cost pathway to meet Nigeria's energy demand in a reduced emission manner up to year 2050. It looks at what might be achieved in each of the covered sectors under different assumptions. The model has been developed by focusing exclusively on Nigeria and its options for GHG emissions reduction and energy security.

The underlying data for the Nigeria Energy Calculator 2050 comes from various sources including government documents and scientific literature. The model describes how the trajectories might look like under various assumptions. Relevant developments, such as the effort for more electricity capacity generation, renewed focus on alternative and renewable energy sources have been taken into consideration. Thus the analysis under the model looks at what might be possible to deliver in the coming years up to 2050, but does not propose or identify the required policy decisions to ensure this future. In other words, the Nigeria Energy 2050 Calculator does not provide a detailed policy framework and the trajectories should not be considered as projections based on policy decisions.

CHAPTER FOUR

SCENARIOS DESCRIPTION

The scenarios applied in this study are presented in this chapter. The energy supply trajectories /scenarios examine different energy generation sectors. These trajectories are presented as four levels of potential roll –out of energy supply infrastructure, representing increasing levels of effort to achieve [1]. The four levels are as follows:

Level 1-the 'Least Effort' scenario: This assumes that little or no effort is being made in terms of interventions on the demand and the supply side.

Level 2- the 'Determined Effort' scenario: This describes the level of effort which is deemed most achievable by the implementation of current policies and programmes of the government.

Level 3- the 'Aggressive Effort' scenario: This describes the level of effort needing significant change which is hard but deliverable.

Level 4- the 'Heroic Effort' scenario: This considers extremely aggressive and ambitious changes that push towards the physical and technical limits of what can be achieved.

The energy demand sectors explore different drivers of change which include levels of behavioural and lifestyle change, levels of technological improvement and change, different technological and fuel choices and structural change. Impact of a particular driver on energy demand is highest at Level 1 and least at Level 4.

Both the supply and demand scenarios are presented below.

Service Sector Cooking

Cooking and other commercial heating activities are the major energy consumers of the service sectors. They account for about 54% of the energy supplied to the sectors. Cooking in this sector is about 80% fuelled by traditional biomass (ECN, 2010). The use of liquefied petroleum gas (LPG), is quite marginal and making the percentage use of unclean energy system on a very high side. For efficient consumption of energy and safer environment, a gradual shift from traditional to modern clean energy source will help bring down demand and pollution rate.

Level 1

Level 1 assumes inefficient practices will continue. Traditional fuels will continue to dominate the supply of energy in service sectors for cooking and heating services. The energy demand will grow with increase economic activities, the energy demand will be 45.2TWh by 2050.

Level 2

Level 2 assumes uptake of LPG for cooking and improve efficiency in cooking stoves and water heating, will reduce the percentage usage of traditional biomass for cooking and heating purposes in the service sector. In this level, the energy demand will reduce to 40.7TWh which is about 30% reduction in fuelwood.

Level 3

Level 3 assumes high use of LPG in the service sectors for cooking and water heating, thereby reducing the use of traditional biomass. The use of electricity for cooking will be significant. There will be a further reduction in energy demand to 36.1TWh. LPG will contribute 25% of the total energy demand, thereby reducing the share of fuelwood by 50%.

Level 4

Level 4, assumes full dependence of the use of electricity and LPG in service sectors. Traditional biomass will have minimal contribution of about 16% and the use of more efficient cooking stoves will further reduce the energy demand for cooking and hot water heating. The energy demand will be 31.6TWh. With both Electricity and LPG contributing 20% and 40% share respectively. Kerosene will substitute fuelwood as source of fuel in the sector, contributing about 24%.

Commercial Cooking

Service Sector Cooling: Air Conditioning

Energy consumption for air-conditioning would increase due to improvements in the nation's economy (GDP 7.0%), urbanization and lifestyle. The use of air conditioners for space cooling is fuelled 100% by electricity and is more used within the urban settlement in Nigeria for commercial service buildings. It is estimated that electricity demand for space cooling will increased significantly by 2050. Total electricity consumed for service sector cooling is 7.64TWh in 2010.

Level 1

Level 1 assumes an increase in energy demand for service sector cooling in line with current trend i.e. an increase in economic activities and a high percentage contribution of service sector to the economy by 2050. The cooling energy demand for service sector is estimated to be 98.33TWh considering less energy efficiency by 2050.

Level 2

Level 2 assumes a decrease in cooling energy demand for service sector due to improved efficiency by about 10%. The cooling energy demand for service sector is estimated to be 78.67TWh by 2050.

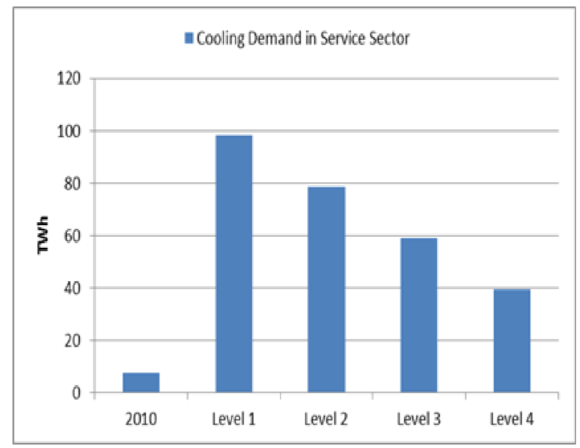
Level 3

Level 3 assumes a 20% improvement in energy efficiency and decrease in contribution of the service sector to the economy. The cooling energy demand for service sector is expected to reduce to about 59TWh.

Level 4

Level 4 assumes a decrease in cooling energy demand for service sector to about 40TWh. The decrease will be due to high improvement in energy efficiency, energy building code and low contribution of the service sector to the economy.

Service Sector Cooling



Service Sector Lighting & Appliances

The service sector electricity consumption in Nigeria is estimated to be about 25% of the final electricity demand as at 2010. Lighting and major appliances like ceiling fans, televisions, refrigerators, computers and others account for about 30% of electricity consumption in the service sector. The technologies employed are mostly less efficient types. With the rising contribution of service sector to the economy, the energy demand in this sector will increase. The electricity demand for service sector lighting and appliances is 10.13TWh.

Level 1

Level 1 assumes an increase in lighting and appliances, the demand for energy in the service sector will increase significantly with increase in economic activities. The efficiencies of the lighting and appliances remain the same as today. The electricity demand for the service sector is estimated to be 118.78TWh.

Level 2

Level 2 assume that more efficient appliances are replaced. Appliances like TVs, Computers, CFLs & LED lights and energy building codes is maintained. Also, the behaviour towards application of lighting and appliances has improved. The energy demand for lighting and appliances is estimated to reduce by 20%, the demand for electricity in the sector will be about 90TWh.

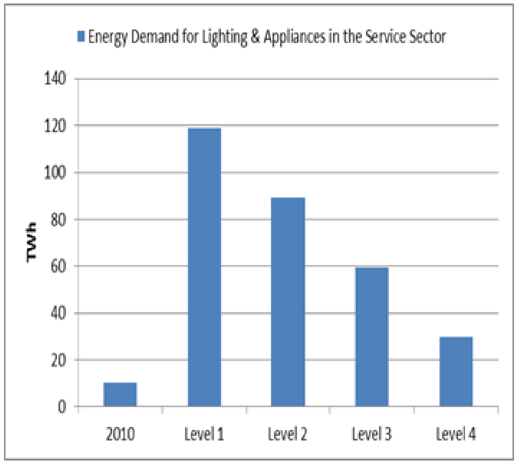
Level 3

Level 3 assumes that the use of inefficient appliances decreases by about 50% with efficient technologies by 2050. The electricity demand in the service sector for lighting and appliances will be about 60TWh.

Level 4

Level 4 assumes 100% total penetration of highly efficiency technologies and low contribution of the sector to the economy. The lighting and appliances demand will be about 30TWh. This will be about thrice the value of 2010.

Retail **Lighting** Office Relamping Leeds MPS Electrical Ltd



Residential Cooking

Cooking and other domestic heating activities are the major energy consumers of the household sectors. They account for about 85% of the energy supplied to the sectors. Cooking in the urban household is about 50% fuelled by traditional biomass, while in the rural household, 99.8% of cooking and other heating are fuelled by traditional and 0.2% by fossils (ECN, 2010). At current situation, the technologies employed are mostly traditional three-stone system and kerosene stove with efficiency of 10% and 30% respectively. The use of liquefied petroleum gas (LPG), is quite marginal and localized within the urban areas, making the percentage use of unclean energy system on a very high side. For efficient consumption of energy and safer environment, a gradual shift from traditional to modern clean energy source will help bring down demand and pollution rate.

Level 1

Level 1 assumes inefficient practices will continue due to poor economic situation. Traditional fuels will continue to dominate the supply of energy in household sectors for cooking and heating services. The energy demand will grow due to growth in population; the energy demand per household will be 6966kWh by 2050 with about 43million household.

Level 2

Level 2 assumes uptake of LPG for cooking and improve efficiency in cooking stoves and water heating, will reduce the percentage usage of traditional biomass for cooking and heating purposes in the household. In this level, the energy demand per household will reduce to 5225kWh which is about 30% reduction in fuelwood.

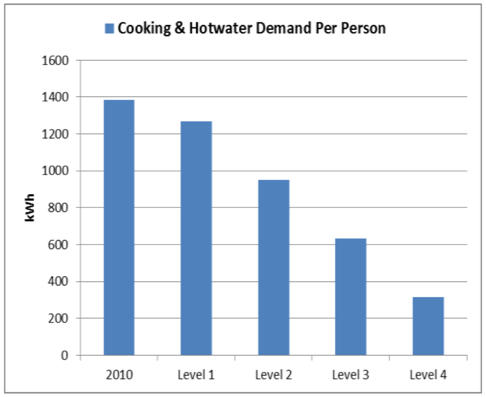
Level 3

Level 3 assumes high use of LPG in the household sectors for cooking and water heating, thereby reducing the use of traditional biomass. The use of electricity for cooking will be significant. There will be a further reduction in energy demand per household to 3,483kWh. LPG will contribute 25% of the total energy demand, thereby reducing the share of fuelwood by 50%.

Level 4

Level 4, assumes full dependence of the use of electricity and LPG in both rural urban households sectors. Traditional biomass will have minimal contribution of about 20% and the use of more efficient cooking stoves will further reduce the energy demand for cooking and hot water heating. The energy demand per household will be 1,741kWh. With both Electricity and LPG contributing 20% and 40% share respectively. Kerosene will substitute fuelwood as source of fuel for both rural and urban households.

LSJ Nigeria Awka outdoor cooking



Residential Cooling: Air Conditioning

Energy consumption for air-conditioning would increase due to improvements in the nation's economy (GDP 7.0%), population growth (3.2%), urbanization and lifestyle. The use of air conditioners for space cooling is fuelled 100% by electricity and is more used within the urban settlement in Nigeria for residential buildings. It is estimated that electricity consumption for space cooling will increased significantly by 2050. Total electricity consumed for residential cooling is 37.59TWh in 2010.

Level 1

Level 1 assumes an increase in energy consumption for residential cooling in line with current trend i.e. an increase in energy demand per household and 100% ownership of air-conditioner in the urban settlement and 20% in the rural settlement. The cooling energy demand per household is estimated to be 5,000kWh by 2050.

Level 2

Level 2 assumes a decrease in cooling energy demand per household of 4,000kWh with 75% ownership of air conditioners in the urban settlement and 15% rural settlement.

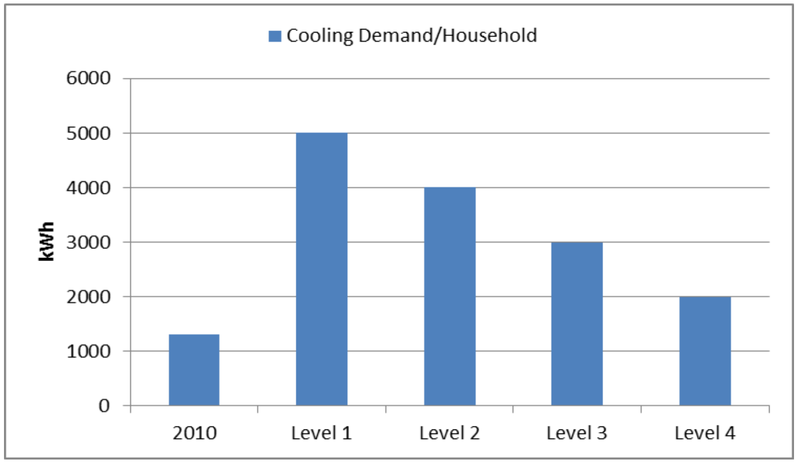
Level 3

Level 3 assumes a decrease in cooling energy demand per household of 3,000kWh with 50% ownership of air conditioners in the urban settlement and 10% rural settlement.

Level 4

Level 4 assumes a decrease in cooling energy demand per household of 2,000kWh with 25% ownership of air conditioners in the urban settlement and 5% rural settlement.

Residential Cooling Systems



Residential Lighting & Appliances

The residential electricity consumption in Nigeria is estimated to be about 58% of the final electricity demand as at 2010. Lighting and major appliances like ceiling fans, televisions, refrigerators and others account for about 60% of electricity consumption in the residential sectors. The technologies employed are mostly less efficient types. With the rising population and more access to electricity the demand for energy in the residential sector will continue to rise. The electricity demand per person for lighting and appliances is 131kWh.

Level 1

Level 1 assumes an increase in lighting and appliances and 100% access to electricity, the demand for energy in the residential sector will increase significantly with increase in population, change in life style due to increase in income and economic activities. The electricity demand per person for lighting and appliances will be 2,525kWh.

Level 2

Level 2 assume that 20% of inefficient appliances will be replaced by efficient types. i.e. LED TVs, refrigerators. Government, through its policies will encourage efficient use of energy for lighting/other appliances, building designs and orientation. The use of incandescent bulbs is reduced while that of CFL is increased along with a small share of LED lights, as well as the use of natural lighting and motion sensors facilities for lighting will further decrease electricity consumption. The electricity demand per person for lighting and appliances will be 1,894kWh.

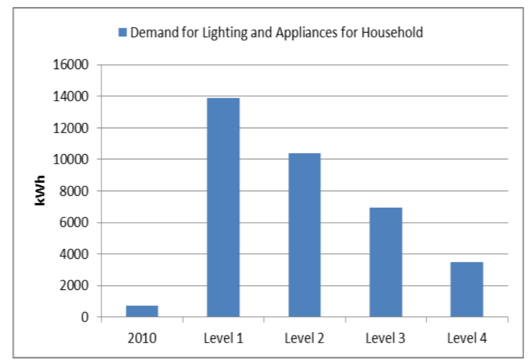
Level 3

Level 3 assumes that the use of inefficient appliances decreases by about 50% with efficient technologies by 2050. The electricity demand per person for lighting and appliances will be 1,263kWh.

Level 4

Level 4 assumes 100% total penetration of highly efficiency technologies in the lighting and other appliances use for residential sector. The electricity demand per person for lighting and appliances will be 631kWh.

Lighting and appliances



Domestic Passenger Travels

In 2010, 6,000km/year with 90% of passenger movements were by road with car taking the dominant position. Fossil fuel still dominated as the only source of fuelling. The future of domestic travel will still largely be due to economic activities and increase in population with more people travelling further than today.

Level 1

In 2050, the energy demand will increase significantly with passenger travel double (12,000km) compared to the base year 2010. The mode of transportation is 50% by Cars, 20% by Buses, 1% by Trains, 20% by Motorcycles/Tricycles, 3.5% by Bike/Walking, 0.5% Ferry and 5% Aeroplane of the modal share.

Level 2

The energy demand decrease by 10% compared to Level 1. The mode of transportation will decrease for Cars and Motorcycles/Tricycles, and increases for Buses, Trains, Bike/Walking, Ferry and Aeroplane. The share of Train increases from 1% in level 1 to 8.1% in level 2.

Level 3

In 2050, there is continuous decline in energy demand due to a shift to more energy efficient vehicles and decline in the use of cars and motorcycles/tricycles. The proportional share of cars and motorcycles/tricycles will reduce to 40% and 10% respectively, while the share of buses and train increase to 23% and 13% respectively.

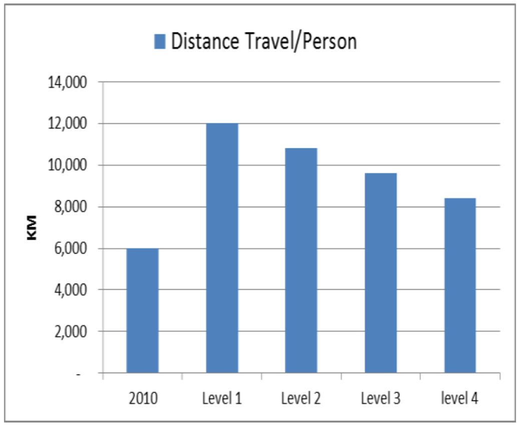
Level 4

This level assumes a significant increase in the use of aeroplane for passenger travel compared to level 1, the share of aeroplane will be 10% compared to 5% as of today. Share of cars will reduce to 35% and motorcycles/tricycles will reduce to 5%. Buses and train will contribute a about half of the total travels.

Interaction

The emission reduction in the sub-sector will be made possible if the fuelling is taking from low carbon options.

Domestic train transport in Nigeria



Freight transport

In 2010, total amount of goods moved was 70.89 billion tons-kilometers (4.7 billion vehicle-km) with 95% of them by road, less than 1% by train and remaining portion through pipelines. The conventional fossil fuel technology dominates the fuel supply. Domestic freight was principally 60% by train in the pre 1960s but declined after 1960s with road sector progressively leading with higher share. The train sub-sector had the highest last in 1980 with a capacity of about 1400 million ton-km then it declined to at 77 million ton-km. In the future, the freight levels will depend on balance between heavy good vehicles on the road and the rail network. With inland waterways linked to about 20 states in the Federation, water transport will be competing for its own share.

Level 1

This level assumes growth of production of goods and services and transportation. The freight activities are expected to grow 9 folds and modal share between road, rail and pipeline assume to remain the same as of 2010.

Level 2

Level 2 assumes that by 2050, a reduction in freight movement by road to 75% while the rail system is picking up taking 10% of the share. The waterways in Nigeria is also assumes to be dredged from the South to the North opening up for freight movement and should have a share of 2%, while pipeline increases to 13%. This level assumes a 20% increase in efficiency of freight activities over level 1.

Level 3

Level 3 assumes that by 2050, the freight shift from road to rail, water and pipeline continues to grow. The modal shift is motivated by the need to reduce traffic volume on the road. The gas pipeline network expansion programme continues to grow reducing the need for trucks for petrol and gas distribution. The level assumes 40% decrease in freight below the level 1, with increase in shares of rail, pipeline and Berge, 17%, 15% and 3% respectively, thereby reducing the share of road to 65%

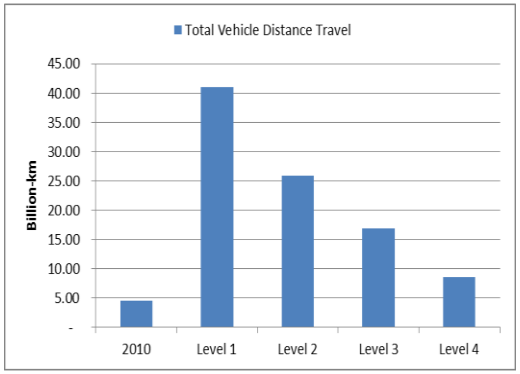
Level 4

Level 4 assumes that by 2050, the share of road will reduce to 50% with heavy goods vehicle (HGV) using natural gas contributing about 15%, electric trucks 1% and diesel trucks 84%. The rail, berge and the pipeline shares will increase significant by 25%, 5% and 20% respectively. Split in rail will be 40% diesel and 60% electric trains. This level assumes a further reduction of 60% freight movement compared to level 1.

Interaction

A shift to low carbon technology will be needed to reduce the effect of the growth on the environment. Rail is twelve times more efficient than trucks and almost twice as efficient as ships. Therefore, modal shifts and alternative fuels will be useful for low carbon development

Goods transported from port to warehouse in Lagos.



Low Carbon Option Travels

In 2010, all energies are from fossil fuels. The transport energy growth as a result of social-economic and population changes in by 2050 will throw up impacts on the sustainable future of the world. Therefore, a low/zero technologies and fuels are necessities in Nigeria. Alternative technologies such as bioenergy, Liquefied Petroleum Gas/ Compressed Natural gas (LPG/CNG), hybrid and electric vehicles in the road transport and the rail sector should be gradually adopted to ensure sustainable development.

Level 1

Level assumes growth happened by 2050 resulting in continuous dominance of internal combustion engines (ICE) at 100%

Level 2

It assumes by 2050, a reduction of ICE engines by 30% and introduction of hybrid electric vehicles (HEV) and electric vehicles (EV) at 7% and 3% respectively. Introduction of ICE engines using Gaseous hydrocarbon (LPG/CNG) contributing 18%.

Level 3

In 2050, low carbon technologies and fuels development continue to grow as a result of use of modern technologies. The share of low carbon technologies for cars, buses and trains are 25%, 25% and 65% respectively. The modal split for ICE engine between liquid hydrocarbon and gaseous hydrocarbon are 75% and 25% respectively.

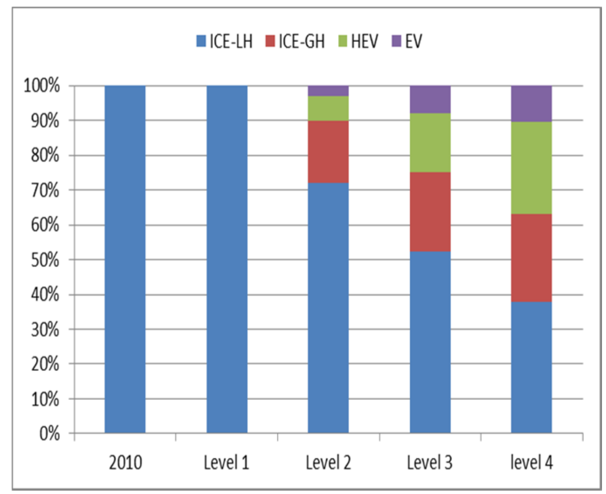
Level 4

Level 4 assumes that by 2050, the climate change has become a concerned in the emerging economies like Nigeria so there is greater drive towards making vehicles more 'greener'. The low carbon emission cars and buses and the use of electric trains have a share of 40% for cars and buses and 70% for electric train. The modal split for ICE engine between liquid hydrocarbon and gaseous hydrocarbon will be 60% and 40% respectively.

Interaction

The assumptions will heavily depend on radical change in the electricity production in other to power the low carbon industries and to charge electric cars. It is also important that the electricity is mainly from gas-powered stations and other renewables.

Shift to low carbon technologies



Growth in Industry

The Nigerian industrial sector includes basically Manufacturing, Construction and Mining. The industrial sector was responsible for about 20% of total Nigerian Energy Demand. In addition to emissions from the energy used, the sector also emitted some quantity of CO2 directly from its processes. 10% of the total energy demand was supplied by traditional fuel, 42% by Electricity, 4% by liquid fuels, 33% by gaseous fuel and the rest by feedstock and coke with steel coal. The changes in the industrial sector are based on the yearly percentage contribution of manufacturing, construction and mining. The yearly percentage contributions are based on a 7% GDP growth.

Trajectory A

In Trajectory A, it is assumed that the Nigerian industry will expand, because of the need for more Manufacturing, more Construction and higher Mining activities. Assuming a growth rate of 7% (similar to the Nigeria's GDP growth rate), industrial growth output will be 20% per annum. The Industrial sector will contribute 25.3% of the total GDP.

Trajectory B

Trajectory B assumes that the growth trend of 2010 will continue but more emphasis on growth rate of manufacturing, construction, mining and others to be 15%, 11.3%, 7.5% and 4.5% respectively. This will lead to a decrease in total energy demand by 25% compared to trajectory A.

Trajectory C

Trajectory C assumes that the industrial output will decrease by 50% which will lead to annual growth rate of the manufacturing, construction, mining and others to be 10%, 7.5%, 5% and 3% respectively.

Trajectory D

Trajectory D assumes a low industrial growth with average growth rate of the manufacturing, construction, mining and others to be 6%, 4.5%, 3.0% and 1.8% respectively. This shows a 70% decrease in industrial output compared to Trajectory A.

Energy Intensity of Industry

As in the case with Growth in the Energy Industry, the future of Industrial Sector's energy Intensity will change with time. The changes in energy intensities in the industrial sector are based on the use of efficient technologies, use of modern fuel and contribution of the sub-sectors: manufacturing, construction, mining and others.

Level 1

Level 1 assumes that no change in energy intensity for the Industrial sub-sectors by 2050. The energy intensities remain the same as of 2010.

Level 2

Level 2 assumes a 20% improvement in energy intensity by 2050; this will relate to -0.5% annual growth rate over the period. This will have relative reduction in energy demand compared to level 1.

Level 3

Level 3 assumes there will be 40% improvement in energy intensity and at least a 30% average reduction in process emission. Industry will have 35% of the overall energy demand reduction compared to level 1.

Level 4

Level 4 assumes a 50% improvement in energy intensity and an annual growth rate of -1.25%. This will reduce emission by about 40% compared to level 1 value. Energy demand will also reduce significantly.

Land Dedicated to Bio-energy

Attention is now being focused globally on renewable energy as alternative to depleting fossil fuel and its effects on the environment. Nigeria is not an exception in this process. About 50% of Nigeria renewable energy potential is from agricultural residue and forestry residue of approximately 152 and 43.4 million tonnes (dry). The Nigeria land mass is 923,768 km2.

Trajectory I

This trajectory assumes land dedicated to Arable and Grass land remain the same as at
2010. 5% of the total land mass will be dedicated to arable land used for food crops, first and second generation's energy crops. While 20% of the total land mass is dedicated as grass land used for second generation energy crops and livestock.

Trajectory 2

This trajectory assumes an increase in the arable land to 11%, with food crop having 7%, first and second generation's energy crops having 2% each. Percentage of land dedicated to grass land remains the same. Afforestation has reduced the desert land area from 35% in the base year (2010) to 25% of the total mass land area by 2050.

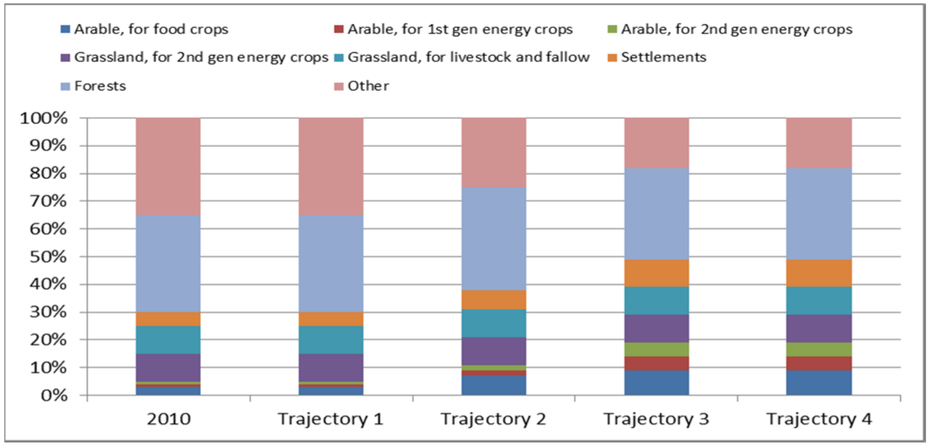
Trajectory 3

This trajectory assumes a further increase in arable land to 19% with food crops, first and second generation's energy crops contributing 9%, 5% and 5% respectively. More aggressive afforestation exercise has further reduced the desert land area to 18%.

Trajectory 4

This is same as trajectory 3 above.

Crop residues (Rice husks)



Energy Crop (Bio-diesel)

The potential of future energy generation lies in the use of liquid bio-fuels for vehicle and cottage industries. Presently the fuel used for vehicles and to produce motive-energy (energy to power vehicles) is gasoline, diesel or kerosene from the fossil. The introduction of bio-diesel to such applications will increase the self-sufficiency of communities in their energy supply. In addition, bio-fuels are a clean source of energy with a high potential to generate employment for those in remote areas. While the policy for the promotion of bio- energy exists, implementation is slow. A community based energy plantation of non- edible liquid bio-fuel crops like Jatropha and castor plant is to be established for the production of biodiesel. The oil content of the seeds varies from 30 to 60% depending on the variety, place and the method of oil extraction. About 3 - 4 kg of Jatropha seeds are needed to produce one litre of Jatropha oil. One hectare of Jatropha farm can yield ten tones of Jatropha seeds (i.e.10 tones/hectare). This can further calculated to mean that approximately 3,000litres of oil can be obtained per hectare of land.

Level 1

Jatropha plant, cultivation on wasteland is projected to be at 0.4 million hectares by 2050; oil yield to 0.24 million tonnes and biodiesel production is 0.12 million toe by 2020.

Level 2

Jatropha, cultivation on wasteland is projected to increase to 0.8 million hectares by 2050; oil yield to 1.02 million tonnes and biodiesel production to 0.51 million toe by 2050.

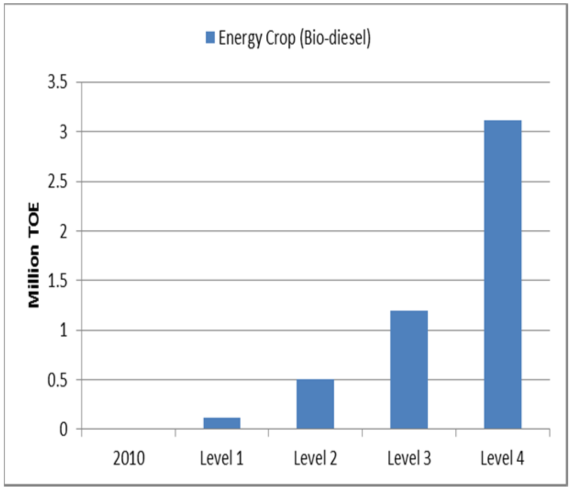
Level 3

Jatropha, cultivation on wasteland is projected to increase to 1.4 million hectares by 2050; oil yield to 2.4 million tonnes and biodiesel production to 1.20 million toe by 2050. At this level other oil seed crops like castor, neem and shear butter are been cultivated to meet oil need for biodiesel production.

Level 4

Jatropha, castor, neem, and shear butter, cultivation is projected to reach 3.9 million hectares by 2050; oil yield to 6.23 million tonnes and biodiesel production to 3.12 million toe by 2050.

Jatropha farm (Source:Field work)



Energy Crop (Bio-ethanol)

Nigerian Government initiates a mandated biofuel blending programs in 2005 under the National Biofuels Policy. These programs specify blending of bio-ethanol (E10) with gasoline. The National Policy on Biofuels was released in 2007. The feedstocks identified for bio-ethanol productions are; cassava, sugarcane and sweet sorghum. However, for now cassava is the main feedstock cultivated for bio-ethanol production in Nigeria while sugarcane and sweet sorghum government have set up a committee for feasibility studies on their production. Nigeria produces more than 41 million tonnes of cassava yearly with the average yield of 15 tonnes/hectare of tubers and ethanol production of 100litres per tonne of cassava (i.e. 4.1bilion litres/year). The plan to blend ethanol with petroleum for domestic use is driven by the need to reduce the cost of fuel importation, since Nigeria's refineries are not working at optimum capacity and to respond to climate change.

Level 1

Cassava cultivation area is 2.8 Mha. Sugarcane and sweet sorghum cultivation areas are at 0.1Mha (by 2050). Bio-ethanol production from cassava crops reaches 0.50Mtoe by 2020 and zero from Sugarcane and sweet sorghum.

Level 2

Cassava cultivation area is at 3.0 Mha. Sugarcane and sweet sorghum cultivation areas are projected to increase gradually to 0.8 Mha by 2025. Total bio-ethanol production from cassava crops reaches 1.50Mtoe by 2030. Bio-ethanol production from Sugarcane and sweet sorghum is 2.20 Mtoe. Total bio-ethanol production reaches 3.70Mtoe/year by 2050.

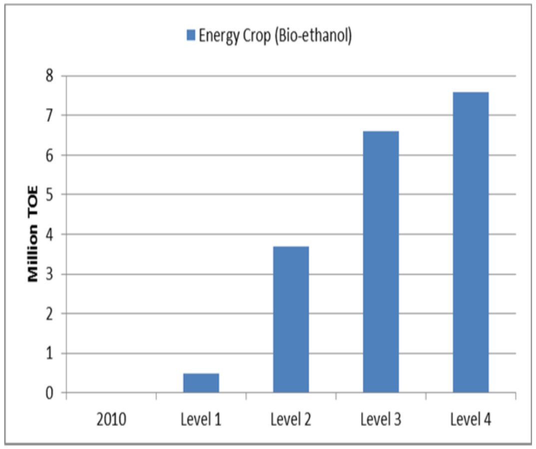
Level 3

Cassava cultivation area is increase to 3.8 Mha. Sugarcane and sweet sorghum cultivation areas are projected to increase gradually to 1.3Mha by 2030. Total bio-ethanol from cassava crops reaches 2.8 Mtoe by 2040. Bio-ethanol production from sugarcane and sweet sorghum is 3.8 Mtoe. Total bio-ethanol production reaches 6.6mtoe/year by 2050.

Level 4

Cassava cultivation area now reached 4.0 Mha. Sugarcane and sweet sorghum cultivation areas are projected to increase to 3.5Mha by 2050. Total bio-ethanol production from cassava crops reaches 4.6 Mtoe by 2050. Bio-ethanol production from sugarcane and sweet sorghum is 7.6Mtoe/year. Total bio-ethanol production reaches 12.20 Mtoe/year by 2050.

Cassava tubers (www.cropsforbiofuel.blogspot.com)



Gaseous Waste (Biogas)

Biogas is similar to natural gas. Is the gaseous emission from anaerobic degradation of organic matter (from plants or animals) by a consortium of bacteria. Biogas is principally a mixture of methane (CH_4) and carbon dioxide (CO_2) along with other trace gases. Biogas is produced in all natural environments that have low levels of oxygen (O_2) and have degradable organic matter present. These natural sources of biogas include: aquatic sediments, wet soils, buried organic matter. Man's activities create additional sources including landfills, waste lagoons, and waste storage structures. Biogas technology permits the recovery of biogas from anaerobic digestion of organic matter using sealed vessels, and makes the biogas available for use as fuel for direct heating, electrical generation or mechanical power and other uses.

Level 1

At this levels waste products generated from the production of bio-ethanol and bio- diesel is use in the biogas production.

Level 2

At this level, the range of potential waste feed-stocks is much broader including: municipal wastewater, residual sludge, food waste, food processing wastewater, dairy manure, poultry manure, and aquaculture wastewater, seafood processing wastewater, yard wastes, and municipal solid wastes for the biogas production.

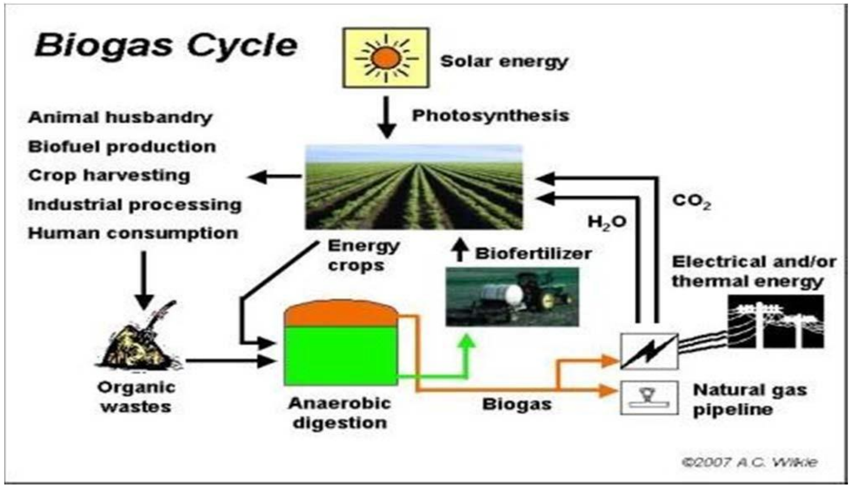
Level 3

This level we assume more technologies of biogas production is massively develop or imported for the conversion process, and millions cubic meter (m^3) of biogas is produce.

Level 4

At this level the biogas produce with high quality has Caloric value ranges between 6000 to 7500 kcal and these can generate high energy for electric power.

Zorg Biogas's plant (zorgbiogas.com)



Volume of Waste & Recycling

The rise in population and living standards in Nigeria has produced a huge amount of domestic waste. Waste to energy holds a large potential in Nigeria, both in urban and rural areas, which can yield useful energy in a number of ways. Nigeria generates 0.44 -0.66 kg/capita/day of municipal solid waste (MSW) with a waste density of 200 - 400 kg/m3. MSW includes Industrial, Domestic, Construction and Sewage wastes. Energy generation through biochemical conversion or combustion will depend on its levels of segregation and collection efficiency. Hence, it is assumed under all scenarios that by 2050, both urban and rural areas will have MSW collection efficiency of approximately 98% and segregation levels of 88%.

Level 1

Level 1 assumes that the total waste generated is about 252% increase from 2010 level of 41 million tonnes of waste. Industrial and domestic waste contributes about 60 and 41 million tonnes respectively.

Level 2

Level 2 assumes that a reduction of about 19% of total waste compared to level 1 value of 104 million tonnes. Industrial waste will contribute the highest value of about 47 million tonnes and domestic waste contributes about 34 million tonnes while construction and sewage contributes about 2.4 million tonnes of waste.

Level 3

Level 3 assumes a further reduction of about 43% compared to level 1 value of 104 million tonnes of wastes. Industry, domestic, construction and sewages contributing about 28, 29, 0.7 and 1.7 million tonnes of waste.

Level 4

At this level, the value at 2050 remains the same value as of 2010. The 2010 value is 41 million tonnes. Industrial and domestic waste contributes about 21 and 18 million tonnes respectively while construction and sewages contributes about 0.7 and 1.7 million tonnes of waste respectively.

Domestic Wastes in Nigeria.

Coal Production in Nigeria

Nigeria had proven coal reserves of about 650 million tonnes of coal equivalent (TCE) while the inferred reserves are about 2.75 billion TCE. This consists of 49% sub- bituminous, 39% bituminous and 12% lignite coals. Currently, there is no coal power plant in the country. Coal is the oldest commercial fuel in Nigeria with production dating from 1916 when 24,500 tonnes were produced. Production rose to a peak of 905,397 tonnes in 1959 during which it contributed over 70% to commercial energy consumption in the country. 2010 production stood at about 0.046 million TCE .

Central Production Case

This level assumes that coal production will increase from minimal value of 0.046 million TCE to a high value of 135.12 million TCE by 2050. The level assumes a high contribution of coal to electricity generation mix.

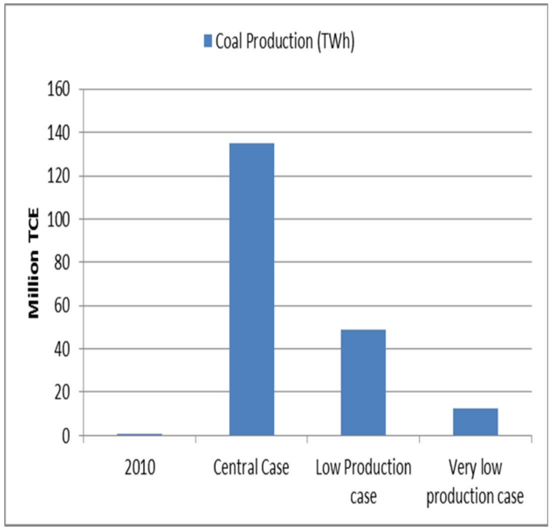
Lower Production Case

This level assumes an increase in coal production compared to 2010 level. The production will increase to 49.13 million TCE by 2050, but a reduction of about 63% compared to the Central Production Case. The reduction in production is attributed to little contribution of coal to the electricity generation mix in the country.

Very Low Production Case

The very low production case assumes about 12.28 million TCE of coal production by 2050. This is a reduction of about 91% and 75% compared to Central Production Case and Low Production Case respectively. The low production is attributed to low demand from coal

Coal Mine, Enugu



Domestic Gas Production

As of January 2010, Nigeria had 187 Tcf of proven natural gas reserve. A total of 2.39 Tcf of natural gas was produced in 2010. Of this amount, the country utilized 1.81 Tcf, while the remaining portion representing 24.3% was flared. The country domestic consumption was 224 Bcf of dry natural gas in 2010, less than 20% of its total production, mostly for electricity generation and as feedstock for industrial applications.

Central Production Case

This level assumes that by 2050, domestic gas production will increase to 5.43Tcf while gas flaring reduces to 2%. This production figures will be driven by the high domestic demand especially, the increase in power generation and the use of gas as an alternative to fuelwood.

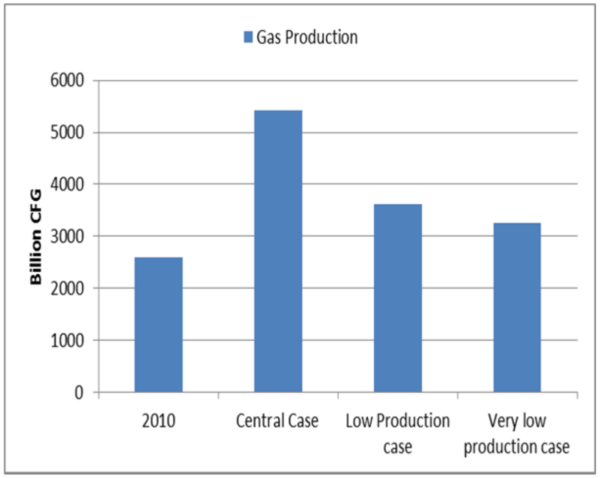
Lower Production Case

This level assumes that by 2050, domestic gas production will increase to 3.62Tcf, and domestic consumption is expected to increases with construction of gas facilities that will reduce flaring.

Very Low Production Case

This level assumes that by 2050, a minimal increase of domestic gas production to 3.26Tcf. There is a little Infrastructural development of gas to power generation and for domestic use.

Nigeria gas production facility (sweetcrudereports.com)



Domestic Oil Production

Nigeria had a proven reserve estimate of 37.2 billion barrels of predominantly low sulphur light crude, as of January 2010. At the current rate of exploitation and production, the expected life-span of this reserve is about 44 years. In 2010, the production in the county was 919.52 million boe with a daily average of 2.45 million boe. Tar sands reserve, estimated to be 42 billion barrels of oil equivalent can also contribute to future oil production in the future.

Central Production Case

This level assumes that by 2050, domestic crude oil production increase to 1,011.47 million boe with the adoption of more advanced development and production technologies and with increased exploitation from deepwater offshore terrains.

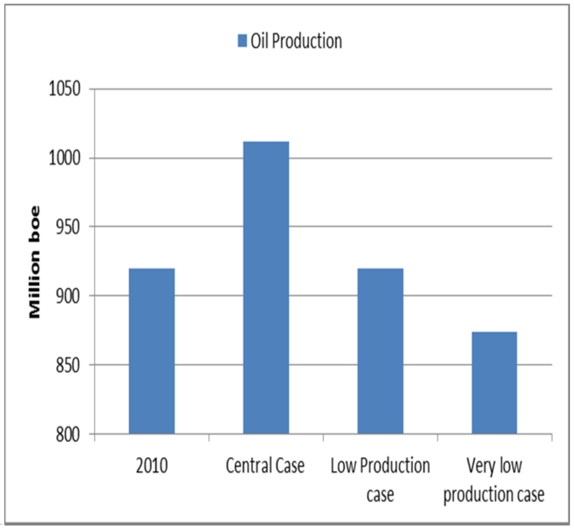
Lower Production Case

This level assumes that by 2050, domestic crude oil production will remain at 919.52 million boe. Projections are predicated on absence change in the present fiscal regime for the participating production companies or lack of new investments in the oil subsector arising from gloomy business climate for the companies.

Very Low Production Case

This level assumes that by 2050, domestic oil production decreases to 873.54 million boe.

Offshore Oil Rig in Nigeria



Traditional Fuel (Fuelwood)

Despite the abundance of oil and gas and high potential for hydro-electricity, Nigeria still depends on traditional energy source such as wood fuel for its domestic energy needs. According to the Forest Resources Assessment Report of 2012, that total wood fuel been removed from forests in 2010 amounted to 54.9 million tonnes. Fuelwood is widely used for heating, cooking, cottage industrial applications and food processing. Currently, these traditional energy sources account for about 55% of Nigeria's primary energy requirements, even though they are usually not included in a country's commercial energy consumption calculations. This is because their importance decreases as the country's economy transforms.

Level 1

At this level wood fuel consumption remained the same as of 2010 and deforestation is on the high side.

Level 2

In this level, by 2020 we can see reduction in the use of wood fuel and a gradual picking up in the use of natural gas and biogas for heating. Total wood fuel consumption decreased to 40.5 million tonnes.

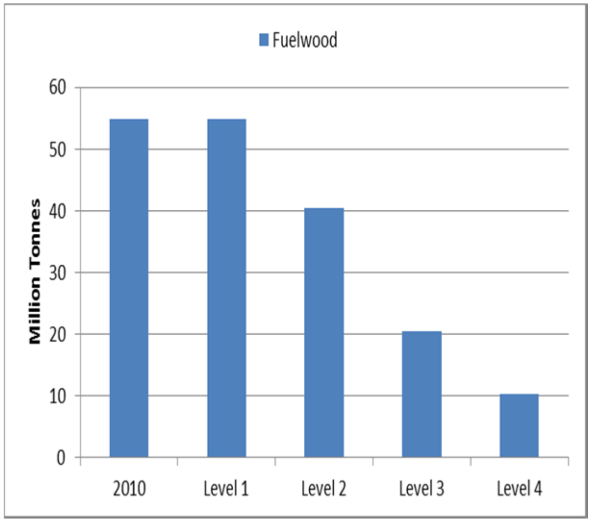
Level 3

At this level, about 30% reduction in the use of wood fuel and more than 40% increase in the use of natural gas and biogas for heating. More efficient and improve technology in the use of wood fuel stove is available by 2030. The wood fuel consumption drastically falls to about 20.4 million tonnes.

Level 4

In this level by 2050, 78% of domestic heating will be biogas, natural gas and electric, while our forest is conserved. Modern technology of improved efficient use of traditional biomass is common and the wood fuel used decreases to 10.3 million tonnes.

A pyramid of Firewood: selling point



Large Hydropower stations

As at 2010 Nigeria had 1.94 GW capacity of large-scale hydropower with available capacity of 1.23 GW which generated about 6.46TWh. Large-scale hydroelectricity generated 29.64% of the total electricity generation by the national electricity grid.

Level 1

Level 1 assumes that the total hydropower capacity is maintained at the 2010 level of 1.94 GW by rehabilitating the hydropower plants to operate at full capacity. This will generate approximately 9.98TWh of electricity at 60% capacitor factor.

Level 2

Level 2 assumes that the hydropower capacity reaches 5.24 GW by 2030 through rehabilitating the existing hydropower to operate at full capacity and adding 3.3 GW large hydro power stations. The capacity will remain constant up to 2050. This will generate approximately 27.54TWh of electricity at 60% capacity factor.

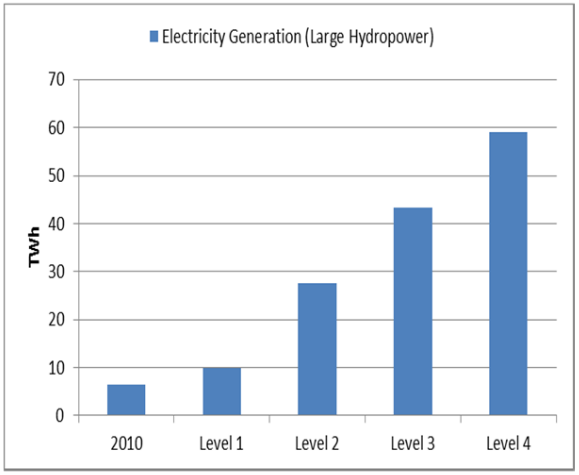
Level 3

Level 3 assumes the total hydropower capacity reaches 6.99 GW by 2035 by deploying 3.3 GW of large hydropower capacity. This capacity represents 47% of the country's hydropower potentials. The capacity will generate about 43.31TWh of electricity. Implementing level 3 requires a strong commitment in terms of financing, planning and construction.

Level 4

Level 4 assumes the hydropower capacity reaches 15 GW by 2050, through utilising all the country's hydropower potentials. This capacity can generate 59.13TWh of electricity. This can be achieved through public private partnership (PPP) due to high investment cost that is required in the implementation

Shiroro Hydro Electric Power Plant, Nigeria



Small Hydropower stations

As at 2010 Nigeria had 0.064 GW capacity of small-scale. The small-scale hydro consists of power plant below 10MW and all the existing small hydro power plant are not connected to the national electricity grid. Rather, they are connected to specified area (mini grid).

Level 1

Level 1 assumes that the total small hydropower capacity is maintained at the 2010 level of 0.064 GW. This will generate approximately 0.28TWh of electricity at 50% capacitor factor.

Level 2

Level 2 assumes that the small hydropower capacity reaches 0.53 GW by 2050 through investment in building new small scale hydropower plants. This will generate approximately 2.32TWh of electricity at 50% capacity factor.

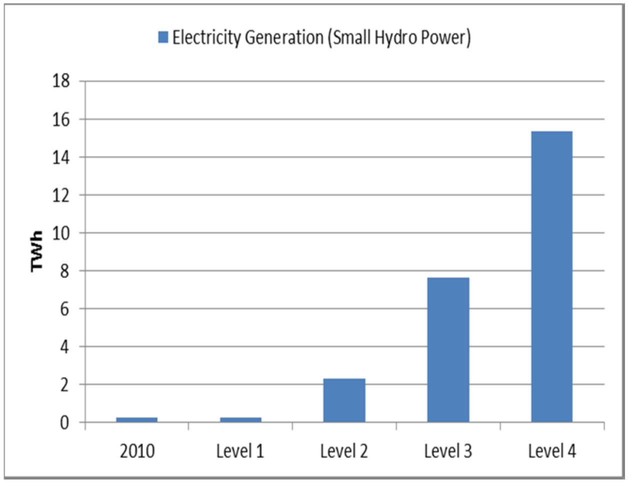
Level 3

Level 3 assumes the total small hydropower capacity reaches 1.75 GW by 2050. This capacity represents 47% of the country's small hydropower potentials. The capacity will generate about 7.67TWh of electricity.

Level 4

Level 4 assumes the hydropower capacity reaches 3.5 GW by 2050, through utilising about 95% of the country's hydropower potentials. This capacity can generate 15.33TWh of electricity. This can be achieved through public private partnership (PPP) due to high investment cost that is required in the implementation.

Small Hydro Power Plant



Natural Gas Power Stations

Installed capacity of natural gas power plants in 2010 was 6.5GW with 2.9GW available and produced 17.604TWh at an average load factor of 0.23, mainly due to constraints in natural gas supply and aging of some units.

Level 1

Assumes that the capacity of 2010 level should operate at full capacity by rehabilitating the power plants and no more power plants are introduced up to 2050. This should produce 39.86TWh at 70% load factor.

Level 2

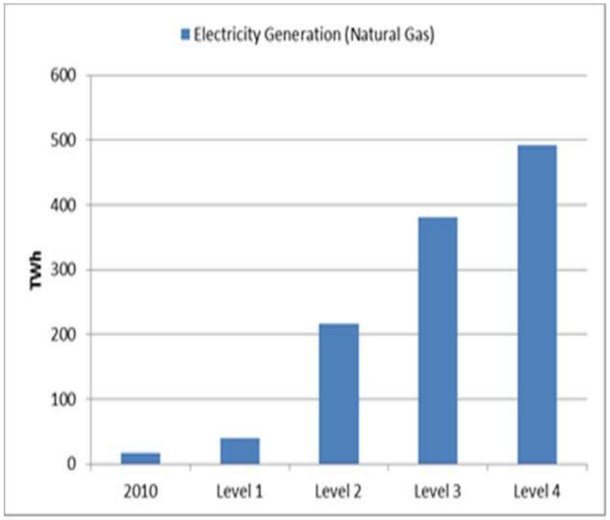
Assumes that the capacity of 2010 level should operate at full capacity by rehabilitating the power plants and an additional capacity of 4.86GW should be available by 2020 making a total of 11.3GW and increase to 35.3GW by 2050 at 70% load factor. This should produce 216.46TWh.

Level 3

Level 3 assumes total natural gas power plants of 16.3GW should be available by 2020 and another capacity of 1.25GW should be added by 2025. By 2050 a capacity of 62.2GW through independent Power Producer (IPPs) should be achieved which should produce 381.41TWh.

Level 4

Government's Gas Revolution Programme is fully operational and gas is not a constraint. Assumes natural gas power plants capacity reaches 80.20GW by 2050 which should produce 491.79TWh. This target is based on "energy requirement for vision 20:2020 and beyond" for Nigeria.



Geregu Power Plant (gas), Nigeria

Coal Power Stations

Nigeria has coal reserve of about 2.75 billion tonne which is made up of sub-bituminous, bituminous and lignite. The coal has a calorific value of 23,112.24 – 17,676.07kJ. Currently coal is not contributing to the Nigerian electricity generation mix.

Level 1

Level 1 assumes that coal power plant is introduced in the country with a capacity of 1.4 GW by 2025. Remain the same up to 2050. This will generate approximately 9.20TWh at 75% load factor.

Level 2

Level 2 assumes that coal power plant is introduced in the country with a capacity of 1.4 GW by 2025. Another power plant of 3GW capacity is to be added by Federal Government by 2035. This makes a total of 4.5 GW by 2020 which is maintained up to 2050. This will generate approximately 29.57TWh of electricity at 75% load factor.

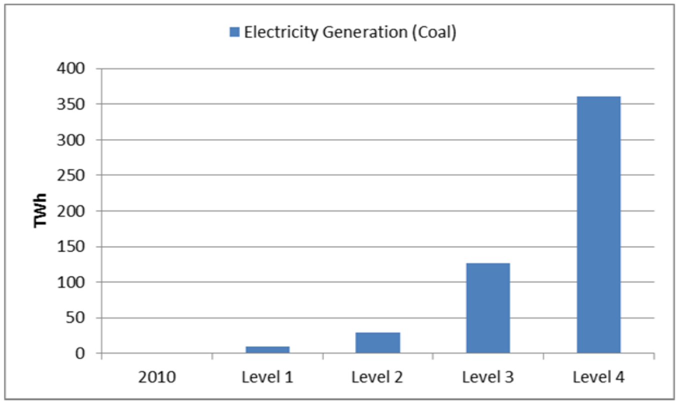
Level 3

Level 3 assumes that 1.4 GW of coal plant becomes available by 2025 and increase to 19.25 by 2050. This will generate approximately 126.47TWh.

Level 4

Level 4 assumes the coal power plant capacity should reach 55GW by 2050 and produce 361.35TWh/y of electricity. This should use about 78% of Nigerian coal reserve in 40 years. This can be achieved through public private partnership (PPP) due to high investment cost that is required in the implementation.

1984MW, Supercritical Harrison Power Station, West Virginia, U.S.A



Nuclear Power Stations

The Uranium or Nuclear fuel in Nigeria is not yet quantified. Though there is no nuclear power station in the Nigeria, it is part of the plan for sustainable electricity generation mix.

Level 1

Level 1 assumes that nuclear power station will not be available in the electricity generation mix by 2050.

Level 2

Level 2 assumes that nuclear power station of 1 GW should become available by 2023 and another capacity of 4.0 GW should come online by 2030 which makes cumulative capacity of 5.0 GW available by 2035 and remain constant up to 2050. This will generate approximately 35,040 GWh of electricity at 80% capacity factor.

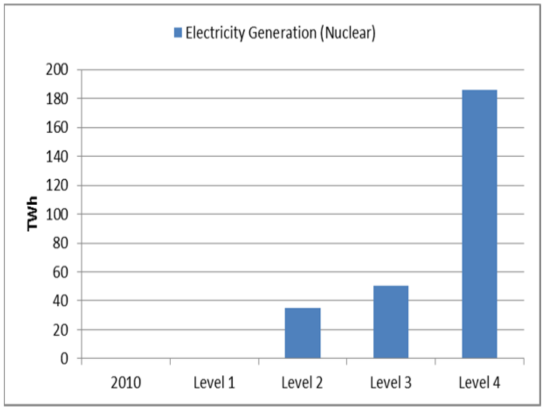
Level 3

Level 3 assumes that nuclear power stations of 7.2GW should become available by 2030 and remains constant up to 2050. That is 1.0 GW Nuclear power should be introduced by 2023. Another plant of 6.2 GW is to become available by 2030. This will generate approximately 50,457GWh of electricity. Implementing level 3 requires a strong commitment in terms of financing, planning and construction.

Level 4

Level 4 assumes that nuclear power station of 1.0 GW should become available by 2023. It is assumed that capacity addition grows at the rate of 14% per annum through to 2050 similar to the build rate for Japan. Hence, capacity is increased to 10.52GW by 2040 the overall cumulative capacity of 40.0 GW is achieved by 2050. This will generate approximately 280,320GWh of electricity. This can be achieved through government's strong commitment and diplomacy to convince the world that the nuclear system is mainly for power generation purpose.

Nuclear Power Plant: Courtesy Penn Energy



Stand Alone Solar Photo Voltaic (PV) for Electricity

In 2010 Nigeria had 0.015GW stand-alone solar PV installation. This figure is given as an approximate value which accounts for solar panels used by individuals and also government development projects which are basically for solar street lights, solar powered bore-holes and vaccine refrigeration in clinics. It is estimated that the solar potential in Nigeria ranges between 4.0kWh/m2/day to 6.5kWh/m2/day for an average of 5 hours every day.

Level 1

Level 1 assumes that solar PV's contribution remains 4GW which produces 7.36TWh by 2050.

Level 2

Level 2 assumes that solar PV capacity reaches 2GW in 2020 and 16GW by 2050. This should produce 29.4TWh with 21% capacity factor. At this level it is assumed that a portion of the supply will be integrated into the National grid system and will power about three states as it is anticipated that the country will have solar farms.

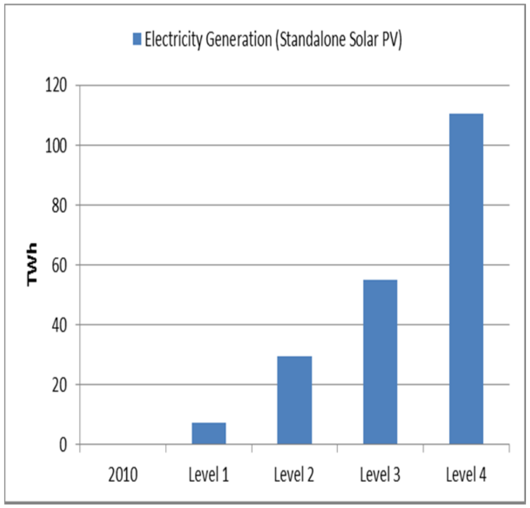
Level 3

Level 3 assumes that solar PV capacity reaches 30GW in 2050 thereby producing 55.19TWh. It is assumed that this figure will account for solar PV installed on rooftops in rural areas and more in urban areas which is estimated to multiply rapidly to accommodate the present demand for solar PV technology.

Level 4

Level 4 assumes that solar PV capacity reaches 60GW in 2050 by utilizing 0.05% of Nigeria's land mass which should produce 110.38TWh. Level 4 assumes that more solar PV's will be used as stand-alone (dispersed)

5.5 kWp Solar PV Plant at Laje in Ondo State, Nigeria.



Grid Solar Photo Voltaic (PV) for Electricity

In 2010, Nigeria had no grid solar PV installation. This solar PV will be connected to national grid. It is estimated that the solar potential in Nigeria ranges between 4.0kWh/m2/day to 6.5kWh/m2/day for an average of 5 hours every day.

Level I

Level I assumes that solar PV's contribution remains 0.7GW which produces 1.29TWh and will remain about the same level up till 2050.

Level 2

Level 2 assumes that solar PV capacity reaches 2GW in 2020 producing and 9GW by 2050. This should produce 16.56TWh with 21% capacity factor. At this level it is assumed that a portion of the supply will be integrated into the National grid system and will power about three states as it is anticipated that the country will have solar farms.

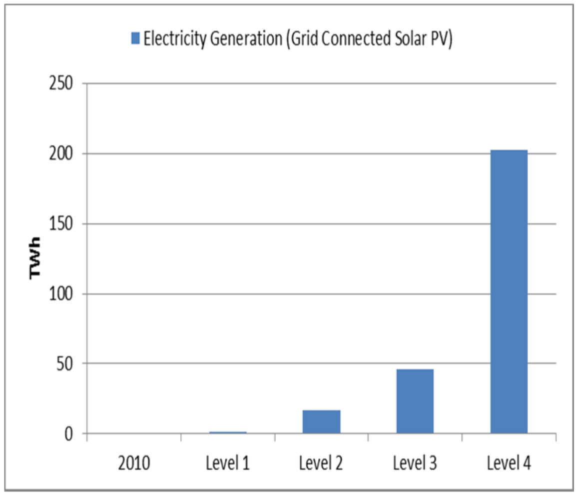
Level 3

Level 3 assumes that solar PV capacity reaches 25GW in 2050 thereby producing 43.97TWh. It is assumed that this figure will account for solar PV installed on rooftops in rural areas and more in urban areas which is estimated to multiply rapidly to accommodate the present demand for solar PV technology.

Level 4

Level 4 assumes that solar PV capacity reaches 110GW in 2050 by utilizing 0.05% of Nigeria's land mass which should produce 202.36TWh. Level 4 assumes that more solar farms will be built for generating electricity for the national grid.

Grid Connected Solar Photo Voltaic, China.



Concentrated Solar Power

It is estimated that the solar potential in Nigeria ranges between 4.0 -6.5 kWh/m2/day or an average of 5 peak sun hour per day. The northern parts of Nigeria with latitude 10oN have been identified as having potential for solar CSP power plants. The absence of large bodies of water for cooling and attendant cost could limit the adoption of this technology. 1% of the Nigerian land mass has the potential to generate 500GW of electricity using CSP

Level 1

Level 1 assumes that there will be no solar CSP installations up to 2050.

Level 2

Level 2 assumes that there would be 1GW CSP power plant by 2050 which should generate 1.84TWh of electricity with 20% capacity factor.

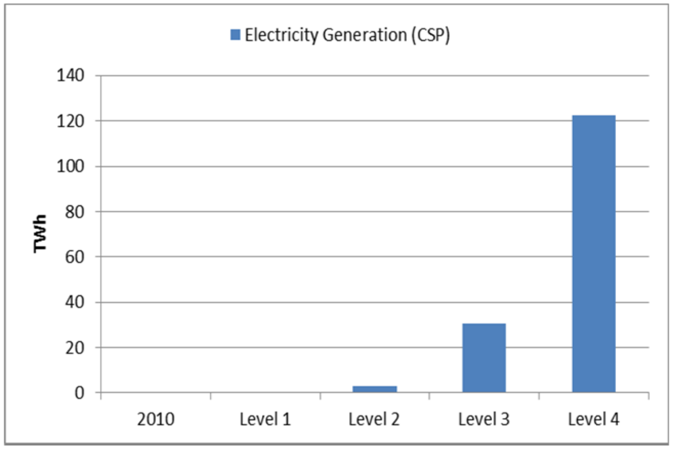
Level 3

Level 3 assumes existence of 10GW CSP power plant by 2050 contributing 18.4TWh of electricity by 2050.

Level 4

Level 3 assumes existence of 40GW CSP plant by 2050. This capacity will generate 73.58TWh of electricity by 2050. This requires a huge investment which necessitates the public private partnership.

50 MW Bokpoort CSP Plant owned by ACWA Power in South Africa
Source: CSP Worldwide Status by Dr. Julian Blanco



Wind Power

In Nigeria, wind energy resources at 10m shows that some sites have wind regime between 1.0 to 5.1 m/s. The wind regimes are classified into four regimes; > 4.0m/s,
3.1 ≤ 4.0m/s, 2.1 ≤ 3.0 m/s and 1.0 ≤ 2.0 m/s. Hence, Nigeria falls in the poor / moderate wind regime. The wind speeds in the country are generally weak in the South except for the coastal regions and offshore, which are windy. Currently there are wind power plant of few kW mainly for water system and pilot project.

Level 1

Level 1 assumes that 0.01GW of wind power is commissioned by 2015 and remain the same up to 2050. This can produce 0.018TWh of electricity with 20% capacity factor.

Level 2

Level 2 assumes that there should be 1GW wind power plant by 2050 which should produce 1.75TWh of electricity with 20% capacity factor.

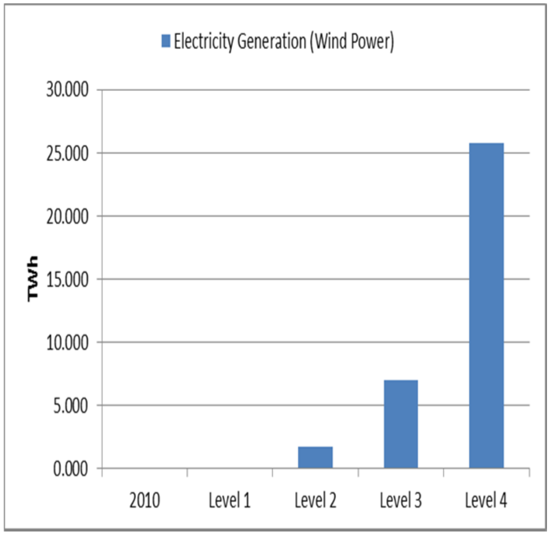
Level 3

Level 3 assumes 4GW capacity of wind power plant should be available by 2050 contributing 7.01TWh of electricity with 20% capacity factor.

Level 4

Level 4 assumes 14.7GW of wind power plant by 2050 which should produce 25.74TWh of electricity with 20% capacity factor.

5kW aero generator in Sayya Gidan Gada, Sokoto State, Nigeria



Biomass Power Plants

Currently there is no biomass power plant in operation in Nigeria, however, a 0.005GW Biomass power plant is under construction. The plant will use agricultural products residues.

Level 1

Assumes that only 0.005GW of biomass power plant will be available up to year 2050. This will produce about 0.04TWh.

Level 2

Assumes a 1GW of biomass power plant should be available by 2050 and producing 7.88TWh with 90% capacity factor.

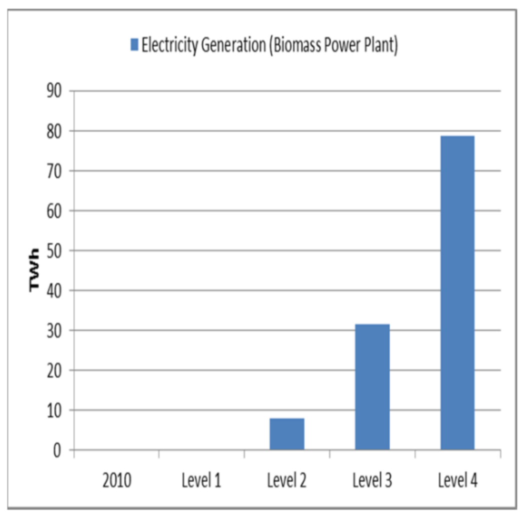
Level 3

Level 3 assumes a 4GW of biomass power plant by 2050 which will produce 31.54TWh with 90% capacity factor.

Level 4

Assumes 10GW (West African Power Poll studies carried out by IRENA) of biomass power plants by 2050. This can produce 78.84TWh. Biomass plant relies on crop residues and energy crops.

37.5 MW Plainfield Biomass Power Plant, Connecticut New England, USA.



Electricity Import

As at 2010 there was no electricity import in Nigerian electricity system. Electricity import will take advantage of the 80GW capacity from Grand Inga project in the Central Africa

Level 1

Level 1 assumes that electricity import shall not take place up to 2050.

Level 2

Level 2 assumes that 1.3GW capacity shall be wheeled from Grand Inga hydro electric project by 2030 and remain the same up to 2050. With 5% transmission losses, 11TWh of electricity shall be imported.

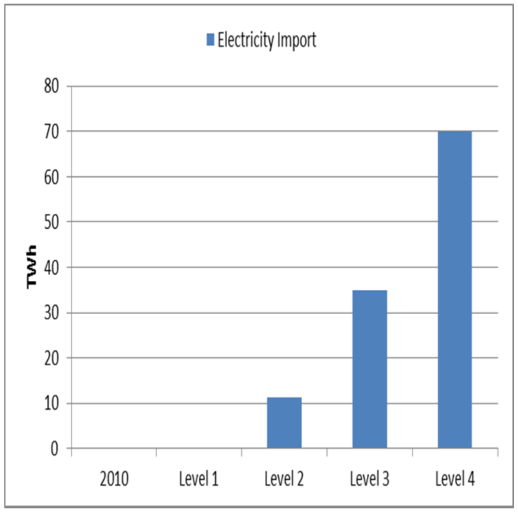
Level 3

Level 3 assumes that 4 GW capacities shall be wheeled to Nigeria Grand Inga hydro electric project by 2030 and remain the same up to 2050. Considering 5% transmission losses, 35TWh shall be imported into the country.

Level 4

Level 4 assumes that 8 GW capacities shall be wheeled to Nigeria from grand Inga hydro electric project by 2050. Considering 5% transmission losses, 70TWh shall be imported.

Electricity Transmission Lines



CHAPTER FIVE

RESULTS

We present two example pathways to explain how understand and interpret the results from the Nigeria Energy Calculator 2050. The first pathway demonstrates what is likely to happen if no effort is made. While the second one shows what could happen if puts greater efforts towards transitioning to meet energy demand.

Under the "No Effort" pathway, all the sectors are locked at Level One setting, reflecting the continuation of existing capacity, trend, technology and no change in consumption behaviour. In the "Great Effort" scenario, there will be no self generation, increase in generation capacity, and increase contribution of renewable energy and introduction of nuclear power to electricity mix.

Results: Electricity Demand

Electricity Demand will increase significantly for the two chosen pathways; initial demand is 115TWh in 2010 will increase to about 1,300TWh for the No Effort Pathway by 2050 with lighting, appliances and cooking contributing more to the demand, the same pattern was observed in the Greater Effort Pathway as demonstrated in fig.8.0 and fig.9.0 respectively. However, the projected demand is reduced compared to No Effort Pathway to about 700TWh.

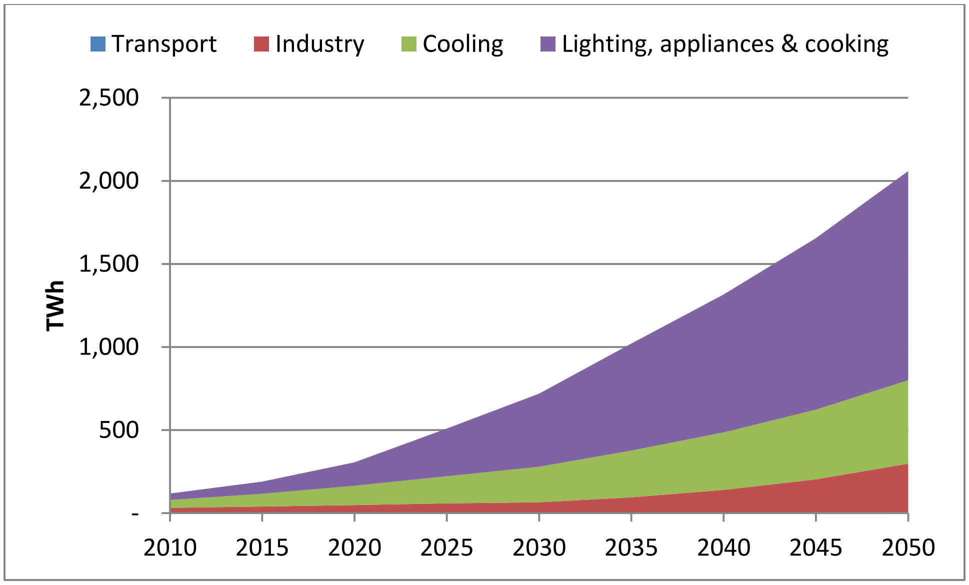


Figure 14: Electricity Demand (No Effort Pathway)

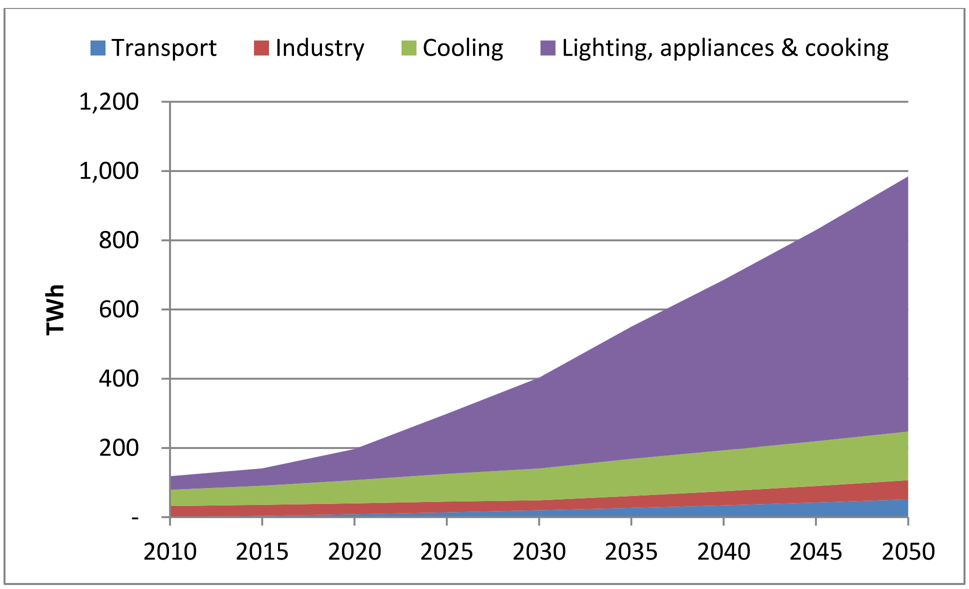


Figure 15: Electricity Demand (Greater Effort Pathway)

Results: Energy Mix of Electricity Demand

Energy mix varies significantly under the two scenarios; in No Effort Pathway use of small generators for power generation dominate, while in the Greater Effort Pathway self generation will be replaced by the increase generation capacity with renewable energy and nuclear power contributing significant percent.

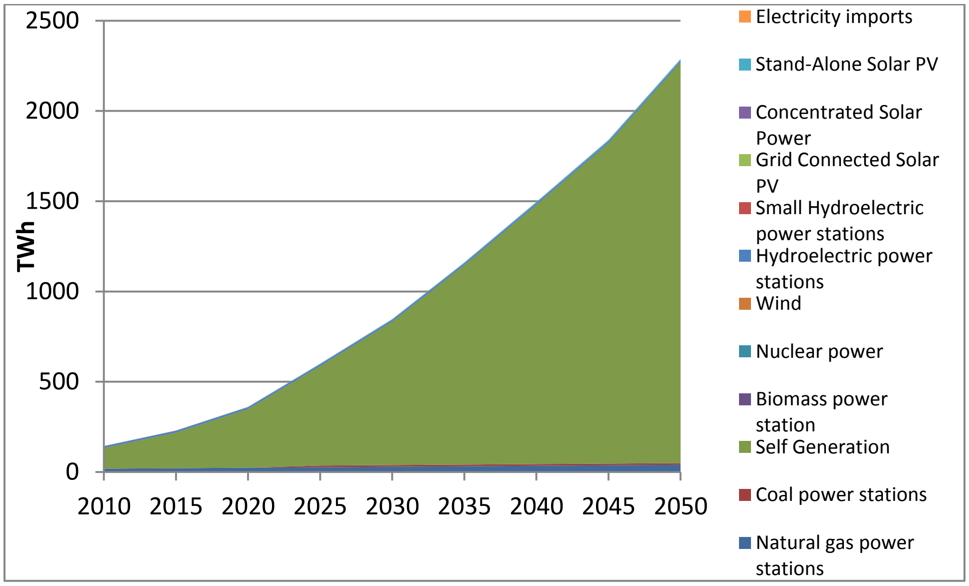


Figure 16: **Electricity Generation Mix (No Effort Pathway)**

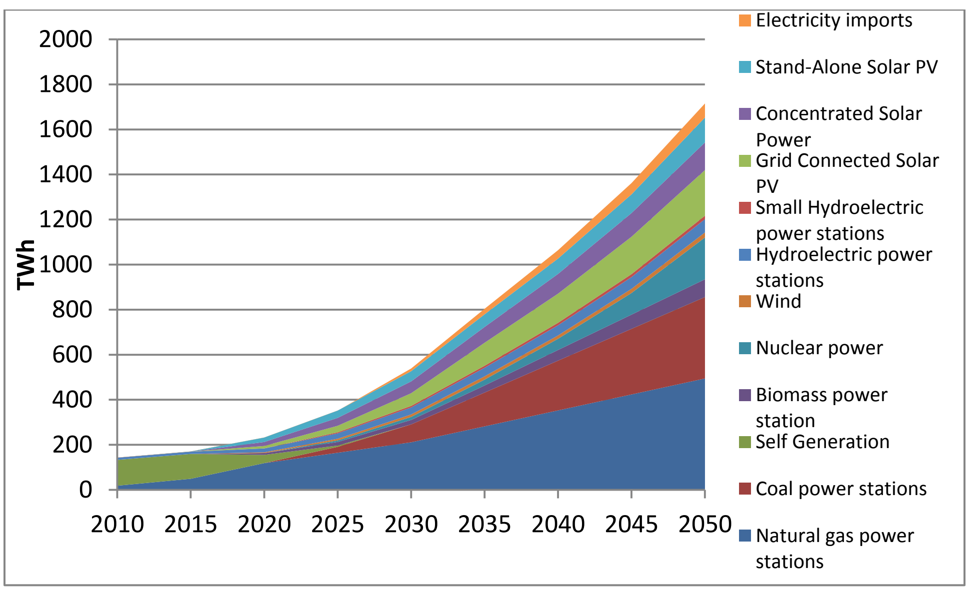


Figure 17: Electricity Generation Mix (Greater Effort Pathway)

Results: Primary Energy Supply

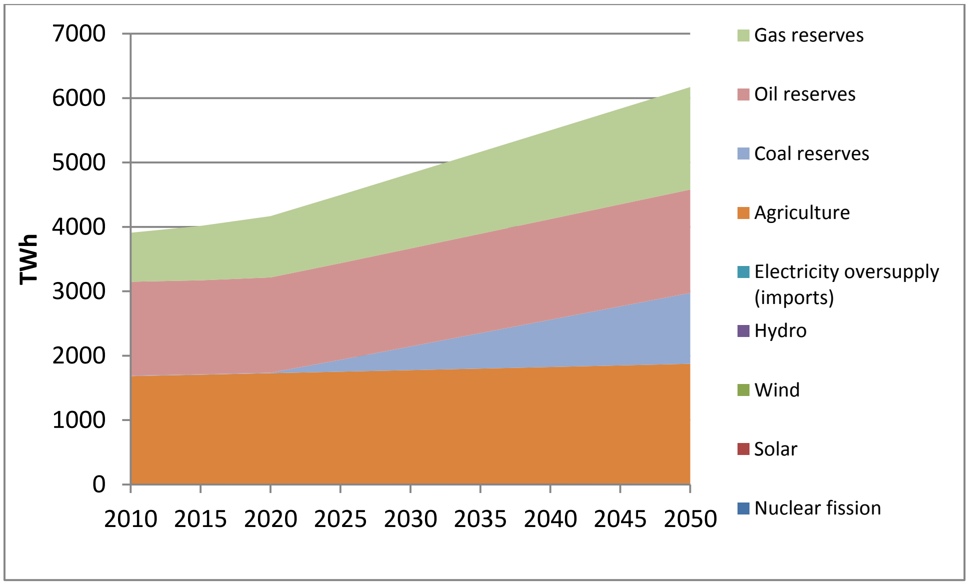


Figure 18: Primary Energy Supply (No Effort Pathway)

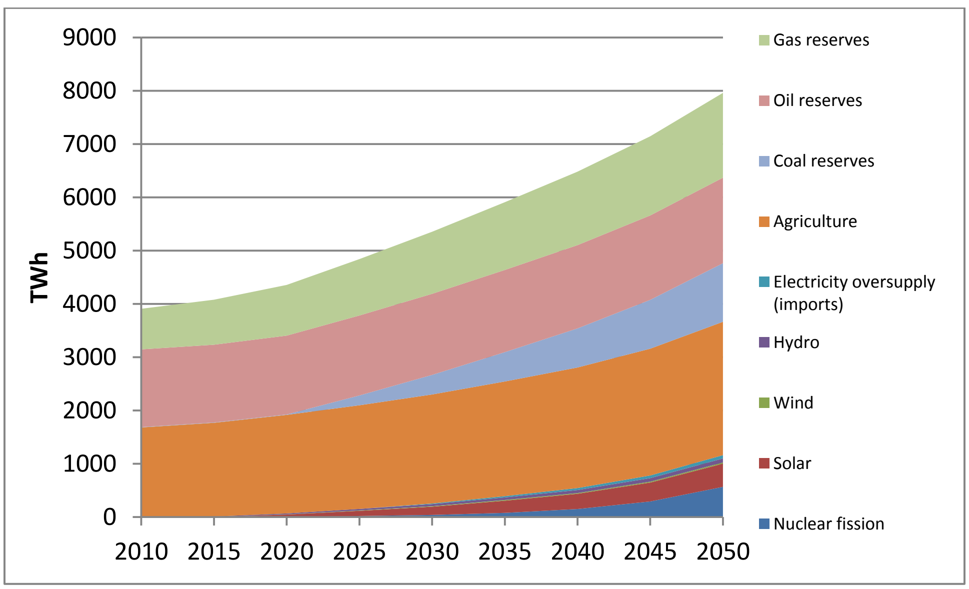


Figure 19: Primary Energy Supply (Greater Effort Pathway)

Results: GHG Emissions

The GHG emission will increase compared to the 2010 level for the two scenarios, this is attributed to increase in energy demand due to population size and growth in economy. The GHG emission will reduce for the Greater Effort Pathway compare to the No Effort Pathway by 2050. The reduction is due to change in technology, penetration of energy efficiency and change in behaviour.

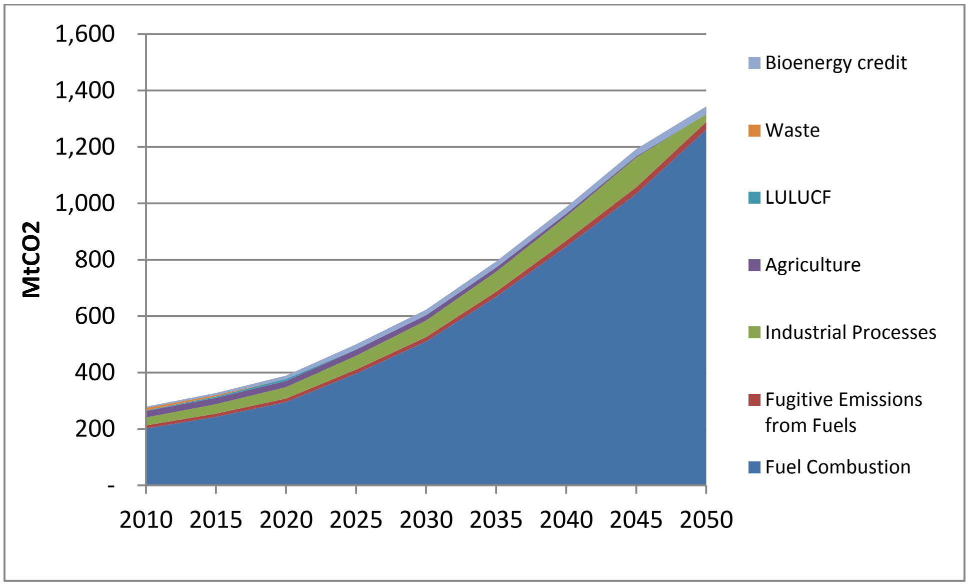


Figure 20: **GHG Emission (No Effort Pathway)**

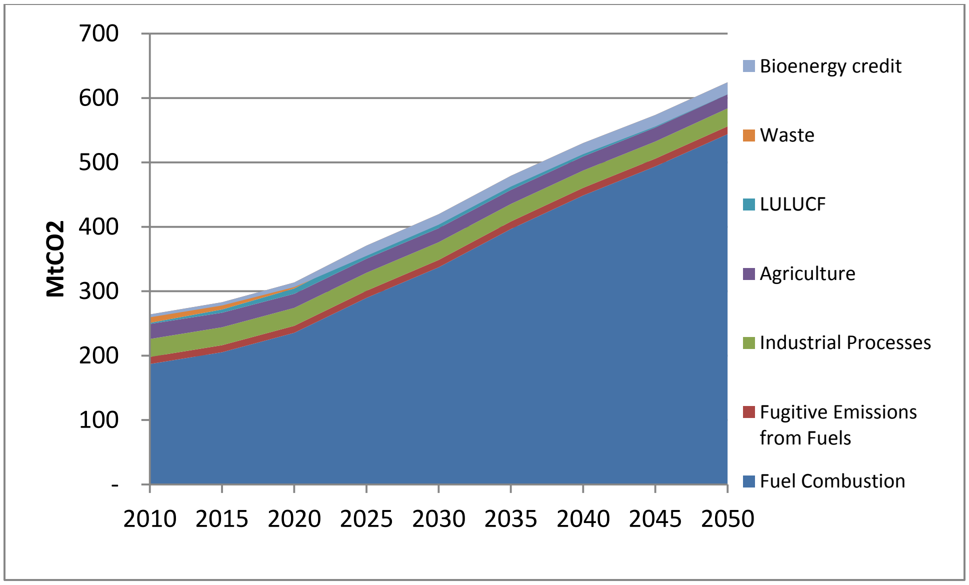


Figure 21: GHG Emission (Greater Effort Pathway)

Electricity Demand

Table 6: Electricity demand by Sector TWh (No Effort Pathway)

Sector	2010	2015	2020	2025	2030	2035	2040	2045	2050
Agriculture and land use	1	1	1	1	1	1	1	1	1
Residential Cooling	39	58	86	121	161	217	270	332	404
Service Sector Cooling	8	19	30	42	53	64	76	87	98
Residential Lighting, Appliances, and Cooking	28	52	108	237	370	552	731	926	1,139
Service Sector Lighting, Appliances, and Cooking	11	21	33	50	70	92	100	107	120
Industrial processes	24	32	40	49	54	82	124	186	278
Domestic passenger transport	-	-	-	-	-	-	-	-	-
Domestic freight	1	2	2	3	3	4	4	5	5
Petroleum refineries	5	5	4	4	3	3	3	3	3
Indigenous fossil-fuel production	1	1	1	2	4	5	7	8	10
Total	**118**	**190**	**306**	**509**	**719**	**1,021**	**1,316**	**1,655**	**2,059**

Table 7: Electricity demand by sector in TWh (Greater Effort Pathway)

Sector	2010	2015	2020	2025	2030	2035	2040	2045	2050
Agriculture and land use	1	1	1	1	2	2	2	2	2
Residential Cooling	39	44	53	63	72	85	94	103	113
Service Sector Cooling	8	11	14	17	20	22	24	26	28
Residential Lighting, Appliances, and Cooking	28	38	77	159	243	356	463	579	701
Service Sector Lighting, Appliances, and Cooking	11	12	13	14	20	26	29	32	36
Industrial processes	24	25	25	24	20	25	29	35	41
Domestic passenger transport	-	1	3	6	10	15	20	26	33
Domestic freight	1	3	5	8	10	12	14	16	18
Petroleum refineries	5	5	4	4	3	3	3	3	3
Indigenous fossil-fuel production	1	1	1	2	4	5	7	8	10
Total	**118**	**141**	**197**	**299**	**403**	**551**	**686**	**830**	**985**

Fuel Used for Electricity

Table 8: Fuels used in electricity generation in TWh (No Effort Pathway)

Fuel	2010	2015	2020	2025	2030	2035	2040	2045	2050
Nuclear	0	0	0	0	0	0	0	0	0
Coal	0	0	0	26	26	26	26	26	26
Oil	145	249	410	695	1002	1394	1813	2241	2803
Gas	39	44	50	56	61	67	73	78	84
Total	**183**	**293**	**460**	**776**	**1089**	**1486**	**1911**	**2345**	**2912**

Table 9: Fuels used in electricity generation in TWh (Greater Effort Pathway)

Fuel	2010	2015	2020	2025	2030	2035	2040	2045	2050
Nuclear	0	0	0	21	41	79	152	294	568
Coal	0	0	24	120	279	509	752	994	1236
Oil	145	139	46	7	0	0	0	0	0
Gas	39	103	249	346	443	592	741	889	1038
Total	**183**	**242**	**319**	**494**	**763**	**1180**	**1645**	**2177**	**2842**

Demand for Industrial Sector

Table 10: Energy Demand in industry by Fuel Type (TWh)

Energy Form	No Effort Pathway	Greater Effort Pathway
Electricity (delivered to end user)	277.90	40.74
Solid hydrocarbons	38. 60	5.70
Liquid hydrocarbons	266.32	39.04
Gaseous hydrocarbons	645.85	94.68
Traditional Fuel	57.90	8.50
Total Energy Demand in Industry	**1286.56**	**188.61**

GHG Emissions for Industrial Sector

Table 11: Emission in industry ($MtCO_2$ Equivalent)

Emission Type	Emission Process	No Effort Pathway	Greater Effort Pathway
CO_2	Fuel Combustion	197.30	28.92545
CH_4	Fuel Combustion	0.36	0.054
N_2O	Fuel Combustion	1.60	0.23
CO_2	Industrial Processes	14.40	14.40
CH_4	Industrial Processes	0.11	0.11
N_2O	Industrial Processes	2.76	2.76
F	Industrial Processes	10.62	10.62
Total Emissions		**227.11**	**57.10**

Transport Sector

Table 12: Breakdown of Passenger Transport by mode and technology in Billion km

Mode	Technology	No Effort Pathway	Greater Effort Pathway
BIKE	BIKE	168.96	135.16
CAR	ICE-LH	2423.34	505.85
CAR	HEV	0	415.60
CAR	EV	0	59.37
CAR	ICE-GH	0	137.74
BUS	ICE-LH	969.34	390.23
BUS	HEV	0	320.61
BUS	EV	0	45.80
BUS	ICE-GH	0	106.26
RAIL	DIESEL	48.47	183.21
RAIL	ELECTRIC	0	427.48
AIR	AIR	242.33	339.27

Table 13: Energy Demand for Passenger Transport (TWh)

Transport Mode	No Effort Pathway	Greater Effort Pathway
Road transport	521.64	105.044
Rail transport	8.56	51.65
Domestic aviation	149.05	209.00
Total	**679.25**	**365.69**

Table 14: Energy Demand for Freight Transport (TWh)

Transport Mode	No Effort Pathway	Greater Effort Pathway
Road transport	169.05	14.43
Rail transport	1.38	13.35
Berge	0	9.64732E-13
Pipeline	5.22	10.45
Total	**175.66**	**38.24**

Service/Residential Sector Demand

Table 15: Cocking Demand in Services Sector by Fuel Type (TWh)

Energy Form	No Effort Pathway	Greater Effort Pathway
Electricity	1.36	6.32
Liquid hydrocarbons	5.42	7.59
Gaseous hydrocarbons	2.26	12.65
Traditional Fuel	36.14	5.06
Total Cooking Energy Demand	**45.17**	**31.62**

Table 16: Lighting and Appliances Demand in the Services Sector (TWh)

Electricity demand	No Effort Pathway	Greater Effort Pathway
Total lighting and appliance demand	118.78	29.70

Table 17: Total Demand in Services Sector (TWh)

Energy Form	No Effort Pathway	Greater Effort Pathway
Electricity (delivered to end user)	120.14	36.02
Liquid hydrocarbons	5.42	7.589
Gaseous hydrocarbons	2.26	12.65
Traditional Fuel	36.14	5.06
Total Services Sector Energy Demand	**163.96**	**61.32**

Table 18: Cocking Demand in the Residential by Fuel Type (TWh)

Demand by Energy Form	No Effort Pathway	Greater Effort Pathway
Cooking demand per household	6.96643E-06	1.74161E-06
Number of households	80778033.98	80778033.98
Electricity	16.88	28.14
Liquid hydrocarbons	67.53	33.76
Gaseous hydrocarbons	28.14	56.27
Traditional Fuel	450.20	22.51
Total cooking demand	**562.73**	**140.68**

Table 19: Residential Lighting and Appliances Demand (TWh)

Demand by Energy Form	No Effort Pathway	Greater Effort Pathway
Lighting and appliance demand per household	1.38887E-05	8.33321E-06
Number of households	80778033.98	80778033.98
Total lighting and appliance demand	**1121.90**	**673.14**

Table 20: Total Residential Demand by Fuel Type (TWh)

Demand by Energy Form	No Effort Pathway	Greater Effort Pathway
Electricity	1138.78	701.28
Liquid hydrocarbons	67.53	33.76
Gaseous hydrocarbons	28.14	56.274
Traditional Fuel	450.20	22.51
Total	**1684.64**	**813.824**

Table 21: Total Cooling Demand by Sectors (TWh)

Demand by Sector	No Effort Pathway	Greater Effort Pathway
Residential	403.89	113.10
Services Sector	98.33	27.53
Total	**502.22**	**140.62**

CHAPTER SIX

CONCLUSION

With the support of the UK-Department of Energy and Climate Change, the Energy Commission of Nigeria has developed the first draft of a web-based Nigeria Energy Calculator 2050.It is developed on the framework of the UK 2050 Pathways calculator. The calculator which can be used both by experts and non-experts in the energy field, will facilitate collection of insights and perspectives from the broad and diverse stakeholders in the Nigerian energy sector towards fashioning policies and plans for the sustainable development of the Nigerian energy sector. The calculator is not intended to replace the face-to-face approach to stakeholder consultation which the ECN had hitherto employed in developing policies and plans for the energy sector, rather, the web-based approach is complementary. The web-based approach can reduce operating costs by alleviating the need for expensive meetings and more effectively gathering input from a far larger group of stakeholders than the usual 100+ stakeholders which the ECN had consulted for articulating the energy policies and plans for Nigeria. In addition, this web-based approach may be the only reliable and inexpensive manner to extract vast amounts of coherent information from the public at large regarding their points of view and what action they might take.

The web-based energy calculator identified the technical, economic, environmental, and societal energy parameters that affect energy demand and supply and how they interact to determine the quantities of energy demand and supply in and presents them in graphical form. Users make their choices or suggest their contributions for the energy system of the future for the country without having to personally carry out the complex analysis required for such exercises and post them to the managers of the calculator via the on-line feedback mechanism of the calculator. The calculator managers collect, collate and analyze the contributions which serve as input into the making of energy policies and plans for the country.

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GLOSSARY OF TERMS

Derived Assumption - a formula that follows from the initial assumptions (more than one variable)

Driver Tree – a diagram showing relationship between an energy driver and other factors or drivers that effect energy demand, energy supply or emissions such as population, cooling/heating energy requirement, number of households, etc.

Driver(s) – factor(s) that affect energy demand, energy supply or emissions such as population, cooling/heating energy requirement, number of households, etc.

Energy Vector – energy carrier sources such as electricity and fuels which provide required energy sources.

Fixed Assumption – inputs that are certain

Level – represents the full range of plausible or possible for action up to 2050, each lever has four options (Level 1-4)

Level Choice – where changes described reflect scales e.g. consumptions, populations, household demand and mode of transport

Lever – a type of action required to meet energy demand and/or reduce emissions; e.g. building nuclear power stations or using more public transport

Trajectory – represents the full range of plausible possible for action up to 2050, each lever has four options (Trajectories 1-4)

Trajectory Choice – where changes described reflect choice e.g. fuel and technology

APPENDIX I

STAKEHOLDERS

ECN UK-DECC BRITISH HC: ONE- DAY EXPERTS/STAKEHOLDERS WORKSHOP ON NIGERIA ENERGY AND EMISSIONS 2050 CALCULATOR PROJECT

REIZ CONTINENETAL HOTEL CENTRAL AREA, ABUJA.THURSDAY, 21ST AUGUST 2014

SECTOR – BRITISH HIGH COMMISSION

S/No.	Name of Participant	Organization & Location
1.	David Woolf	British High Commission

SECTOR - RESEARCH

S/No.	Name of Participant	Organization & Location
1.	Dr. Emmanuel Ogbomida	National Centre for Energy and Environment (NCEE), University of Benin, Benin City
2.	Engr. A. G. Adeogun	National Centre for Hydropower Research and Development (NCHRD), University of Ilorin, Ilorin
3.	Dr. P. E. Ugwuoke	National Centre for Energy Research and Development (NCERD), University of Nigeria, Nsukka
4.	KayodeOlaniyan	National Bureau of Statistics
5.	Ibe Grace	United Nations Development Programme (UNDP), Abuja, Nigeria

LAND USE SECTOR

S/No.	Name of Participant	Organization & Location
1.	Dr. M. M. Alhassan	University of Abuja
2.	Engr. Prof. I. N. Itodo	University of Agriculture, Makurdi
3.	Bello Mohammed	Fed. Min of Agric& Rural Development, Abuja
4.	Dr. Shola O. Adepoju	Forestry Research Institute of Nigeria, Ibadan
5.	Dania Omou R.	University of Benin, Benin City
6.	Dr. (Mrs.) Odia E. O.	University of Benin, Benin City
7.	NengiObuofoubo	National Environmental Standards and Regulator Agency (NESREA)
8.	Yarima D. Ndirpaya	Agricultural Research Council of Nigeria (ARCN)
9.	Prof. E. B. Adams	Institute of Agricultural Research, Ahmadu Bello University (IAR/ABU), Zaria
10.	Dr. E. Ogbomida	University of Benin, Benin City
11.	Dr. Matawlli A. Geidam	Yobe State University, Damaturu
12.	Danladi U. Sifci	Nasarawa State University, Keffi
13.	Arc. P. Luka	Nigerian Institute of Town Planners
14.	Prof. E. B. Amans	Institute of Agricultural Research, Ahmadu Bello University (IAR/ABU), Zaria

HOUSEHOLD & SERVICES SECTORS

S/No.	Name of Participant	Organization & Location
1.	Prof. KabirBala	Department of Building, Ahmadu Bello University, Zaria
2.	Arc. JamilSaad	Dept of Development Control
3.	Joseph Alu	Department of Development Control, Federal Capital Territory Abuja
4.	Yusuf Yahaya	Director, Department of Development Control Federal Capital Territory, Abuja
5.	Oyegbade AzeezReji	National Bureau of Statistics, Abuja
6.	Momoh Jimoh Iboh	National Bureau of Statistics, Abuja
7.	Adeloye Olubunmi	National Bureau of Statistics, Abuja
8.	Izuagie Simeon	National Bureau of Statistics, Abuja
9.	EtiosaUyigue	United Nations Development Programme, Abuja, Nigeria
10.	Dr. Onwusoro M. I.	Ministry of Defence
11.	Kishak Zakka Cinfnat	Nigeria Building and Roads Research Institute (NBRRI) Abuja

FOSSIL ENERGY SECTOR

S/No.	Name of Participant	Organization & Location
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2.	Hamidu Ahmed	Nigerian Gas Company (NGC), Warri
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4.	Dr. Abubakar M. B.	National Centre for Petroleum Research and Development (NCPRD), Bauchi
5.	Bello Mohammed	Federal Ministry of Agriculture and Rural Development (FMA & RD)
6.	Ogolo G. E. (Mrs.)	Federal Ministry of Science and Technology (FMST), Federal Secretariat Complex, Abuja
7.	Mr. Tunde I. Bello	Nigerian Gas Company (NGC), Warri

INDUSTRY SECTOR

S/No.	Name of Participant	Organization & Location
1.	Arinze Uzochukwu	Bank of Industry, Lagos
2.	Dr. Mohammed Dauda	Department of Mechanical Engineering Ahmadu Bello University, Zaria
3.	Aiyedun K. R.	Ajaokuta Steel Company
4.	Mofunanya Lawrence N.	NTMA
5.	Oshiame M. B.	NACCIMA, Lagos
6.	Ibikunle Adams	FMITI, Abuja

TRANSPORT SECTOR

S/No.	Name of Participant	Organization & Location
1.	Joshua Adegoke	Birmingham City University (BCU), United Kingdom
2.	Kafarub Babatunde	Lagos Metropolitan Area Transport Authority (LAMATA)
3.	Bello Sani	Abuja Urban Mass Transport Company (AUMTCO)
4.	Prof. I. C. Ogwude	Federal University of Technology, Owerri
5.	Ogunode Olufemi	Federal Airports Authority of Nigeria (FAAN)
6.	Dr. Andrew E. Ubogu	Federal University, Dutse
7.	Engr. C. N. Njoku	Federal Roads Safety Corps (FRSC)
8.	Engr. Eric Nwafor	National Automotive Council, Abuja
9.	Elkana O. Ngbale	Nigerian Institute of Transport Technology (NITT), Zaria

POWER SECTOR

S/No.	Name of Participant	Organization & Location
1.	Engr. Yusuf Abdulahi	Nigerian Electricity Regulatory Commission
2.	Usman O. Aliyu	Abubakar Tafawa Balewa University, Bauchi
3.	Mudashiru Amusa	NESCO Group, Jos
4.	Engr. Ishaq Yahaya	Bureau of Public Procurement
5.	Engr. Nasiru Y. Beli	North South Power Company (SHE Plc)
6.	Edeh Chioma Felistas	Fed. Min of Environment
7.	Dr. S. O. Balogun	NACHRED, Ilorin
8.	Engr. Balogun Abass	NACHRED, Ilorin
9.	Dr. G. Y. Pam	Mechanical Engineering Department, Ahmadu Bello University, Zaria

APPENDIX II

ENERGY COMMISSION OF NIGERIA

NIGERIA ENERGY AND EMISSIONS 2050 CALCULATOR

PROJECT TEAM & WORKING GROUPS

Project Coordinator – Director General/CEO – Prof. E. J. Bala

Deputy Coordinator – D (EPA) – Engr. J. O. Ojosu

Modelling Team Leader – Ag.D (EPA) - Engr. J. S. Olayande

Project Team

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Dr. A. S. Ahmed

Mr. I. U. Ibrahim

Mr. S. O. Ogunfowora

Mr. Joshua Adegoke

Working Group

A. Land use, Land-use Change and Forestry Group

1. Engr. John A. Ogar / Mr. Abdulrahman Ahmed– Team Leaders
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B. Household & Services Sector Group

1. Engr. J. S. Olayande / Mr. Aminu H. Isa – Team Leaders
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3. Mrs. M. Bawa
4. Mr. AbubakarY. Yahaya
5. Mr. Abdelnasser Abdallah

C. Electricity Supply Group

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D. Transport Group

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3. Mr. Aminu Tukur
4. Mr. Nosa Osagbae
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3. Mr. Tijjani Bello
4. Mr. J.G. Aikhule
5. Mr. Mohammed J. Ladan
6. Engr. Kaisan M. Usman

F. Fossil / Bioenergy Group

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2. Mr. James A. Agba
3. Mr. Nathan Awuapila
4. Mr. Gbise Patrick Tavershima
5. Mr. Alhassan Mohammed
6. Esther N. Obika

G. Excel Programming/ Webtool Group

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