ENERGY COMMISSION OF NIGERIA
(FEDERAL MINISTRY OF ENERGY)

FEDERAL REPUBLIC OF NIGERIA

ASSESSMENT OF ENERGY OPTIONS AND STRATEGIES FOR NIGERIA:

Energy Demand, Supply and Environmental Analysis for Sustainable Energy Development (2000-2030)

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ABBREVIATIONS

ALSCON	Aluminum Smelting Company Nigeria
API	American Petroleum Institute
AGO	Automotive Gas Oil (Diesel)
bcf	Billion cubic feet
b/d	barrels per day
boe	barrels of oil equivalent
bpsd	barrels per stream day
CBN	Central Bank of Nigeria
CNL	Chevron Nigeria Limited
DPK	Dual Purpose Kerosene
ECN	Energy Commission of Nigeria
EGTL	Escravos –Gas- To- Liquid
EIA	Energy Information Administration
EJ	exajoules
ELP	Escravos – Lagos- Pipeline
EXIM	Export Import Bank
FID	Final Investment Decisions
FMST	Federal Ministry of Science and Technology
FME	Federal Ministry of Energy
FMHEnv	Federal Ministry of Housing and Environment
FMAWR	Federal Ministry of Agriculture and Water Resources
FPSO	Floating Production, Storage and Offloading
GDP	Gross Domestic Product
GTL	Gas -To- Liquid
GWh	gigawatt –hour
HPFO	High Pour Fuel Oil
IDA	International Development Association
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPP	Independent Power Plants or Producers
JDZ	Joint Development Zone
kg	kilogrammes
km	kilometer
km^2	kilometer square
kgoe	kilogrammes of oil equivalent
ktoe	thousand tonnes of oil equivalent
kV	kilovolts
kVA	kilovolts – ampere
kW	kilowatts
kWh	kilowatt-hour
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LPFO	Low Pour Fuel Oil
m	meter

m^3	cubic metre
MAED	Model for Analysis of Energy Demand
mb/d	million barrels per day
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental impacts
MDGs	Millennium Development Goals
MIGA	Multilateral Investment Guarantee Agency
MPNU	Mobil Producing Nigeria Unlimited
mmcf/d	million cubic feet per day
Mtoe	Million tones of oil equivalent
MW	megawatts
MWh	megawatt-hour
NAEC	Nigeria Atomic Energy Commission
NAFCON	National Fertilizer Company
NAOC	Nigeria Agip Oil Company Limited
NBS	Nigeria Bureau of Statistics
NEEDS	National Economic Empowerment Development Strategy
NEPA	National Electricity Power Authority
NERC	Nigerian Electricity Regulatory Commission
NESCO	Nigeria Electricity Supply Company
NGC	Nigeria Gas Company
NGL	Natural gas liquids
NIPP	Nigerian Independent Power Plants
NLNG	Nigeria Liquefied Natural Gas
NNPC	Nigerian National Petroleum Corporation
NOC	National Oil Company
OK-LNG	Olokola Liquefied Nigeria Gas
OPEC	Organisation of Petroleum Exporting Countries
PEF	Petroleum Equalisation Fund
PHCN	Power Holding Company Nigeria
PMS	Premium Motor Spirit
scf	standard cubic feet
scf/d	standard cubic feet per day
SPDC	Shell Petroleum Development Company
STP	Sao Tome and Principe
sqm	square metre
t	tonne (s)
tcf	Trillion Cubic Feet
TPNL	Total Petroleum Nigeria Limited
TSGP	Trans-Saharan -Gas-Pipeline
t/yr	tonne (s) per year
VLCC	Very Large Crude Carriers
WAGP	West African Gas Pipeline
WAPCO	West African Portland Cement
WT	Working Team
CST	Country Study Team

SUMMARY

1. Motivation for the Study

The Energy Commission of Nigeria, the government organ responsible for policy formulation on energy, undertook the development of a National Energy Masterplan for Nigeria. The Masterplan required long-term projections of energy demand by sector and energy form, a strategy for supply and utilization with strategy for managing the environmental impact associated with the demand and supply within allowed limits. The Energy Commission resolved to undertake this using objective and computer-based models for planning purposes which the International Atomic Energy Agency (IAEA) had developed. In order to build capacity for such analysis and carry out the Masterplan, the Commission on behalf of Nigeria applied and was subsequently accepted to participate in the IAEA's programme on Sustainable Energy Development in Sub-Saharan Africa (RAF/0/016). This report is the outcome of Nigeria's participation in the project, which commenced in 2001.

2. Objectives and Scope of the Study

The project, Sustainable Energy Development for Sub Saharan Africa, RAF/0/016 had the following objectives:

- To carry out a long-term projection of Energy Demand for the country, taking into account the growth of the economy and the changing sectoral and sub-sectoral utilization intensities,
- To carry out an Electricity Expansion Plan based on the projected demand, available alternative fuels and technologies with their related cost and environmental impact,
- To carry out an energy supply study, taking into consideration the projected demand, available energy resources, primary energy conversion and transportation technologies with constraints and the related cost components.
- To evaluate the environmental impacts associated with electricity generation expansion plan,
- To develop domestic capacity in the medium to long term energy demand and supply planning and in the use of IAEA planning tools which have been selected for the country program and
- To provide valuable inputs to the development of an Energy Masterplan for the country.

This report covers the energy demand projections for the country using the Model for Analysis of Energy (MAED) and the supply strategy using the Model for Energy Supply Strategy Alternatives and their General Environmental impacts (MESSAGE). It should be noted that the demand study covers 2000-2030 while the supply covers 2005-2030.

3. Organization of the Study

The Energy Commission of Nigeria (ECN) as the agency responsible for overall national energy policy and planning provided the co-ordination for the project and maintained necessary linkages with the IAEA. A **Country Study Team (CST),** consisting of expert representatives of relevant

energy and planning ministries and agencies, namely Energy Commission of Nigeria (ECN), Department of Petroleum Resources (DPR), Federal Ministry of Mines & Steel Development (FMMSD), National Bureau of Statistics (NBS), Nigerian Electricity Regulatory Commission (NERC), National Planning Commission (NPC), Nigeria Atomic Energy Commission (NAEC), Power Holding Company of Nigeria (PHCN), Federal Ministry of Housing & Environment (FMHE), Central Bank of Nigeria (CBN), and Nigeria National Petroleum Corporation (NNPC), gave the overall guidance and necessary advice for the study.

A **Working Team (WT)** composed mainly of staff of Energy Commission of Nigeria carried out the technical work of data collection, data analysis, running of the models and analysis of the results. The Working Team also prepared this report.

4. Methodological Approach

The comprehensive assessment of different energy resources and their developmental strategies for Nigeria consisted of two parts, (i) the analysis and projection of energy demand using MAED and (ii) the optimization of the energy supply system using MESSAGE. In this study an integrated computer aided approach was adopted which include:

- Estimating plausible scenarios of future demographic and economic development
- Providing detailed sectoral energy demand projections by applying MAED simulation model to the scenarios of demographic development and economic growth.
- Formulating feasible scenarios of energy supply and using MESSAGE to model optimistic future energy supply scenarios taking into consideration all energy resources in the country, technologies, and environmental constraints.
- Carrying out sensitivity analyses with respect to the fuel prices, the discount rate and investment cost which include fixed with variable operation and maintenance costs.

The MAED requires highly disaggregated data, for instance energy consumption by type was required for each of the economic sectors, namely agriculture, construction, mining, manufacturing, transportation, household and services. The data from agencies were not in the required disaggregated form; hence limited spot surveys were carried out to generate data and information to supplement the available ones.

5.0 Assumptions

Demography
Population is a major driver of energy demand. The medium projection of the population growth by the National Population Commission over the study period of 2000-2030 was used. By this projection the population will grow from 133.767million in 2005 to 235.3 million in 2030 or an average of 2.98% over the study period. This population projection was used for the economic and energy demand scenarios.

Economy
An important determinant of energy demand is the level of economic activity and its structure, measured by the total gross domestic product (GDP) and its shares by the various sectors of the economy. The GDP was guided by assumed projections of the National Economic

Empowerment and Development Strategy (NEEDS) document of government, Millennium Development Goals (MDGs) target for poverty eradication and recent Government's policy on economic growth target by 2020. Three economic growth rate scenarios were used for the study. The Reference Scenario of 7% actually corresponded to that of the NEEDS prescription for poverty reduction by 50% in 2015, the High growth rate scenario of 10% and the Optimistic growth rate scenario of 12% are for achieving an industrializing economy by the year 2002
The country's oil reserves were kept at about 35.3 billion barrels by 2005 and are expected to grow to 40 billion barrels by 2010 with an effective growth rate of 2.75% p.a. At this rate the reserves will probably reach 68.7 billion barrels by 2030. Intense exploration activities are going on at the Niger Delta region of the country in both onshore and offshore fields. There are also some prospective activities in the inland areas of the country and at the Chad Basin and Benue Trough. Natural Gas reserves in the country is set at 4.5 trillion m^3 with more of associated gas (53.5%) and non associated gas (46.4%) that increases with oil exploration, making the country the 7th largest holder in the world and highest in Africa. There is the LNG project that exports the gas for commercial purposes but with the anti flaring policy in place more gas will be available for domestic energy needs. An intensified solid minerals exploration project is also being undertaken in the country that mines the abundant bitumen, coal and other solid minerals with energy value. Hydro, Solar, Wind and other renewable sources are to be tapped, as they are readily available in the country and being captured in the Renewable Energy Master Plan. Consequently, energy resources constraint is not expected within the study period.

Energy Import.
One of the four refineries in the country uses imported heavy crude for the production of lubricating oil and other distillates. Furthermore, government's privatization policy made it unnecessary for the rehabilitation of the country's deteriorating refineries but with public private partnership initiative of government more refineries are expected to be built and the anomaly to come to an end early in the study period.

Energy Use Efficiency
Energy demand per unit of output or activity, that is, the energy intensity (toe/N or kWh/dwelling, or kWh/m^2/floor area), and hence the energy demand, decreases with an increase in the effective energy use efficiency and was modeled to be inversely proportional to the latter. Consequently, for the projection of energy intensities, only the ratio or percentage changes in effective energy use efficiency, relative to the base year value and not the actual values, needed to be given.

6.0 Results

At the start of the study period, the Household and the Transport sectors were identified as the largest energy users. The industrial sector growth rate however, is expected to increase tremendously during the study period. Industrial energy demands will more than double from 2015 to 2035. The industrial sector is expected to consume more energy; therefore motor fuels and electricity share of the total energy demand is highest. The energy demand projected by MAED served as input for the energy supply system optimization based on the MESSAGE model. Other inputs to the optimization process include:

- Description of the existing energy supply system and associated infrastructure for oil and oil products, natural gas, electricity and other fuels.
- Techno-economic and environmental characteristics of all energy technologies and processes of the national energy supply system as well as the technology candidates potentially available in the future.
- Environmental protection requirements stipulated by the Kyoto principle and other regulatory bodies.

The guiding principle in carrying out the analysis of this study is to provide, to the extent possible, quantitative information on the prospects of meeting up the provisions of the overall energy policy and its development in Nigeria. The findings of this study allow the following conclusions to be drawn:

- That within the study period (2005-2030) final energy demand in Nigeria is expected to grow on the average by 4.7%, 7.4%, and 8.7% for the Reference, High growth and Optimistic Scenarios, respectively. The increase is due to the expected industrialization of the country by 2020. In the base year, the household sector had the highest share of all the sectors with 43.2%. But within the study period, the industrial sector gains the highest share followed by the transport sector, services and household sectors, in that order. The growth rates are highest in the Optimistic Scenario and lowest in the Reference Scenario.

- The major fuels in the transport sector will continue to be Premium Motor Spirit (PMS) or gasoline and Associated Gas Oil (AGO) or diesel. Freight activities are expected to increase by 3.89, 9.72 and 16.23 times more than the base year due to increased industrial activities. Similarly Passenger transport is also expected to increase within the study period. To meet the increasing demand of motor fuels the following actions are needed:

    - ❖ The four old refineries are to be rehabilitated for efficiency and capacity built.
    - ❖ New refineries are expected to come on stream by 2015.
    - ❖ Petroleum products importation to meet ever-increasing demand is expected to thin out by 2025.

- In accordance with the National Energy Policy, access to electricity by households is expected to reach 75% by 2020. The study however assumed a further 90% access by 2030. This together with moderate to high economic growth rates, which were assumed in the study, will yield substantial increase in electricity demand, resulting to 36.16%, 33.12% and 32.28%, in the Optimistic, High and Reference Scenarios, respectively.

In the light of the demand profile, supply of electricity to meet the demand would mean:

- ❖ Rehabilitation of the existing six thermal and three hydro power plants to attain installed capacity.
- ❖ Expansion of committed plants to meet the projected demand and consequent supply target.
- ❖ More plants to be constructed within the study period to meet supply target

- ❖ Future gas plants should be combined cycle and be more technologically efficient considering global policy issues on environmental pollution.
- ❖ In accordance with the policy document on energy, nuclear and coal power plants will be introduced by 2015 and have a substantial percentage by the end of the study period.

The supply options would most likely surpass the demand by 130%, if the electricity generation expansion plan is conscientiously implemented, by the end of the study period.

- It is expected that gas will dominate the fuels for electricity generation within the study period. This is understandable as the resource is readily available in the country and requires less cost. In all, gas will provide 72.18%, followed by coal 25.94%, hydro 13.40%, nuclear 10.10% and the renewable sources 2.95% in the High growth Scenario while the trend is similar in the Optimistic and Reference Scenarios.

- The primary energy requirement is still more on the oil and gas sector for both power generation and transportation. By 2035 the energy mix in the high growth scenario is coal 12%, natural gas 34%, oil 43%, hydro 5%, nuclear 4%, non commercial 1% and the renewable sources 1%. Again the trend is similar in the other scenarios.

On environmental problems associated with traditional methods of energy utilization such as fuel wood, presently having a high percentage of use, the model captures a reduction towards the end of the study period for substitutable thermal fuel. Coal is introduced as;

- ▪ Coal briquettes for residential and service sector thermal energy requirements, while natural gas is encouraged for residential, service sector, industrial and other users by 2025. Kerosene or DPK gains prominence due to its penetration in the rural areas with improved burning stoves for cooking and other thermal applications.

- The MESSAGE model provided Environmental impact analysis with the emission of the green house gases in power production. The emissions were highest in the Optimistic Scenario and least in the Reference Scenario.

- In line with existing policies and the global concern about environmental pollution, Flue Gas Desulphurization Technology for all thermal power plants is to be introduced for both existing Power Plant and Refineries and the new ones to be constructed within the study period.

The total investment cost requirements for additional capacity in electricity generation expansion, building of new refineries, coal, natural gas and cultivation of fuelwood for thermal substitutable are $170.36 billion, $308.83 billion and $604.46 billion for the Reference, High Growth and Optimistic Scenarios respectively. They are further broken down as follows:

- The total investment requirement for electricity expansion is $126.21 billion, $232.05 billion, and $459.77 billion for Reference, High Growth and Optimistic Scenarios, respectively

- A total of \$41.58 billion, \$73.97 billion and \$122.05 billion is required for the investment cost of new refineries for the Reference, High Growth and Optimistic Scenarios, respectively

- The total investment requirement for coal is \$477 million, \$550 and \$1,280 million for the three scenarios.

- The O&M cost for the fuelwood is \$23 million, \$30 million and \$73 million for the three scenarios.

- Total investment cost for the natural gas is \$2.1 billion, \$2.26 billion and \$21.36 billion for the three scenarios

The sensitivity analysis remained unchanged for the discount rate and capital cost of the refinery expansion for all the three scenarios. Whilst for the power plant there was a shift in building of one gas plant and the two nuclear plants for all the scenarios.

7.0 the Way Forward

1. There is the need for training on modeling by the IAEA for the old and newly recruited staff of the Energy Commission

2. The introduction of SIMPACTS and FINPLAN models to the Energy Commission of Nigeria so as to continue with the modeling projects thereby further facilitating the use of results from MESSAGE model to analyze the environmental impact and financial analysis of the projected energy supply

3. There is need for the Fellowship awards for some of the officers that conducted this study.

4. There is need for sensitization workshops and seminars for disseminating the outputs of the study to stakeholders and the general public.

1. INTRODUCTION

Energy has been a central concern to human development. The adequate provision of energy is a fundamental component of the conceptual strategy on sustainable development in Nigeria and indeed the rest of the world. Nigeria envisions an economic and industrial growth driven by energy; the country will exploit energy in quantities at prices that will promote the achievement of equitable and sustainable growth. Crude oil is dominant in the development of the country; however, Nigeria's fossil fuel led economy is under severe pressure. Today, large hydropower plants are increasingly threatened by shrinking River Niger, shaking the security of electricity supplies. Human activities upstream, and possibly climate change constitute critical challenges in the strive to meet its energy needs. Also fuelwood remains scarce increasing the vulnerability of the poor and endangering efforts to reduce poverty. Nigeria is transiting from crude oil dependence to a less carbon intensive economy increasingly powered by gas. Gas is expected to be a major source of revenue and it will provide reliable power supply and a cleaner environment. Renewable energy and modern and more efficient conversion of biomass along with conventional energy technologies will provide opportunities to empower people and communities in meeting their energy development needs.

Energy supply infrastructure requires long time for planning and construction and is normally of long life spans. Projection of demand and supply strategies should be based on long-term horizons. A thirty-year period has been chosen for this study. Three scenarios were constructed, namely, a reference scenario which represents the most likely future development, a high growth and an optimistic scenario. The scenarios reflect trends and effects of government policies and private sector behavior.

This study is Assessment of Energy Options and Strategies for Nigeria – Energy Demand, Supply and Environmental Analysis for Sustainable Energy Development (an Emerging Economies) is to determine the provision of adequate total energy in the major sectors of the national economy, with special attention to the requirement of the National Economic Empowerment Development Strategy (NEEDS) and the Millennium Development Goals (MDGs). The study was conducted by the Energy Commission of Nigeria (ECN), under the auspices of the International Atomic Energy Agency's (IAEA) Technical Co-operation project, RAF/0/016, "Sustainable Energy Development in Sub-Saharan Africa."

1.1 Purpose of the Study

This study has been undertaken as a joint effort of the Nigerian Government and the International Atomic Energy Agency (IAEA). Each side adopted clear and well-established responsibilities:

- The Nigerian team had full responsibility for the presentation of the study, including data collection, analysis and preparation of necessary information, execution of the computer runs, interpretation of results and presentation of the draft report of the study;

- The IAEA experts provided guidance and coordination of the study as well as expertise from the collation of the initial data to the analysis of the results. An important task of the IAEA experts was to provide on-the-job training on the use of the MAED, WASP and

MESSAGE models, to transfer knowledge and experience to the counterparts and necessary methodologies and computer planning tools to Nigeria.

1.2 Objectives of the Study

The general objective of the project is to provide Nigeria with modern tools for conducting comprehensive comparative assessment of different energy options, supply options as well as total energy systems in order to identify sustainable strategies to support the expected growth in total energy demand. This is to be achieved through the acquisition and application of IAEA tools that include environment factors in the assessment of energy systems in addition to traditional economic parameters.

The objectives identified for the study were as follows:

- To project the total energy in Nigeria for the period 2005-2035 that is driven by expected demand growth for all energy sources;
- To prepare a comprehensive modeling system for analysis of energy production and energy consumption sectors;
- To perform a detailed analysis of the development of Nigerian Energy sector.
- To identify the potential role of renewable energy sources in the Nigerian energy system;
- To quantify environmental emissions of the whole energy sector associated with the expected growth of energy consumption and possible emission mitigation measures;
- To provide, by consideration of several alternative scenarios, a set of possible scenarios as input to national decision-making in the energy sector.

The scope of the study includes:

- A detailed analysis of the total energy demand;
- Assessment of future supply potential of indigenous energy resources;
- Evolution of future options for electricity;
- Formulation of alternative expansion plans for energy development;
- Assessment of environmental impacts of future electricity generation.

1.3 Organization of the Study

The staff of the Energy Commission of Nigeria (ECN) carried out the implementation of the MAED, WASP and MESSAGE model for the study. Other agencies involved in this study were the Nigerian National Petroleum Corporation (NNPC), Power Holding Company of Nigeria (PHCN), Nigerian Electricity Regulatory Commission (NERC), National Planning Commission (NPC), National Bureau of Statistics (NBS), the Nigeria Atomic Energy Commission (NAEC), the Federal Ministry Of Mines and Steel Development (FMMSD), the Federal Ministry Of Housing and Environment (FMHE) and the Central Bank of Nigeria (CBN).

The ECN provided overall coordination of the national agencies and liaised with the IAEA and its experts. The ECN was also responsible for the execution of the energy modeling using the MAED model (energy demand projection), WASP (electricity expansions) and MESSAGE (energy supply analysis) as well as for preparation of the project report. Within the project team, there were two levels of responsibilities: the Country Study Team (CST) and the Working Team and both coordinated by the Director General of the ECN. Table 1.1 provides the membership of the Country Study team while Table 1.2 shows the composition of the Working Team.

Table 1.1 Composition of the Country Study Team.

Name	National Agencies	Position
Prof. A. S. Sambo	ECN	Coordinator
J. O. Ojosu	ECN	Assistant Coordinator
E. J. Bala	ECN	Member
A.I. Nwaokoagbara	DPR	Member
A. O. Yusuf	FMMSD	Member
E. G. Ofili	NBS	Member
A. O. Yusuf	ECN/NERC	Member
A. M. Yusuf	NPC	Member
H. Famakinwa	NPC	Member
A. A. Jegede	NPC	Member
S. M. Maishanu	SERC	Member
G. Saidu	SERC	Member
M. A. Mundu	NAEC	Member
S. Lawson-Jack	NAEC	Member
J. K. F. Akinbami	CERD	Member
C. M. Olufewose	FMHE	Member
B. S. Adebusuyi	CBN	Member
E. Abutu	PHCN	Member
N. Elebe	NNPC	Member
D. Akindele	NNPC	Member
A. T. Rogo	ECN	Member
J. S. Olayande	ECN	Member
A. O. Aliyu	ECN	Member
A. S. Ahmed	ECN	Member
E. C. M. Iwollo	ECN	Member
I. U. Ibrahim	ECN	Member

Table 1.2 List of Working Team

Name	National Agencies	Position
Prof. A. S. Sambo	ECN	Coordinator
J. O. Ojosu	ECN	Assistant Coordinator
E. J. Bala	ECN	Member
A. M. Umar	ECN	Member
A. T. Rogo	ECN	Member
J. S. Olayande	ECN	Member
A. O. Yusuf	ECN/NERC	Member
A. O. Aliyu	ECN	Member
A. S. Ahmed	ECN	Member
E. C. M. Iwollo	ECN	Member
A. Abdurrahman	ECN	Member
I. H. Zarma	ECN	Member
I. U. Ibrahim	ECN	Member

1.4 Methodological Description

The comprehensive assessment of Nigeria's energy development follows an integrated approach based on assumptions derived from criteria for sustainable energy development. This top-down approach is based on assumptions about the country's economy, population and life style are combined with bottom-up disaggregated specifications and constrains about resources, fuels and technologies to develop scenarios of energy demand and optimal energy supply. The assessment process, depicted in Figure 1.1, included two major modeling components:

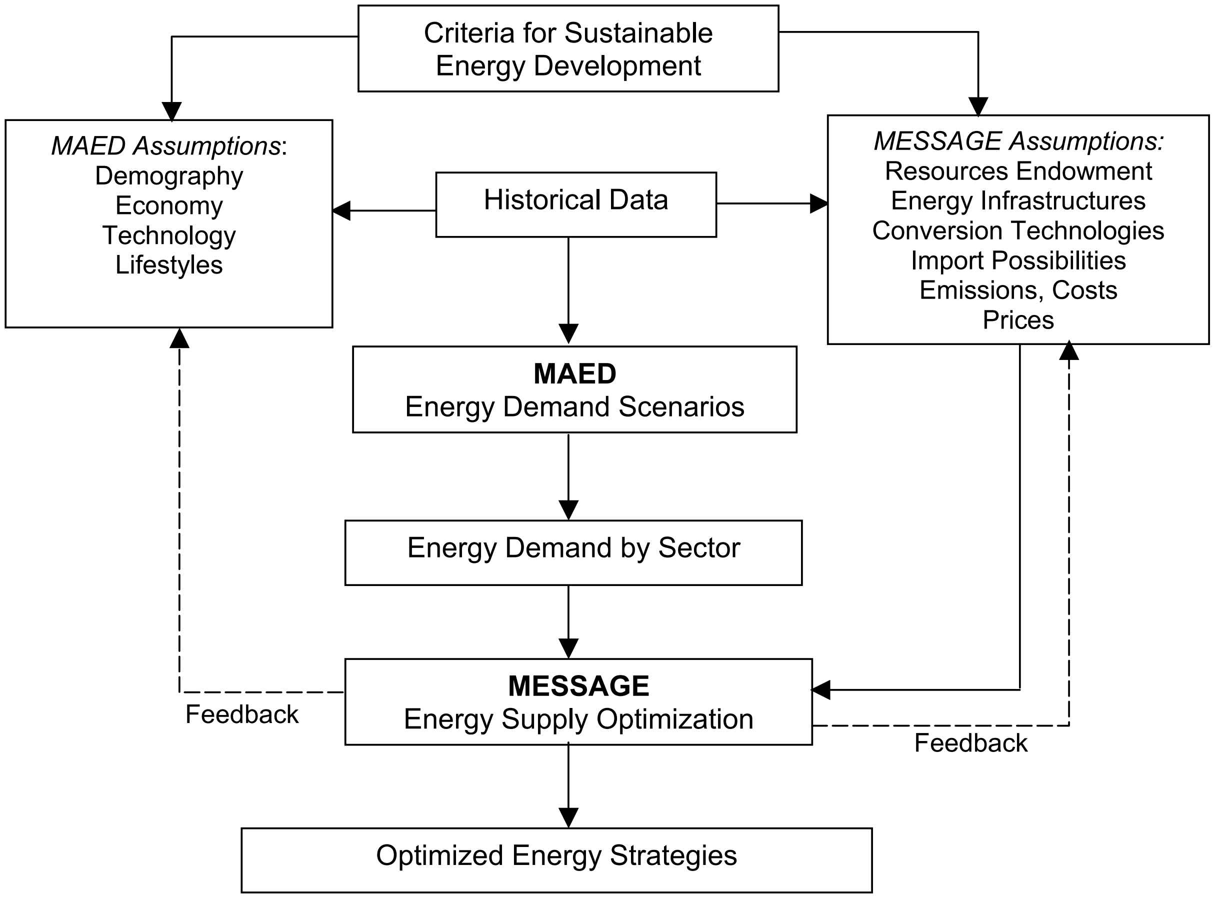

Figure 1.1 Modelling Frameworks

- *Energy demand analysis*: This provided detailed sectoral energy demand projections by applying the model of the International Atomic Energy Agency (IAEA), Model for Analysis of Energy Demand (MAED) based on numerous scenario assumptions like demography, technology progress, behavioral changes, as well as the economic and structural changes and economic growth;

- *Energy supply optimization*: This component allowed the formulation of optimal scenarios of energy supply mixes using the IAEA's Model for Energy Supply Strategy Alternatives and their General Environmental Impacts (MESSAGE), taking into consideration available resources, present energy infrastructure, current and future conversion technologies, and socioeconomic, technical and environmental (policy) constraints.

1.4.1 MAED Model

The analysis of the energy demand projection was carried out using the MAED model. MAED evaluates future energy demand scenarios based on medium to long-term assumption for socioeconomic, technological and demographic development assumptions. The MAED model allowed differentiation between energy demand for specific uses and substitutable energy demand. Energy demand is disaggregated into a number of end- use categories, each corresponding to a given service or to the production of a certain good e.g. industrial sector, transport sector, household and services sector.

The nature of and level of the demand for goods and services are a function of several determining factors, including population growth, GDP growth rates and changes of GDP structure, number of inhabitants per dwelling, number of electrical appliances used in households, peoples' mobility and preferences for transport modes, national priority for the development of certain industries or economic sectors, evolution of the efficiency of certain types of equipment, market penetration of new technologies or energy forms. The expected future dynamics for these determining factors are exogenously introduced.

The analysis and projection of total energy demand using MAED involved the following steps:

- Total final energy consumption is disaggregated into consumption by economic sector e.g. industrial, transport, household and services sectors. Energy consumption in the industrial sector is further divided into consumptions by manufacturing, mining, construction and agriculture. The energy consumption for each sector is categorized into specific energy both non-substitutable and substitutable;
- Assumptions on socioeconomic development and evolution of technologies;
- A set of scenarios, each consistently reflecting future evolution of the energy determinants is prepared;
- The establishment of relationships between the energy demand and the socioeconomic and technological factors identified for each end use category, and based on these relationships, final energy demand is calculated.

1.4.2 The MESSAGE Model

The analysis of the Nigerian energy supply system was carried out using the MESSAGE model. In MESSAGE, the whole energy supply is represented as an oriented network of technologies and activities, starting from extraction or supply of primary energy, passing through energy conversion processes, to transmission and distribution to meet the given demand for the final energy in the industry, transportation, household and services sectors. In this energy network the links represent technologies of transportation and allocation processes of energy whilst the nodes represent energy forms (e.g. electricity, oil and gas).

The principle of the model is the optimization of an objective function (least cost, lowest environmental impact and maximum sufficiency) under a set of constraints. The mathematical method used in the MESSAGE model is linear programming, which means that all technical and economic relations describing the energy system are expressed in terms of linear functions. Fuel and technologies are combined to construct energy chains, where the energy flows from supply to demand. The model variables are determined based on the system of constraints, representing structural and technological properties of the energy system, existing stock of equipment, projected energy demand, energy policies and environmental protection policies.

2. COUNTRY PROFILE

2.1 Geography and Climate

Nigeria is a tropical Sub-Saharan West African country, which lies between latitudes 4^o 1´ and 13^o 9´ North of the Equator and longitudes 2^o 2 and 14^o 30´ East. It is bounded by Benin Republic, Niger, Chad and the Cameroon to the West, North, North East and East, respectively, and by the Atlantic Ocean to the South (Figure 2.1) and occupies an area of 923,768 sq km. The vegetation starts with mangrove forests in the south, which is interspersed by a network of rivers and creeks. It transits to tropical rain forest further inland and progresses into a savannah region further north.

The climate in the southern areas is equatorial, with high humidity and rainfall. The coastal town of Port-Harcourt, for instance, has monthly minimum-maximum temperatures in the range of 18-36 ^{O}C over the year, relative humility at 9.00 am of 61-94% and at 3.00 pm of 30-86%. The average annual rainfall is about 1900 mm. The northern areas are semi-equatorial, with lower humidity and rainfall, for example Sokoto State in the Northwest Region of Nigeria. The rainfall level demarcates the seasons into two, namely, the wet and dry seasons, for instance, has monthly minimum-maximum temperatures in the range of 13-41 ^{O}C over the year, relative humility at 9.00 am of 12-85% and at 3.00 pm of 7-68%. The rainfall level demarcates the system into two; namely, the wet and the dry season. The wet season lasts over April to October, while the dry season lasts over November to March.

Solar radiation intensity varies from an annual average of 3.5 - 7.0 kWh/m^2-day, the annual average of daily sunshine hours varies from 4 - 9 hours/day. Wind speeds vary from 4.0 to 5.1m/s and 1.4 to 3.0 in the north and south, respectively. The nation is blessed with a multitude of rivers. The overall hydropower potential is estimated at 15 GW. The coal reserves are 2.75 billion tonnes for inferred and 6.39 million for proven. Crude oil reserved was estimated to be 4,500 million tonnes of oil equivalent (Mtoe), tar sand (30 billion barrels of oil equivalent), natural gas 4.5 trillion m^3 and preliminary investigations have since confirmed the availability of uranium in especially the north eastern region of the coutry but the magnitude of the reserve is yet to be quantified.

Figure 2.1 Map of Nigeria

2.2 Demography

The population of Nigeria has grown from 119 million in the 2001 to 134 million in 2005. Approximately 36% of the population lives in the urban areas (Table 2.1), the total population growth rate is about 2.83% per annum in 2005. The working population as at 2005 was about 48 million, total salaried working population was 5 million representing about 10% of the working population. Agriculture had the highest working population (29 million) followed by services (8 million), manufacturing (1 million) and construction, energy and mining having less than 1 million.

Table 2.1 Development of Population, (in thousands).

Population	**2001**	**2002**	**2003**	**2004**	**2005**
Total	118,801	122,163	125,620	129,175	133,767
Urban	43,125	44,345	45,600	46,890	48,567
Rural	75,676	77,818	80,620	82,285	85,200
Working	43,600	44,800	46,800	48,087	48,610

2.3 Macroeconomics

The Gross Domestic Product (GDP) and the percentage contributions of the various sectors of the economy over the last five years as from 2000 are shown in Tables 2.2, 2.3 and 2.4. Agriculture consistently contributed the largest share to the GDP (40.10-42.10%) over the five-year period. Of the agricultural components, namely: crop production, livestock, forestry and fishing, crop production contributed more than 80% of the share for the whole five year period. The major crops were yams, cassava, maize, guinea corn, millet, beans and groundnuts.

Table 2.2 Sectoral GDP at Constant 1990 Basic Price (N million)

Sector	2001	2002	2003	2004	2005
Agriculture	182,660.0	38,373.1	203,012.6	216,208.5	231,463.6
Construction	6,106.7	6,372.0	6,929.5	7,622.5	8,544.5
Energy	112,417.4	106,002.1	131,336.6	135,670.7	136,345.5
Manufacturing	15,191.3	16,723.7	17,669.8	19,436.8	21,305.1
Mining	1,131.3	1,180.0	1,244.3	1,379.3	1510.8
Services	114,276.4	131,138.6	134,814.3	147,258.3	159,027.4
GDP	431,783.1	451,785.7	495,007.2	527,576.0	561,931.4

Agriculture is very closely followed by services including transport (26.31-28.95%) and energy sectors (23.46-26.53%). The major contributors in the service sector were trade, government service and banking & insurance, in that order. Together, they accounted for 70-80% of GDP in the service sector. Although energy mining and energy services sector (11-14%) includes utilities, by far the dominant sub-sector was crude petroleum and gas. It accounted for over 95% of the sector's contribution to GDP. In 2005, oil and gas accounted for over 85% of income to the Federation Account and 95% of total export income. This level of dominance by oil and gas over the sector has been maintained over the years. Since 2001, the contribution of gas has been growing, very significantly, with the commencement of the production and export of liquefied natural gas.

Table 2.3 Sectoral GDP at Current Basic Prices (₦ million)

Sector	2001	2002	2003	2004	2005
Agriculture	2,412,050.7	2,755,014.7	3,231,443.6	3,903,758.7	4,541,534.6
Construction	78,601.2	94,402.7	118,557.9	166,078.5	215,786.1
Energy	2,501,390.0	2,695,930.9	4,113,965.3	4,247,716.1	5,664,883.2
Manufacturing	535,796.4	507,836.8	465,811.67	349,316.3	215,786.1
Mining	7,523.3	8,615.8	9,981.9	13,051.3	17,301.5
Services	1,359,836.7	1,733,957.4	1,973,758.5	2,731,145.30	3,916,947.60
GDP	6,895,198.3	7,795,758.3	9,913,518.9	11,411,066.2	14,572,239.1
Exchange rate Naira/US Dollar	117.7	120.5	129.4	133.5	131.6

The contribution of manufacturing to GDP was low, at about 3-4%. Of this, large scale industries accounted for over 85%. Construction and mining made the least contributions at about 2% and 0.3%, respectively. The fastest growing sector of the economy was manufacturing with an average growth of 8.84%, followed closely by construction (8.80%). The growth rates for agriculture and services were comparable at 6.10% and 5.2%, respectively. While agriculture, construction, mining, services and the total GDP (at constant 1990 factor cost) showed modest positive growth rates over 1991-2000, manufacturing and energy declined, with growth rate of -1.26% and –0.025%, respectively. Manufacturing, in particular, showed continued decline from 1991 to 1999, with a slight recovery in 2000. An important contributor to this poor performance of the manufacturing sector was the fall in actual electricity supply capacity during the same period.

The structure of the economy remained essentially the same over the period. The small gains by agriculture (2.9%), services (2.4%) and construction (0.2%) constituted losses by mining, energy (3.1%) and manufacturing (2.5%).

Table 2.4 Sectoral Share of Total GDP (%) at Constant 1990 Basic Prices

Sector	2001	2002	2003	2004	2005
Agriculture	42.1	42.14	41.02	40.10	41.20
Construction	1.41	1.41	1.40	1.44	1.52
Energy	26.04	23.46	26.53	25.72	24.26
Manufacturing	3.42	3.60	3.49	3.70	3.80
Mining	0.26	0.26	0.25	0.26	0.27
Services	26.77	29.13	27.31	28.78	28.95
Total	100	100	100	100	100

2.4 Indigenous Resource Development

2.4.1 Oil

Nigeria is an oil exporting country with significant reserve that ranks 6th in the world and is a member of Organisation of Petroleum Exporting Countries (OPEC). The oil reserve is presently estimated at 35.3 billion barrels of oil (4500Mtoe), while the production capacity is about 3 million barrels/day (mb/d). The OPEC quota restricts actual production to around 2.5 – 2.8 mb/d. The long-term policy is to continue to increase the reserve base to the highest-level possible, and increase OPEC quota in consonance with increases in reserve base and productivity.

Most of the production is from on-shore fields in the Niger Delta Basin. There's significant production, however, in the shallow and deep offshore concessions. The greater part of new fields will come from the offshore areas of the basin. The policy strategy adopted by Government for the development of the deepwater fields is to use Production Sharing Contracts and Sole Risk arrangements.

2.4.2 Natural Gas

The natural gas reserve is 4.5 trillion m^3 (4090Mtoe or 167.8EJ), composed of 53.5% associated gas and 46.5% non-associated gas. Nigeria is ranked 7th in the world gas reserves. Gas utilization has remained for below production. Of the 5.8 billion m^3 produced in 2002, 47.8% was flared. It is planned that all gas utilization projects will be based on associated gas until the latter is fully committed. The exception is the existing Nigeria Liquefied Natural Gas project, which predominantly uses non-associated gas, though it is planned to progressively increase the utilization of associated gas.

A study of natural gas utilization in the country estimated a projected demand potential of about 201 million m^3 per day by 2010 and 297 million m^3 per day by 2020, for the combined domestic and export markets, and for field use. At these utilization rates, the reserve life spans will be 55 and 35 years, respectively, so that there should be no resource constraint. The domestic market will be composed mostly of power, cement, fertilizer, steel and other projects (aluminum, petrochemicals, manufacturing and distribution). By far the largest present domestic consumer, as well as source of future potential for domestic market expansion is the power sector.

The export market potentials are in liquefied natural gas (LNG), natural gas liquids (NGL), gas to liquid (GTL), pipeline gas, and gas-based chemicals projects. Already, the Joint Venture Nigeria LNG plant at Bonny now has three producing trains. The 4th and 5th trains were to have been commissioned in 2005, while the 6th train was billed to start production in 2006, bringing the total capacity to 20.4 million tonnes/yr (27.35 billion m^3 per yr). Expansion to ten trains is envisaged in the future, while other wholly owned private sector LNG plants are being planned. The West African Gas Pipeline project is underway. It involves a concession agreement by Nigeria, Benin Republic, Togo and Ghana to pipe Nigeria gas on an offshore route from the Lagos end of the Escravos-Lagos Gas Pipeline at Alagbado to Takoradi in Ghana, with spur lines at Benin, Togo, Tema (Ghana) and Takoradi. The line may be extended to the Ghana/Cote d' Ivoire border at Effasu and later to Senegal. The pipeline capacity is to be 620 million scf/d. Preliminary considerations are being given to Nigeria-Algeria Trans Sahara Gas Pipeline, which is destined for the European market.

2.4.3 Coal

The inferred and proven reserves of coal in the country are respectively 2.75 billion tonnes and 6.39 million tonnes. It occurs in 13 states and 17 mine sites. Of these, only four mine sites have been developed, namely, Okpara and Onyeama underground mines at Enugu, Okaba surface mine in Kogi State and Owukpa underground mine in Benue State. Nigerian coals are mostly bituminous, with medium to high calorific values and so are good for power generation and for thermal applications. They are also low in sulphur and ash content and thus have a high export potential. They are mostly non-coking but can be blended with imported coal for coking use, for instance in Ajaokuta Steel Plant. Some coking coal deposits exist, however, at Lafia-Obi in Nasarawa State.

Presently, local consumption of coal is low due to loss of the power and train locomotives markets to natural gas, hydro and diesel, and due to the run down state of its other major consumer, the Nkalagu Cement factory. Due to the new focus on developing the solid minerals sector, especially with foreign and domestic private sector capital, the coal market will be re-built. The National Programme on Alternatives to Fuelwood will establish a coal briquetting plants as one of the strategies for fighting desertification and soil erosion. In all, the estimated domestic potential demand for coal is in excess of 600,000*t*/yr, while the current consumption is only about 10,000 tonnes/yr.

2.4.4 Tar Sands or Bitumen

Tar sands deposits exist in the southwest region of the country, in a belt 4.6km wide and 120km long, which runs from Edo, through Ondo and Ogun to Lagos States. It is reputed to be the second largest deposit in the world, second only to Venezuela's Dada field. At 31billion boe, the reserves are almost equal to the currently known crude oil reserves. Heavy oil for the production of bitumen or asphalt and other heavy oil fractions are obtained from the tar sands.

2.4.5 Hydro Power

Hydropower is derived from the potential energy available from water due to the height difference between its storage level and the tailwater to which it is discharged. The technical hydropower potential in Nigeria has been estimated at about 15GW, of which about 14% (1.9GW from Kainji, Jebba and Shiroro) was being utilized as at 2000 which represented some 30% of the total installed grid-connected electricity generation capacity of the country.

2.4.6 Solar Energy

Nigeria is blessed with solar radiation intensity, which varies from an annual average figure of 7.0kwh/m^2 at the extreme north to 3.5 kWh/m2 in the extreme south. These figures are more than sufficient for both thermal and photovoltaic applications.

2.4.7 Biomass Energy

The biomass resources of Nigeria consist of wood, forage grasses and shrubs, animal wastes arising from forestry, agricultural, municipal and industrial activities as well as aquatic biomass. The primary way to utilize biomass is through direct combustion. Biomass is the leading source of energy for Nigeria contributing about 37% of the total energy demand. Nigeria's estimated biomass resources are 144 million tones/year. The country is presently consuming about 43million tonnes of fuelwood annually.

2.4.8 Wind Power

Wind resources can best be exploited where the wind power density is At least 400 W/m^2 at 30m above ground. Wind speeds in Nigeria vary considerably, with the extreme North having from 4.0 to 5.12m/s and 1.4 to 3.0m/s in the southern part of the country. Nigeria was a poor/moderate wind regime. It is also observed that the wind speeds in the country are generally weak in the south except for coastal regions and offshore.

2.4.9 Uranium

Uranium ore exist mostly in the northern part of the country. It is believed that it is the same deposits that extend to Niger Republic where French companies have been mining the ore. More is required to quantify the Nigerian uranium ore.
The nation shall promote private sector participation in the electricity sub-sector, while ensuring broad-based participation of Nigerians

2.5 Energy Related Policies

The National Energy Policy is an overall energy policy document for the country, with which all other energy sub-sectoral policies must be compatible with and be derived there from. It was approved in 2003 and its 9-point objectives summarise the thrust of the policy and are as follows:

- To achieve national energy security and efficiently provide for the nation's energy needs with a diversified and optimal energy mix ;
- To guarantee increased contribution of energy production activities to national income;
- To guarantee adequate, reliable and sustainable supply of energy at appropriate costs and in an environmentally friendly manner;
- To guarantee efficient and cost effective consumption pattern of energy resources;
- To accelerate the process of acquisition and diffusion of technology and managerial expertise in the energy sector and indigenous participation in energy sector industries, for stability and self-reliance;
- To promote increased investments and development of the energy sector industries with substantial private sector participation;
- To ensure a comprehensive, integrated and well-informed energy sector plans and programmes;
- To foster international co-operation in energy trade and projects development in both the Africa region and the world at large;

- To foster international co-operation in energy trade and projects development in both the Africa region and the world at large;
- To successfully use the nation's abundant energy resources to promote international co-operation.

The policy document has provisions for the exploitation of all the nation's energy resources (oil, gas, tar sands, coal, uranium, hydropower, solar, biomass, wind, etc). It further provides for energy utilization issues namely, electricity, energy efficiency and conservation, environment, industry, agriculture, research and development etc, as well as for energy management issues such as energy financing, planning and policy implementation. With regards to power, it provides for the re-introduction of coal for power generation (especially with cleaner coal technologies), increased use of natural gas and expansion of the gas network (which should also facilitate the termination of natural gas flaring by 2008), further utilization of the balance (9GW) of large-scale hydropower potential in the country, utilization of the smaller-scale renewable energy technologies (solar, wind, micro-hydro etc), - especially for distributed, isolated and rural power supply as well as the development of nuclear power for electricity generation in the long term. Further provisions in respect of electricity include that:

- The nation shall make steady and reliable electric power available at all times, at economic rates, for economic, industrial and social activities;
- The nation shall continue to engage intensively in the development of electric power with a view to making reliable electricity available to 75% of the population by the year 2020

-The nation shall promote private sector participation in the electricity sub-sector, while ensuring broad-based participation of Nigerians.

For oil and gas, the policy provides for the increase of the reserve base, increase in value added to the natural resources, expansion of the domestic consumption and network for gas, indigenous and foreign private sector participation in addition to the deregulation and privatization of the upstream and downstream sectors of the industry.

Apart from the role envisaged in the National Energy Policy for renewable energy in rural and isolated power supply, as indicated above, the policy provides for de-emphasising the use of fuelwood but rather it promotes the use of renewable energy and other and technologies as alternatives to fuelwood. In this regard, the policy also promotes the use of smokeless coal briquettes in place of fuelwood.

2.6 Environmental Aspects

The most serious environmental problems in Nigeria are land degradation due to desertification, soil erosion, land and sea pollution due to natural gas flaring, oil spillages, oil waste leakages and discharges; atmospheric pollution from exhausts of vehicles, power plants and other combustion equipment; environmental pollution from municipal wastes and blocked gutters. Power generation has linkages to most of these aspects of environmental damage. The increased availability and use of electricity for lighting and cooking by higher and medium income households will reduce the pressure on kerosene. The latter fuel may then be more available to lower income households who may use more of it for cooking, thereby reducing the use of fuelwood and thus, reducing the latter's contribution to soil erosion and desertification.

With regards to natural gas flaring (23.9 and 27.9 billion m^3 in 2000 and 2002, respectively), government has set the target year of 2008 for its termination. Increased use of natural gas for power generation is one of the key strategies for achieving the target. Indeed, most power plants currently under construction or being planned are gas based. With a CO_2 ratio for gas, oil and coal of 1:1.43:1.95, respectively, natural gas is environmentally cleaner than oil and coal for power generation. Thus, from environmental considerations, the existing policy, which favours the use of natural gas, is in the right direction.

Environmental problems also arise from hydropower plants, though mostly of a different nature from those due to thermal power plants. They arise from the flooding of catchment areas, displacement of persons and loss of agriculture and other lands, the emission of methane and ammonia from decaying vegetable matter in flooded areas, and the growth and spread of some water borne disease vectors.

All new power plant projects are subject to Environmental Impact Assessments before approval for construction, as required by the environmental law.

3. ENERGY DEMAND ANALYSIS

3.1 Patterns of Energy Consumption

Prior to the 1960s, energy demand and consumption constituted, very predominantly, of non-commercial energy, namely, fuelwood, charcoal, agricultural wastes and residues and solar radiation. The major commercial fuel was coal, which was used by the railways and for power generation. Modest contributions came from petroleum products (petrol and diesel) and electricity (from coal and diesel generators).

The structure of energy demand has drastically changed since then. Commercial production of crude oil started in December 1957, with the first exports in 1958. Coal production peaked in 1959 and has experienced continued decline since then, due in part to the introduction of diesel power engines in the railways in the 1960s and eventual stoppage of power production from coal. The first gas turbine power plant was built at Afam, near Port Harcourt, in 1965 with an initial capacity of 56 MW. The first domestic refinery was also commissioned in Port Harcourt in 1965, with a capacity of 60,000 bpd. Furthermore, the first hydroelectric power plant, Kainji, started operations in 1968 with an initial capacity of 320 MW. These developments signaled the beginning of the change in the structure of the energy sector from coal to petroleum dominance of commercial energy. They also signaled the beginnings of the eventual dominance of the economy by the energy sector, especially by the oil and gas sub-sector. Figure 3.1 shows the consumption of primary energy source types over the period 2001 – 2005.

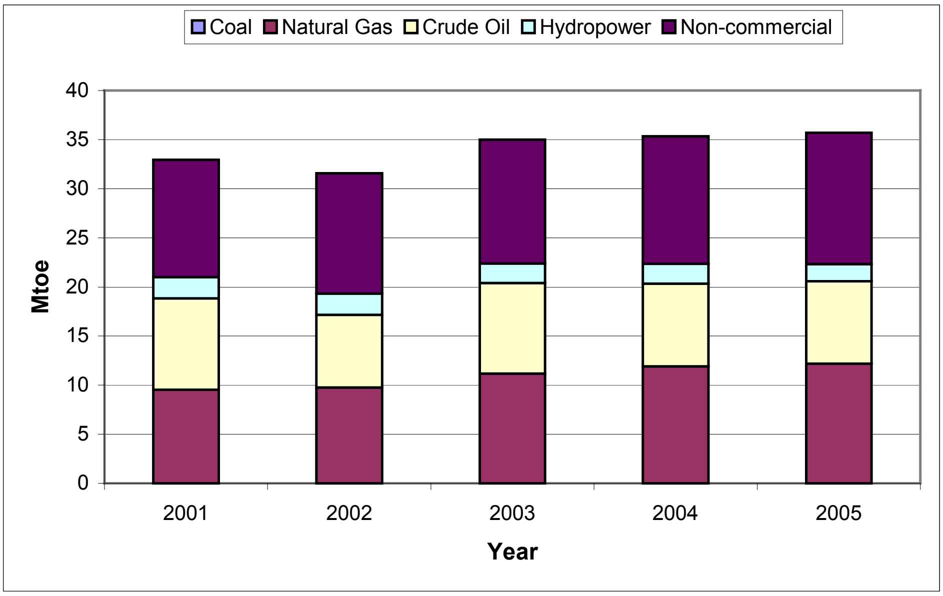

Figure 3.1 Consumption of Primary Energy Sources

Up to the end of the last decade, fuelwood and charcoal provided the single largest share of primary energy consumption in the country. Over the period 2001-2005, the share fluctuated within the range of 32-40%. About 95% of the total fuelwood consumption was used in households for cooking and for cottage industries. A smaller proportion of the fuelwood and charcoal consumed was used in the service sector (restaurants, schools, prisons, etc). The next most highly consumed primary energy resource was petroleum products (31%), consisting mostly of premium motor spirit (PMS) and automotive gas oil (AGO) generally referred to as petrol and diesel for transportation and power generation, but also including kerosene (households), aviation kerosene (transport), fuel oil (industry), liquefied petroleum gas (households), as well as lubricating oil, bitumen and asphalt (construction). By 2000 however, natural gas surpassed petroleum products and by 2005, it contributed about 34% to total primary energy consumption (next to fuelwood's 37%). Up to 1999 natural gas was mostly used for power generation. As from 2000, however, the use of the gas as feedstock for liquefied natural gas production for export became predominant. There is also an increasing use of natural gas for thermal applications (steam production) and feedstock to other industries in the manufacturing industry. Combined use of gas in LNG, power generation and industrial heating is expected to terminate gas flaring, which was 54% in 2000, by 2008. The share of oil product consumption by types in 2005 is shown in Figure 3.2.

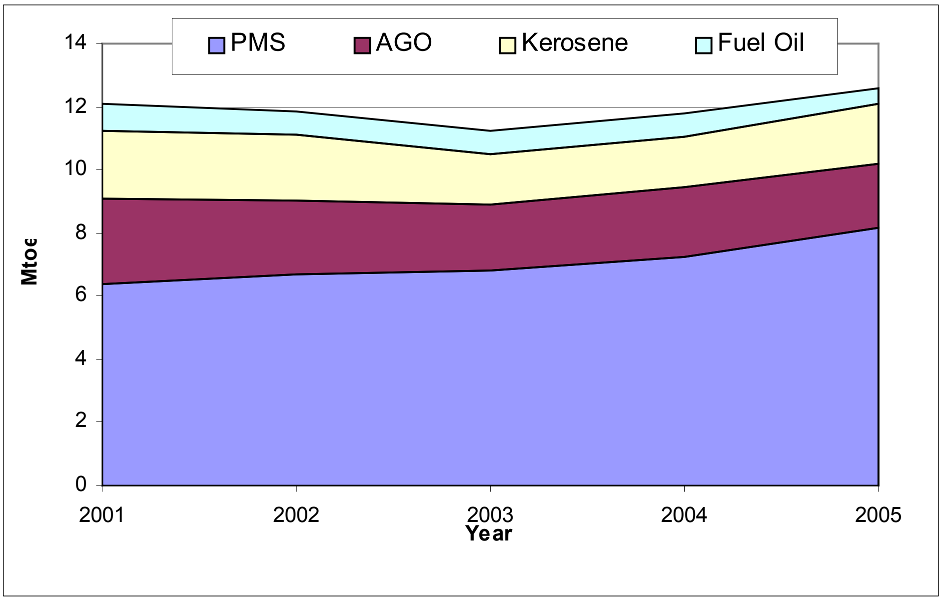

Figure 3.2 Consumption of oil Product in Nigeria.

Table 3.1 gives the GDP/capita and the intensities of energy consumption with respect to population and gross domestic product. The GDP per capita at 1990 constant factor cost recorded a general increase. There was, however, a slight recovery from 2000. The actual values did not vary much, being generally between N1040.00 and N1010.00 per capita. With the exception of 1996, 1997 and 1999, the energy consumption per capita and energy consumption per unit of GDP remained fairly constant around the averages of 0.32 toe/cap and 0.31 toe/ N'000, respectively, for the period 1991-2000. However, the values were slightly higher in the first half than in the second half of the decade. Over 1992-1994, the hydropower consumption seemed unusually high and will have contributed to the increased energy intensities for that period. With regards to the intensities for grid electricity consumption, the averages over the second halves of the last decade and first half of this decade, namely, (157.84 and 155.56 kWh/cap) and (143.36 and 121.22 kWh/N'000) differ by 7.83 kWh/cap and 18.16 kWh/N'000, respectively, and show lower values in the second half. This is due to the fact that while population and GDP grew, electricity generation and consumption stagnated in the first half of the decade and in fact showed a decrease towards the end of the decade, as shown in Table 3.1.

Table 3.1 GDP per Capita and Energy Intensities

Year	Total Energy (ktoe)	Total Grid Elect (GWh)	Energy/ Cap (toe/ cap)	Grid – Elect /cap (kWh/ cap)	Energy/GDP (toe/₦ '000)	Grid Elect/GDP (kWh/₦ '000)
2001	31591.81	17023.00	0.30	143.36	0.29	136.62
2002	35010.55	18961.00	0.32	147.53	0.31	141.25
2003	35337.07	16691.00	0.32	140.04	0.30	135.16
2004	35682.01	16855.00	0.31	129.85	0.30	123.19
2005	45606.85	16201.00	0.39	121.22	0.36	136.82

3.2 Final Energy Consumptions

The total final energy consumption in Nigeria varied between 36 Mtoe and 39 Mtoe in 2001 and 2005. Figure 3.3 shows the final energy consumed by sectors for the period under consideration

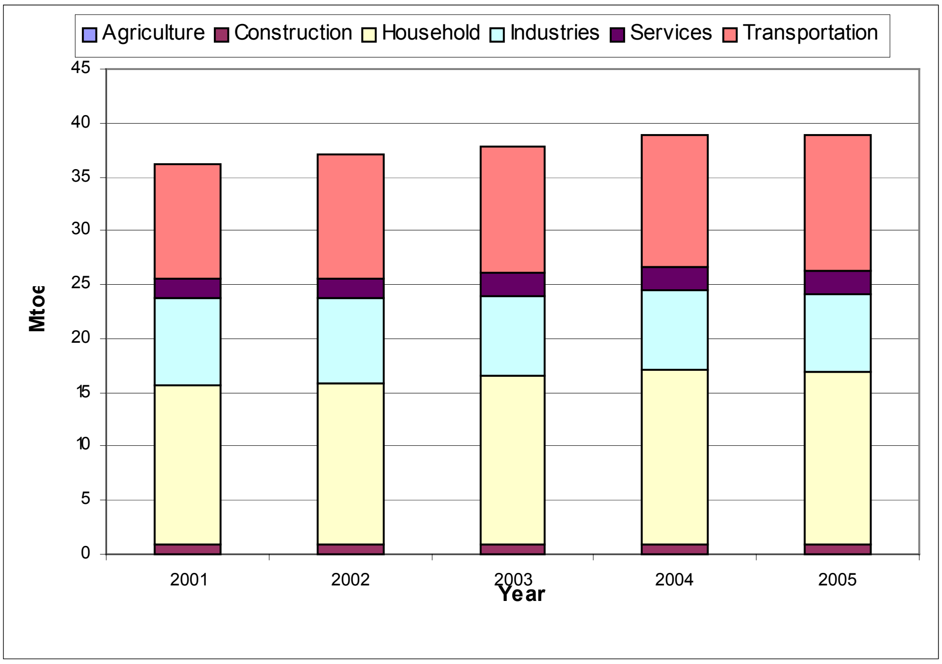

Figure 3.3 Final Energy Consumption in Nigeria

An analysis of the final energy demand by sector shows a slight increase in the share of household and transport, whilst there was slight decrease in the industrial sector (Figure 3.4). The decline in the industrial sector was due to closure of some industries, especially in 2004.

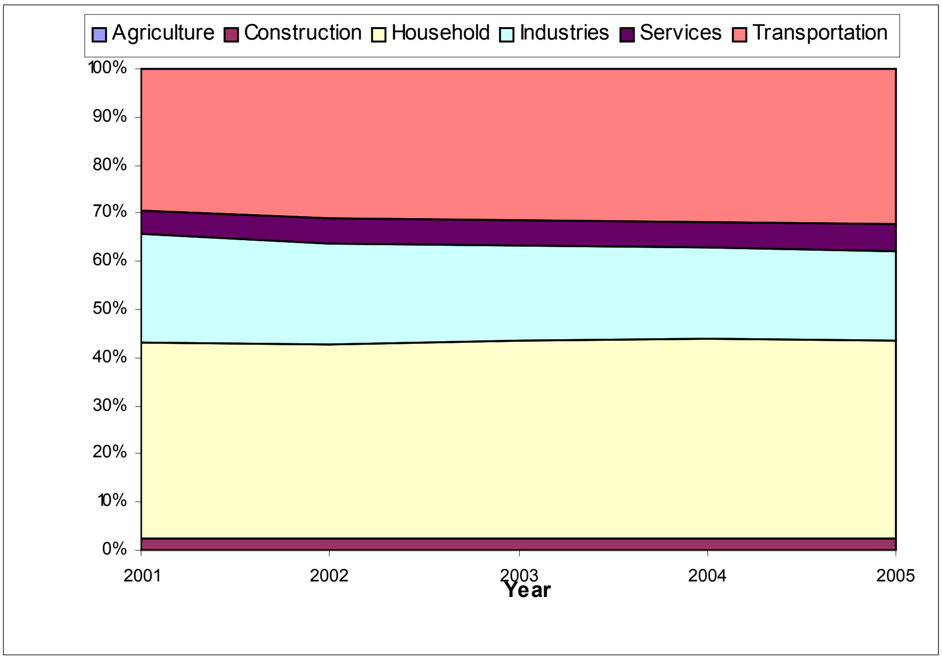

Figure 3.4 Structure of the Final Energy Consumption in Nigeria.

Analyses of final consumption of different energy forms (electricity, Motor fuel and heat) as shown in Figure 3.5, heating is contributing about 40% of the final energy, electricity and motor fuel were contributing an average of 60% between 2001 and 2005. The contribution of the electricity in the final energy forms consist of all the primary energy used in generation of electricity for the grid and self-generation. Self-generation in Nigeria accounts for a significant percentage of the electricity. Many industries relied on generators for electricity production. The energy efficiency of these generators is low; most generators have less than 30% energy efficiency. Fuelwood contributed about 98% of the heating.

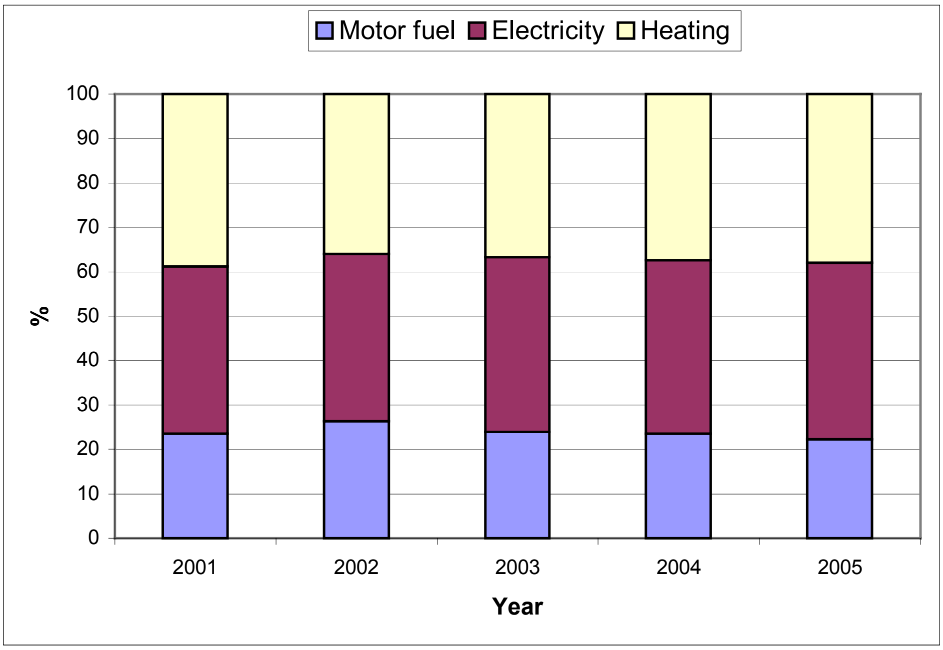

Figure 3.5 Structure of Final Energy Consumption in Nigeria by Energy Forms.

There is high-energy intensity in Nigeria; the intensity is caused by several factors which include:

- Low energy prices;
- Inefficiency of old technologies;
- Low thermal infrastructure:
- Old automobiles;
- Energy control;
- Inadequate metering of energy consumption.

Enhancement of energy efficiency is an important strategy in development of energy sector in Nigeria. Energy intensity in Nigeria increased in the period from 2001-2005. In 2005 it was 36% and the increase is attributed to the decline in economic activities in some sectors of the economy, and the significant share of the household and transport sectors in the total final energy. The dynamics of energy intensity is reflecting significant changes in energy consumption per value added, especially in agriculture, construction and services sectors.

Energy saving potential can be assessed using several indicators, such as primary energy intensity, final energy intensity, consumption per capita, e.t.c. The most commonly used indicator is primary intensity. This indicator is defined as the ratio of total primary consumption per unit of current price GDP. Comparing the energy intensity of Nigeria with other countries shows that Nigeria has higher energy intensity than the developed countries, It was noted that Russia and Ukraine have higher energy intensity than Nigeria (Figure 3.7). In comparing indicators of primary energy intensity, structural differences of energy systems like differences in generation mix, non-energy consumption, transmission and distribution losses and final energy consumption play important roles, and vary for different countries.

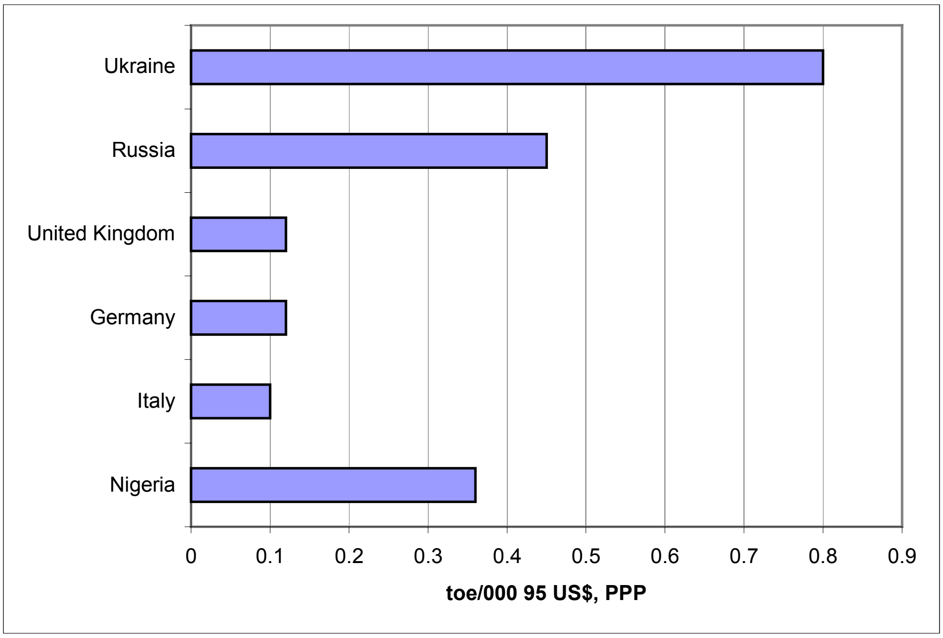

Figure 3.6 Primary Energy Intensity for Selected Countries

Energy efficiency can be improved by using modern technologies in manufacturing, as well as increased share of modern vehicles in the transport.

3.3 Socio-Economic Development

The level and structure of energy demand and supply in an economy depend on its socio-economic activities. They depend, specifically, on the driving factors or focal outputs in each activity area whose levels and technologies determine the consumption of energy, as well as on the linkages between the driving factors and the energy demand, the domestic capability to supply the energy or power demand, opportunities for imports and on the prices. The driving factors for energy demand include population, economic growth, level of production or value added, number of households, number of persons employed, floor area served in the service sector, etc. The linkages include technologies and efficiencies for energy conversion and consumption, degree of automation, penetration of the use of an energy resource, indices of standard of living (such as persons/car), fuel prices, sources of fuels (domestic or foreign), financing capability and policy constraints such as environmental regulations, emphasis or otherwise, on particular fuels. For energy demand estimates, the set of linkages (other than the constraints) for any socio-economic activity can ultimately be expressed as energy consumption intensity, i.e., energy consumption per unit of the driving factor, for that activity.

Three possible scenarios of the development of the economy were chosen based on the policy of the Nigerian government, namely:

- Reference scenario (basic or moderate economic growth);
- High growth scenario (high economic growth);
- Optimistic scenario.

3.3.1 Reference Scenario

The reference or low growth scenario was based on the possibility that the economy will evolve on the basis of 'business as usual' approach. The sectoral average growth rates recorded over the period (2001-2005) were therefore adopted for the first 5-year period of the plan. These were improved slightly over the remaining periods of the plan. The resulting overall annual growth rate for the total GDP over the plan period (2000-2030) is 7% for this scenario.

3.3.2 High Growth Scenario

The overall growth rate of the economy over the plan period, for this scenario, is 10% p.a. Since agriculture and services constituted about 40% of the GDP, each (about 80% total), their respective effective annual GDP growth rates for the plan period should not be greatly different from 10%, otherwise it would imply unrealistic growth rates for one or more of the other sub-sectors.

3.3.3 Optimistic Scenario

The Nigeria government is proposing a total GDP growth rate of 13% over (2010-2035). We consider this very challenging particularly in view of past performances of the economy. The NEEDS document targets an overall GDP growth rate for the economy of 10%, over (2000-2030) if its strategies are fully implemented with a high level of success. While this is within achievable scope, we consider it an optimistic expectation. Consequently, the total GDP growth rate of 13% p.a. was adopted here as the optimistic scenario. To realistically achieve this growth rate, however, the overall growth rates for agriculture and services have to be in the neighbourhoods of 10% p.a., for the plan period. NEEDS had proposed growth rates of 10% for agriculture and 11% for manufacturing over (2005-2007). These were equally adopted for the starting 5-year period of the plan, i.e. for (2000-2005). For agriculture, it will rise to 10% over (2010-2015), while for manufacturing it will rise to 11% over the same period. The growth rates will remain at these values, for the sectors, for the rest of the study period. The growth rate was started with 13% for construction over the initial period (2000-2005) as was the case in the reference scenario, but will decrease less rapidly than in the reference case to 8% by (2025-2030). The starting growth rate of 13% for mining was also the same as in the reference case. However, it will evolve to a higher value of 16% by (2010-2015) and remain at that value up to (2025-2030). The services sector had shown growth rates comparable to, but slightly higher than those for agriculture. The values used for this scenario ranged from 8% to 11%. The energy sector was also projected to grow more rapidly by about 0.5% to 1% than for the reference case.

These sectoral growth rates, however, agree with the adopted overall economy growth rate of 7% p.a. for the reference scenario.

3.4 Assumptions for the Scenarios

The MAED model requires the determination of the future development of the most important indicators affecting energy demand in branches of the national economy. The following are the main factors influencing the economic development:

- Demography;
- Economy Growth;
- Energy Efficiency;
- Freight and Passenger Transportation;
- Energy Consumptions.

3.4.1 Demography

The population projections were taken based on the 2006 population census. Only one demographic scenario was considered. This correspond to the reference scenario, the projections were based on assumptions regarding fertility, mortality and migration.

Table 3.2 Projections of Demographic Parameters

	2005	2010	2015	2020	2025	2030
Total Population (million)	133.7	151.7	171.8	192.2	213.1	235.3
Growth rate (%)	2.83	2.74	2.53	2.27	2.08	2.00
Urban population (million)	48.5	61.0	74.7	91.1	111.1	136.2
Urban Share (%)	36.3	40.2	43.5	47.4	52.1	57.9
Potential labour force (million)	74.89	89.50	102.48	119.73	139.23	161.24
Actual labour force (million)	42.15	49.38	57.98	68.10	79.86	93.31
Number of persons per household	5.8	5.6	5.4	5.2	5.0	4.8

The projections of potential labour force equaled the projected total population within the age range 15 years and above (Table 3.2).

The actual labour force projections were also taken from the 2006 census, but for the age range 15+. The projections depended also on the projected activity rates by age and by gender. With 2001 activity rates of 58.78 and 34.01 for males and females, respectively, the activity rates were projected at growth rates of 2.86% and 2.5% for males and females respectively. The projected labour force in the service sector was based on the reference value of 7.9 million in 2002, the growth in total labour force and the projected growth of economic activities in the service sector, relative to the total economy. The number of persons per household was also taken from the projections by the National Population Commission.

3.4.2 Economic Growth

It is assumed that average GDP growth rate during the period 2005 – 2030 will be 7% in the Reference Scenario, 10% for the High Growth Scenario and 13% for the Optimistic Scenario. Projected GDP growth in constant 1990 factor cost is presented in Table 3.3, changes of GDP structure for the three scenarios are presented in Table 3.4 and a comparison of GDP for various branches of the economy in 2030 are presented in Table 3.5. The major changes occur with manufacturing growing at the expense of agriculture in the three scenarios.

Table 3.3 GDP and Value Added in the Reference Scenario

	2005	2010	2015	2020	2025	2030
Total GDP, Bill Naira	435.70	611.09	873.23	1,247.83	1,766.58	2,477.71
GDP growth rate, %		7.00	7.40	7.40	7.20	7.00
GDP/cap, Naira	3,288.92	4,029.72	5,082.08	6,491.15	8,290.70	10,531.97
Agriculture, Bill. Naira	175.34	234.66	317.09	421.15	546.40	691.28
Construction, Bill. Naira	12.20	22.01	39.29	67.39	110.40	173.45
Mining, Bill. Naira	1.57	2.46	3.83	5.99	9.18	13.64
Manufacturing, Bill. Naira	30.29	49.49	82.51	137.27	226.13	371.66
Energy, Bill. Naira	40.74	49.49	61.13	74.49	90.10	107.78
Services, Bill. Naira	175.58	252.99	369.39	541.57	784.35	1,119.93

Table 3.4 Changes of GDP Structure by Scenario, %

	2005	2010	2015	2020	2025	2030
Reference Scenario						
Agriculture	40.2	38.4	36.3	33.8	30.9	27.9
Construction	2.8	3.6	4.5	5.4	6.3	7.0
Energy	9.4	8.1	7.0	6.0	5.1	4.4
Manufacturing	7.0	8.1	9.5	11.0	12.8	15.0
Mining	0.4	0.4	0.4	0.5	0.5	0.6
Services	40.3	41.4	42.3	43.4	44.4	45.2
High Growth Scenario						
Agriculture	39.3	35.8	31.7	27.3	23.0	19.2
Construction	2.8	3.6	4.5	5.4	6.3	7.0
Energy	9.3	7.9	6.6	5.5	4.4	3.5
Manufacturing	8.4	11.6	15.0	18.4	21.6	24.0
Mining	0.4	0.4	0.4	0.5	0.5	0.6
Services	39.8	40.7	41.8	43.0	44.2	45.7
Optimistic Scenario						
Agriculture	38.6	34.9	30.5	25.8	21.1	16.1
Construction	2.7	3.3	3.9	4.6	5.4	6.3
Energy	9.3	7.8	6.5	5.3	4.1	3.0
Manufacturing	8.4	11.6	15.0	18.4	21.6	25.0
Mining	0.4	0.4	0.4	0.5	0.5	0.6
Services	40.6	42.0	43.7	45.4	47.3	49.0

Table 3.5 Comparison of GDP and Structure in 2030

	GDP, Billion Naira			GDP Structure, %		
	Reference	High Growth Scenario	Optimistic Scenario	Reference Scenario	High Growth Scenario	Optimistic Scenario
Agriculture	691.28	1,092.20	1,575.40	27.90	19.20	16.14
Construction	173.45	398.20	614.93	7.00	7.00	6.30
Energy	371.66	1,365.26	2,440.21	4.35	3.50	3.00
Manufacturing	371.66	1365.26	2440.21	15.00	24.00	25.00
Mining	13.64	31.86	54.65	0.55	0.56	0.56
Services	1,119.93	2601.94	4782.81	45.20	45.74	49.00

3.4.3 Evolution of Energy Intensity in Industry

Energy intensities in the industrial sectors of the economy, for the Reference Scenario, are presented in Table 3.6.

Agriculture was the highest contributor to the total GDP in the base year (41.5%). However, the technologies utilized were predominantly traditional. The low level of mechanization in the sector is reflected in the low energy intensities. Construction was comparatively high in the usage of motor fuels for powering construction equipment, compared to the demand for the fuel for powering mining equipment and agricultural tractors. In manufacturing, motor fuel types would normally be required for transportation and self-generation of electricity. However, all needs for transportation fuel are accounted for under transportation, while electricity consumption includes electricity from grid supply as well as from self-generation. Hence the use of motor fuels would not feature in the manufacturing sector.

Table 3.6 Final Energy Intensity in Industry, kWh/₦

	2005	2010	2015	2020	2025	2030
Agriculture						
Motor Fuels	0.0700	0.0903	0.1087	0.1254	0.1407	0.1546
Electricity for specific uses	0.000022	0.000022	0.000022	0.000022	0.000023	0.000023
Thermal uses	0.000367	0.000482	0.000591	0.000694	0.000790	0.000881
Construction						
Motor Fuels	1.5514	1.5544	1.5586	1.5640	1.5706	1.5800
Electricity for specific uses	0.131200	0.132800	0.134965	0.137760	0.140430	0.143119
Thermal uses	0.004013	0.003967	0.003924	0.003883	0.003845	0.003809
Mining						
Motor Fuels	0.2043	0.2047	0.2053	0.2061	0.2070	0.2079
Electricity for specific uses	0.025281	0.025315	0.025346	0.025377	0.025405	0.025433
Thermal uses	0.111166	0.110464	0.109805	0.109185	0.108600	0.108047
Manufacturing						
Motor Fuels	0	0	0	0	0	0
Electricity for specific uses	0.9195	0.9242	0.9287	0.9335	0.9380	0.9424
Thermal uses	1.0563	1.0232	0.9919	0.9629	0.9351	0.9090
Electricity for specific uses						
Basic materials	1.2568	1.2662	1.2751	1.2834	1.2912	1.2987
Machines/equipment	0.7688	0.7746	0.7800	0.7851	0.7899	0.7945
Non-durables	0.7475	0.7420	0.7368	0.7320	0.7276	0.7234
Thermal uses						
Basic materials	1.8096	1.7400	1.6756	1.6157	1.5600	1.5080
Machines/equipment	0.6227	0.6127	0.6030	0.5935	0.5844	0.5755
Non-durables	0.7087	0.6814	0.6562	0.6327	0.6109	0.5905

Energy intensities in manufacturing at 0.9154 kWh/₦ and 1.2487 kWh/₦, for specific electricity and useful thermal energy, respectively, were expectedly higher than for the other industrial sectors. Within manufacturing, the basic materials sub-sector had the highest intensity of consumption of electricity, but its specific consumption of thermal energy was surprisingly lower than for machines and equipment sub-sector. It is noted, however, that the large iron and steel plants (Ajaokuta and Delta) and the aluminium plant at Ikot Abasi, which would have contributed highly to thermal energy consumption, were non-functional in 2005. This fact was taken into consideration in the construction of the scenarios.

3.4.4 Freight and Passenger Transportation

The important changes in the transport sector are related to the increase of total activity and mobility of the population (Table 3.7).

Table 3.7 Development of Freight and Passenger Transportation

	2005	2030		
		Reference Scenario	High Growth Scenario	Optimistic Scenario
Freight, billion tkm	92.52	450.00	991.41	1594.24
Passenger intracity, billion pkm	122.55	401.84	409.42	515.59
Passenger intercity, billion pkm	194.85	497.29	537.07	565.03

Freight activity is composed of truck (road transport), train and pipeline, since barge transport was not accounted for. Freight activity is projected to be 3.86, 9.72 and 16.23 times the base year value of 92.52 billion tkm, respectively for the Reference, High Growth and Optimistic Scenarios by 2030. This is so because of high industrial activity, which requires movement of raw materials to production centres as well as transport of products to consumption centres. It is also assumed that the railway system would be revitalized leading to increase in the share of railway in freight transport. Vandalization of pipelines carrying crude, petroleum products and natural gas around across the country as a result of poverty and community agitations would have been eliminated, thereby paving way for increased use of pipelines for transport of fluids, taking advantage of the cost effectiveness in relation to other transport modes. Passenger intracity transport is expected to increase by 2.28, 2.34 and 3.21 times the base year value of 122.55 billion pkm, respectively, for the Reference, High Growth and Optimistic Scenarios by 2030. For intercity passenger transport, increases of 1.55, 1.76, and 1.90 times the base year value of 194.85 billion pkm are expected for the Reference, High Growth and Optimistic Scenarios respectively. While increases are expected to result from higher income levels, increased business and social activities, improvements in availability and effectiveness of information and communication facilities would equally reduce mobility.

3.4.5 Specific Energy Consumption in the Household Sector

Energy in the households is used mostly for thermal applications, lighting and as specific electricity for lighting and for appliances. A range of alternative fuels can provide the thermal energy needs. Hence computations of the energy demand were done firstly at the level of useful energy and then aggregated from different energy carriers, before these were reconverted to final energy. The energy demand, expressed in the form of useful energy, permits policy decisions to be easily made on the preferred use of particular fuels or energy carriers, to meet thermal energy demands.

Various factors influence energy consumption in the household sector. These include size and number of persons per dwelling, energy prices, improvement in quality and standards of living, income level, efficiencies of the energy consuming devices, etc. Some factors increase energy consumption, while others decrease it. The development of energy consumption per dwelling for the Reference Scenario is presented in Table 3.8.

Table 3.8 Energy Intensities in Households (Reference Scenario), kWh/dwelling/year

Factors for existing buildings		2005	2010	2015	2020	2025	2030
Cooling requirements	kWh/dw/yr	3220.00	3310.00	3393.00	3463.00	3517.00	3587.00
Dwellings with AC	%	12.80	15.30	18.30	21.90	26.20	31.30
Factors for existing buildings							
Cooling requirements	kWh/dw/yr	3220.00	3310.00	3393.00	3463.00	3517.00	3587.00
Dwellings with AC	%	16.70	21.50	27.10	30.30	32.10	33.00
Factors for old & new buildings							
Cooling requirements	kWh/dw/yr	3220.00	3310.00	3393.00	3463.00	3517.00	3587.00
Cooking	kWh/dw/yr	564.95	514.01	471.50	435.48	404.57	377.77
Electricity consumption per dwelling	kWh/dw/yr	1632.21	1895.92	2204.38	2565.39	2988.10	3483.30
Water heating	kWh/dw/yr	387.97	407.52	428.13	449.79	472.45	496.05

It is assumed that the cooling requirements will be the same for existing buildings and those constructed after the base year. However, the percentage of dwellings with air-conditioners are expected to increase from 10.7% in the base year to 31.3% for existing buildings and 33% for buildings constructed after the base year as a result of increased income levels. Indicators of energy consumption in the household sector are presented in Table 3.9

All dwellings are assumed to use hot water at one time or the other during the year in the country, especially during harmattan in the northern part of the country and during the rainy season in the south. By 2030, energy requirement for water heating is projected to increase by 1.7, 2.3 and 3.2 times the base year value of 61.6kWh/dw/a for the Reference, High Growth and Optimistic Scenarios.

Table 3.9 Indicators of Energy Consumption in the Household Sector

	Unit	2005	2010	2015	2020	2025	2030
Electricity penetration	%	46.0	72.0	86.0	93.3	94.0	95.0
Electricity consumption per dwelling							
Reference Scenario	KWh/dw/yr	1632.21	1895.92	2204.38	2565.39	2988.10	3483.3
High Growth Scenario	KWh/dw/yr	2006.0	2863.6	4540.0	5310.0	5630.0	5630.0
Optimistic Scenario	KWh/dw/yr	2470.0	3730.0	5230.0	6170.0	6630.0	6600.0
Electricity penetration into cooking							
Reference Scenario	%	3.90	4.95	6.71	8.60	8.86	8.8
High Growth Scenario	%	3.9	5.37	8.0	10.8	11.5	11.5
Optimistic Scenario	%	3.9	5.37	8.0	10.8	11.5	11.5
Penetration into cooking							
Noncommercial	%	72.12	66.70	59.70	49.10	36.70	15.00
Fossil - High Growth Scenario	%	23.98	28.35	33.59	42.30	54.44	76.20
Fossil - Optimistic Scenario	%						
Hot water per capita							
Reference Scenario	kWh/cap/yr	66.9	72.8	79.3	86.5	94.5	103.3
High Growth Scenario	kWh/cap/yr	75.5	92.6	111.0	134.9	139.0	139.0
Optimistic Scenario	kWh/cap/yr	80.0	99.0	132.6	187.0	202.0	198.0
Fossil Fuels (FF) for lighting							
FF per dw for lighting	kWh/dw/yr	650.00	600.00	600.00	600.00	600.00	600.00
Dwellings with FF for lighting	%	87.50	72.40	64.00	56.60	50.70	45.00

Electricity consumption per dwelling, from both grid and non-grid sources, was estimated as 1406.65kWh in the base year and about 40% of the value is used for lighting, 20% for appliances, 18% for water heating and 16% for air-conditioning. Cooking accounted for about 3%. Electricity consumption is projected to increase by 2.5, 4.0 and 5.0 times the base year value in 2030 for the Reference, High Growth and Optimistic Scenarios respectively. It is projected that electricity would account for about 9% of the total cooking energy requirements by 2030 for the Reference Scenario and about 12% for both the High Growth and Optimistic Scenarios. Fossil fuels which accounted for about 23% of the cooking energy requirements is projected to increase to 76% in 2030 for the Scenario and 73% for both the High growth and Optimistic Scenarios. The contribution on non-commercials (mainly fuelwood) to cooking energy in the base year was about 74%. It is assumed that with increased income levels, drive to reduce deforestation and desertification, and government policy of utilizing the abundant natural gas resources in the country, the contribution would be brought as low as 15% for each scenario by 2030.

About 87.5% of households use kerosene for lighting in the country. The proportion is projected to reduce to 45% by 2030 for the three scenarios with the quantity involved reducing from 700kWh/dw/a to 600kWh/dw/a for each scenario.

3.4.6 Indicators of Energy Consumption in the Services Sector

Energy consumption in the service sector is dependent on the increase of total floor area and changes of specific energy consumption per m^2. Assumptions about development of the main factors influencing energy demand are presented in Table 3.10. The main assumptions are:

- The floor area of the service sector would increase from 368million m^2 in 2000 to 1200million m^2 in 2030 for the three scenarios;
- Electricity requirements of old floor space would increase from 20.9 kWh/sqm/yr in 2000 to 43.6, 53.2 and 63.8 kWh/sqm/yr for the Reference, High Growth and Optimistic Scenarios respectively in 2030;
- Electricity requirements of new floor space would increase from 19.4 kWh/sqm/yr in 2000 to 68, 71 and 75 kWh/sqm/yr for the Reference, High Growth and Optimistic Scenarios respectively in 2030;
- Cooling requirements would increase from 115.1kWh/sqm/yr to 300, 320 and 345 kWh/sqm/yr.

Table 3.10 Indicators of Energy Consumption in the Service Sector

	Unit	2005	2010	2015	2020	2025	2030
Floor area of SS	mill sqm	461.89	565.03	682.79	833.24	1002.67	1200.00
Electricity requirements of old floor space							
Reference	kWh/sqm/yr	22.9	29.1	39.2	42.6	43.6	43.6
High Growth Scenario	kWh/sqm/yr	22.9	33.6	44.0	51.0	53.8	53.2
Optimistic Scenario	kWh/sqm/yr	22.9	38.0	51.0	60.4	64.4	63.8
Electricity requirements of new floor space							
Reference	kWh/sqm/yr	24.0	28.3	37.7	54.0	64.4	68.0
High Growth Scenario	kWh/sqm/yr	24.0	30.2	40.9	58.7	67.8	71.0
Optimistic Scenario	kWh/sqm/yr	24.0	32.0	46.0	62.2	70.8	75.0
Cooling requirement							
Reference	kWh/sqm/yr	135.0	167.0	200.0	238.0	270.0	300.0
High Growth Scenario	kWh/sqm/yr	135.0	176.0	226.0	268.0	297.0	320.0
Optimistic Scenario	kWh/sqm/yr	135.0	194.0	252.0	296.0	320.0	345.0

3.5 Energy Demand Projections

3.5.1 Total Final Energy Demand

The total final energy demand will grow from 30.42 million toe (Mtoe) in the base year to 120.28, 256.81 and 373.22 Mtoe in 2030, for the reference, high growth and optimistic scenarios, respectively. The values include kerosene (fossil fuel) demand for lighting mostly in households and the service sector. The growth rates of the total final energy demand over the period 2000-2030 are 4.7%, 7.4% and 8.7% p.a., for the, reference, high growth and optimistic scenarios respectively. The trends are shown in Table 3.11 and Figure 3.7. The increase in the growth rates of energy demand for the reference, high growth and optimistic scenarios are due to additional energy requirements for increased economic activities especially with manufacturing sector making more contributions, increasing access to electricity by all the sectors of the economy, increasing mechanization and automation of the industrial sectors.

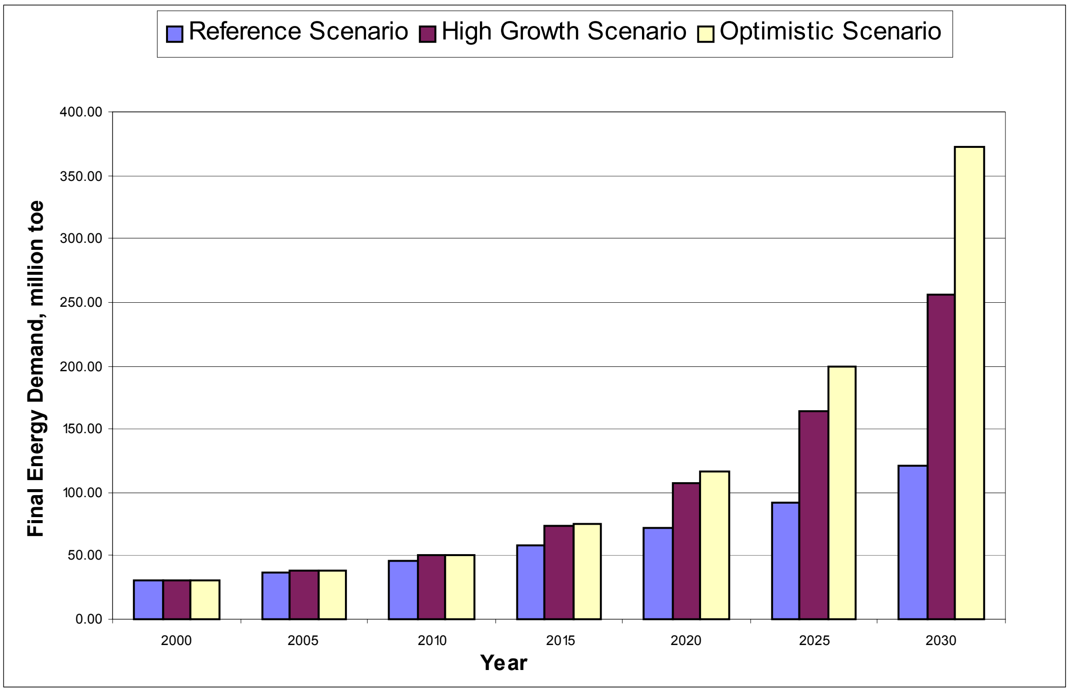

Figure 3.7 Total Final Energy Demand, Year

Table 3.11: Total Commercial and Non-Commercial Final Energy Demand, million toe

Energy Carrier Category / Scenario	Final Energy, million toe				Average growth rate, %			Overall Growth rate, %
	2000	2010	2020	2030	2010	2020	2030	2000-2030
Total Final Energy Demand								
Reference	30.42	44.37	69.67	120.28	3.79	4.82	5.83	4.7
High Growth	30.42	50.75	106.94	256.81	5.81	7.98	9.43	7.4
Optimistic	30.42	52.25	119.36	373.22	6.30	8.86	13.28	8.7
Commercial Final Energy Demand								
Reference	17.72	30.54	59.98	115.90	5.60	6.98	6.81	6.5
High Growth	17.72	35.38	94.93	251.47	7.16	10.37	10.23	9.2
Optimistic	17.72	37.38	107.48	368.03	7.75	11.14	13.10	10.6
Non-commercial Final Energy Demand								
Reference	12.70	15.37	12.00	5.34	1.92	-2.44	-7.78	-2.8
High Growth	12.70	14.87	11.87	5.19	1.59	-2.23	-7.95	-2.9
Optimistic	12.70	13.83	9.69	4.38	0.85	-3.50	-7.63	-3.5
Shares of Commercial Final Energy, %								
Reference	58.24	68.83	86.09	96.36				
High Growth	58.24	69.72	88.77	97.92				
Optimistic	58.24	71.53	90.05	98.61				

Of the total final energy demand of 30.42mtoe in the base year, commercial energy constituted 17.72mtoe or 58.24%, while non-commercial energy (fuelwood and charcoal) constituted the balance of 12.70Mtoe (41.76%). By 2030, the share of commercial energy will have risen significantly to 96.36%, 97.92% and 98.61% for the reference, high growth and optimistic scenarios, respectively. The changing values of these components are presented in Table 3.11 and Figure 3.8. While commercial energy shows positive growths in all scenarios, non-commercial energy will rise between 2005 and 2010 for the three growth scenarios and then decline in all cases, with the highest decline being experienced in the optimistic scenario. The initial rise in non-commercial energy demand is attributable to the fact that there is inadequate supply of commercial energy, especially electricity and it would take some time to bridge the gap. Economic growth will certainly affect the transition from traditional fuels to commercial fuels (fuelwood and charcoal to kerosene, coal, LPG, electricity and solar), especially for cooking and water heating in the household and services sectors. The change over will be least for the reference scenario and highest for the optimistic case. The very significant decline in the quantum and share of non-commercial energy will require a vigorous and concerted programme in the provision of alternatives.

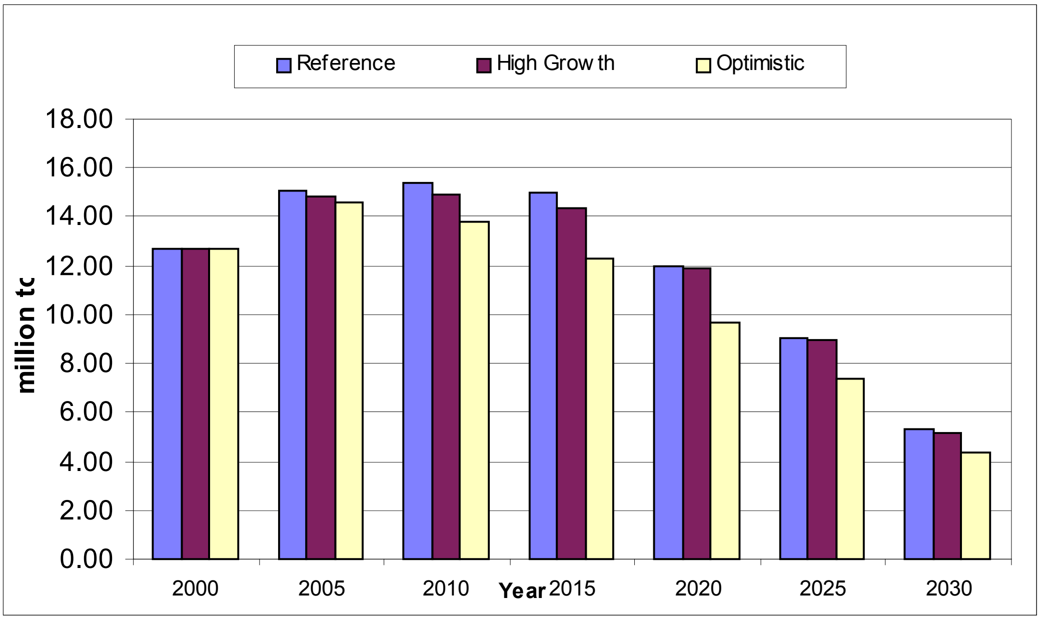

Figure 3.8 Non-Commercial Final Energy

3.5.2 Energy and Non-energy Components of Commercial Final Energy

Energy and non-energy applications of energy sources are presented in Table 3.12. The total commercial energy consumption in the base year was 17.72mtoe (or 97.49%) while non-energy applications amounted to 0.46mtoe (or 2.51%). The major energy use of commercial energy sources in that year was for power generation, road and air transportation as well as household and services sector uses. Non-energy use included natural gas for the production of fertilizer, petrochemicals, LPG use as propellant in aerosols (insecticides and perfumes) manufacture and kerosene for cleaning in pharmaceutical and dyeing in textile, industries. By 2030, the share of energy uses will have increased marginally to 98.19%, 97.33% and 97.38% for the reference, high growth and optimistic scenarios respectively, with corresponding decreases in the share of non-energy applications. A very large quantity of natural gas (5730 million standard cubic meters in 2005) is used for the production of LNG and natural gas liquids for the export market. This is however treated separately in the study. The dominant non-energy use in the future will be feedstock of natural gas for LNG, NGL, and GTL for the export market and fertilizer and petrochemicals production.

Table 3.12 Energy and Non-Energy use of Commercial Final Energy Demand (million toe)

Energy Carrier Category / Scenario	2000	2010	2020	2030	2010	2020	2030	2000-2030
	Commercial Final Energy for Energy Uses				Av. growth rate, %			Overall g.r. %
Reference	17.26	29.94	58.97	113.77	5.66	7.01	6.79	6.49
High Growth	17.26	34.67	92.99	244.56	7.22	10.37	10.15	9.24
Optimistic	17. 26	36.65	105.32	358.12	7.82	11.13	13.02	10.64
Commercial Final Energy for Non-Energy Uses								
Reference	0.46	0.60	1.01	2.13	2.75	5.38	7.73	5.27
High Growth	0.46	0.71	1.94	6.91	4.54	10.55	13.52	9.47
Optimistic	0.46	0.72	2.17	9.91	4.66	11.65	16.42	10.80
Shares of Energy Use, %								
Reference	97.49	98.08	98.34	98.19				
High Growth	97.49	98.03	98.00	97.33				
Optimistic	97.49	98.11	98.02	97.38				

3.5.3 Final Energy Demand Per Capita

Per capita total, commercial and non-commercial energy demands are presented in Table 3.13, and Figures 3.9, 3.10 & 3.11. The per capita total energy demand will increase from 264.06kgoe/cap to 511.29, 1091.65 and 1586.50 for the reference, high growth and optimistic scenarios by 2030 respectively. While commercial energy demand per capita shows strong positive overall growth rates of 3.96%, 6.68% and 8.04% for the reference, high growth and optimistic scenarios, respectively, from the base year value of 153.79kgoe/cap, the non-commercial energy demand will continuously decline for all scenarios, over the plan period.

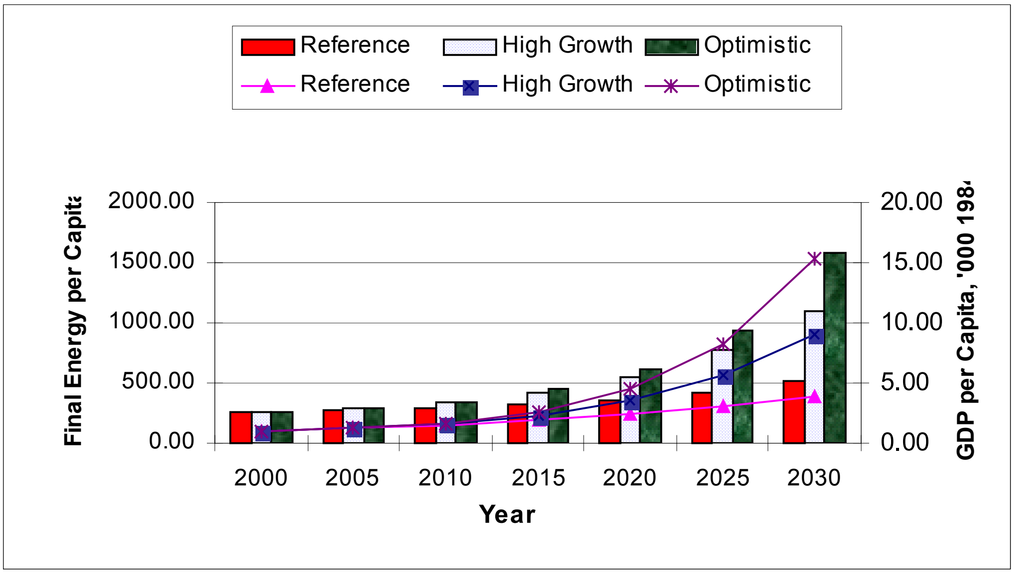

Figure 3.9 Total Final Energy and GDP per Capital

Table 3.13 Per capita Energy Demand

Scenario	Total per capita Final Energy Demand, kgoe					GDP/cap ('000₦/cap)				
	2000	2010	2020	2030	Overall g.r.	2000	2010	2020	2030	Overall g.r.
Reference	264.06	292.61	362.43	511.29	2.23	1.05	1.49	2.40	3.90	4.48
High Growth	264.06	334.66	556.29	1091.65	4.84	1.05	1.57	3.53	8.96	7.42
Optimistic	264.06	344.55	620.90	1586.50	6.16	1.05	1.68	4.52	15.37	9.37
Commercial per capita										
Reference	153.79	201.41	312.03	492.68	3.96					
High Growth	153.79	233.32	493.85	1068.94	6.68					
Optimistic	153.79	246.47	559.14	1564.45	8.04					
Non-commercial per capita										
Reference	110.26	101.34	62.45	22.70	-5.13					
High Growth	110.26	98.08	61.76	22.05	-5.22					
Optimistic	110.26	91.20	50.40	18.62	-5.76					

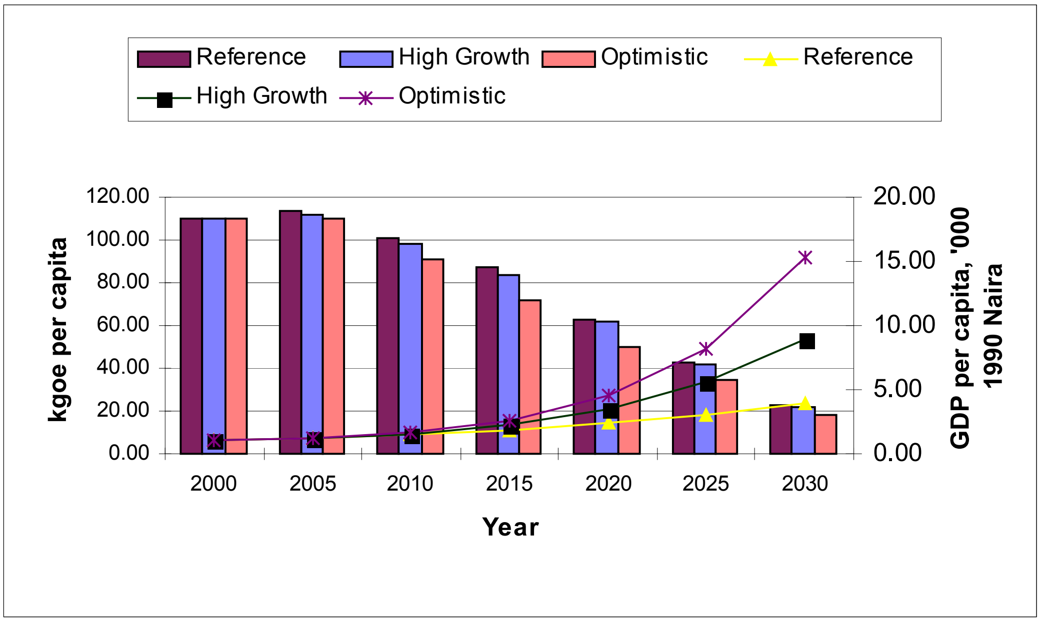

Figure 3.10 Commercial Energy and GDP per Capita.

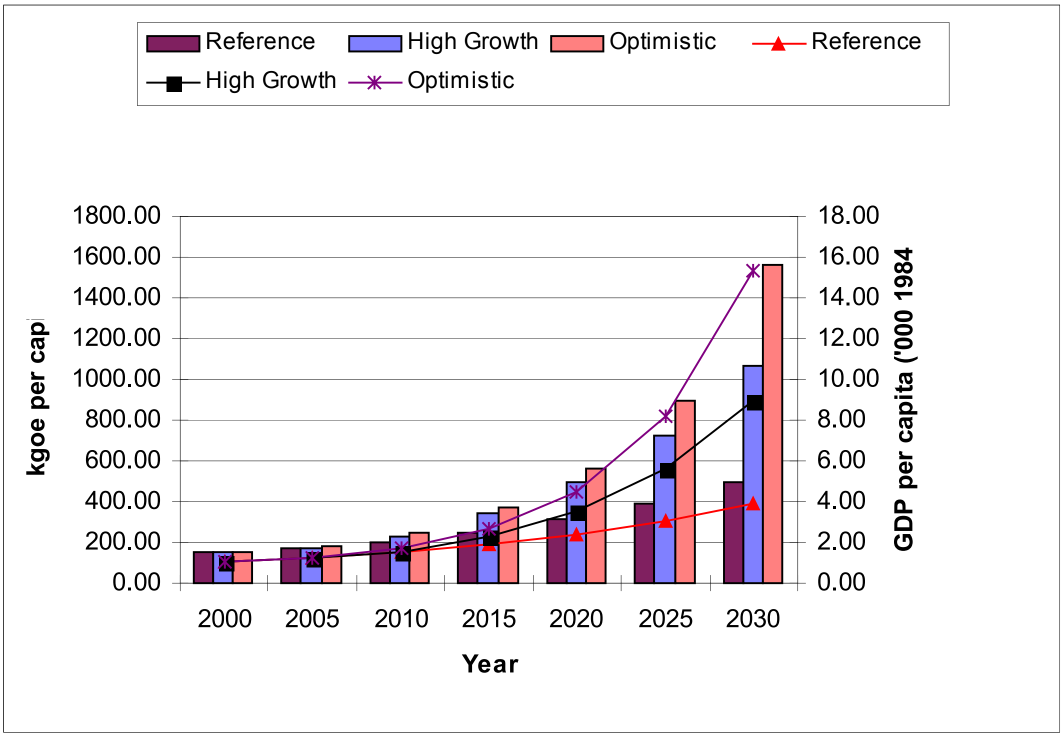

Figure 3.11 Non-Commercial Energy and GDP per Capita.

3.5.4 Income Elasticity of Final Energy Demand

The income elasticity of energy demand for energy measures the responsiveness of the quantity of energy demanded to the income level of the population. This is estimated using the ratio of energy demand growth rate to GDP growth rate, as shown in Table 3.14.

Thee fact that the income elasticity of energy demand is generally less than unity in all scenarios underscores the importance of energy as a necessity for socio-economic development.

Table 3.14 (a) Income Elasticity of Energy Demand (a) Total Final Energy Demand

	2000-2010	2010-2020	2020-2030	2000-2030
Growth Rates of Total Final Energy, % p.a.				
Reference	4.20	4.60	5.35	4.72
High Growth	5.15	7.83	9.16	7.37
Optimistic	5.34	8.63	12.26	8.71
GDP growth rates, % p.a.				
Reference	6.50	7.40	7.10	7.00
High Growth	7.04	11.04	12.00	10.00
Optimistic	7.78	13.04	15.32	12.00
Income Elasticity				
Reference	0.65	0.62	0.75	0.67
High Growth	0.73	0.71	0.76	0.74
Optimistic	0.69	0.66	0.80	0.73

Table 3.14 (b) Commercial Final Energy Demand for All Uses

	2000-2010	2010-2020	2020-2030	2000-2030
Growth Rates of Commercial Final Energy, % p.a.				
Reference	5.6	6.98	6.81	6.5
High Growth	7.16	10.37	10.23	9.2
Optimistic	7.75	11.14	13.1	10.6
Income Elasticity				
Reference	0.86	0.94	0.96	0.93
High Growth	1.02	0.94	0.85	0.92
Optimistic	1.00	0.85	0.86	0.88

Table 3.14 (c) Commercial Final Energy Demand for Energy Uses

Growth Rates of Commercial Final Energy, % p.a.	2000-2010	2010-2020	2020-2030	2000-2030
Reference	5.66	7.01	6.79	6.49
High Growth	7.22	10.37	10.15	9.24
Optimistic	7.82	11.13	13.02	10.64
Income Elasticity				
Reference	0.87	0.95	0.96	0.93
High Growth	1.03	0.94	0.85	0.92
Optimistic	1.00	0.85	0.85	0.89

Table 3.14 (d) Commercial and Non-Commercial Final Energy Demand for Energy Uses

Growth Rates of Commercial and Non-Commercial Final Energy Demand for Energy Uses, % p.a.	2000-2010	2010-2020	2020-2030	2000-2030
Reference	4.22	4.59	5.31	4.71
High Growth	5.16	7.79	9.07	7.32
Optimistic	5.35	8.58	12.17	8.66
Income Elasticity				
Reference	0.65	0.62	0.75	0.67
High Growth	0.73	0.71	0.76	0.73
Optimistic	0.69	0.66	0.79	0.72

3.5.5 Final Energy Demand by Energy Form

Table 3.15 presents various forms of the projections of total final energy demand by energy form for the three scenarios. The shares are plotted in Figure 3.12. In the base year, non-commercials provided the highest energy demand with 12.70 mtoe (out of 30.42 mtoe), which constituted a share of 41.76%. Motor fuels followed fairly closely with 10.46mtoe or 30.1%. Fossil substitutable provided 3.53mtoe (11.60%) while electricity and coke/steam coal gave 3.19 mtoe (10.50%). Soft solar made no significant contribution in that year. For soft solar, only the energy from commercial or engineered solar technologies was considered. This excluded the open-to-sun or natural use of solar radiation, which, nevertheless, provided a substantial part of the energy for the drying of agricultural products (and of course for photosynthesis). Figure 3.12 shows the projections of the various energy forms for the reference scenario.

Table 3.15 Distribution of Final Energy Demand by Energy Form, Mtoe

Scenario / Energy Form	2000	2005	2010	2015	2020	2025	2030
Reference							
Total	30.42	37.27	45.91	57.74	71.99	92.27	121.24
Non-commercial	12.70	15.04	15.37	14.97	12.00	9.05	5.34
Electricity	3.19	4.86	8.56	13.86	21.30	30.78	43.84
Soft solar	0	0	0.00	0.01	0.03	0.06	0.09
Fossil	3.53	4.38	5.76	8.28	12.06	17.58	25.89
Motor fuels	10.46	12.31	15.30	19.27	24.53	31.47	40.68
Coke + Steel Coal	0.09	0.17	0.31	0.59	1.04	1.89	3.27
Feedstock	0.46	0.51	0.60	0.75	1.01	1.44	2.13
High Growth							
Total	30.42	38.03	50.26	72.85	106.81	163.52	256.65
Non-commercial	12.70	14.80	14.87	14.38	11.87	8.94	5.19
Electricity	3.19	5.37	11.21	22.35	36.81	56.09	85.00
Soft solar	0.00	0.00	0.00	0.02	0.05	0.09	0.12
Fossil	3.53	4.76	7.29	12.66	22.99	42.31	75.08
Motor fuels	10.46	12.35	15.70	21.21	30.58	46.47	72.23
Coke + Steel Coal	0.09	0.21	0.47	1.13	2.56	5.92	12.14
Feedstock	0.46	0.54	0.71	1.10	1.94	3.69	6.91
Optimistic							
Total	30.42	38.07	51.21	75.38	117.17	198.54	372.41
Non-commercial	12.70	14.60	13.83	12.29	9.69	7.40	4.38
Electricity	3.19	5.68	12.89	24.97	42.12	68.48	120.20
Soft solar	0.00	0.00	0.00	0.02	0.05	0.09	0.11
Fossil	3.53	4.74	7.38	13.55	26.48	54.49	117.86
Motor fuels	10.46	12.30	15.90	22.18	33.74	56.25	102.22
Coke + St Coal	0.09	0.21	0.48	1.22	2.93	7.35	17.72
Feedstock	0.46	0.53	0.72	1.16	2.17	4.49	9.91

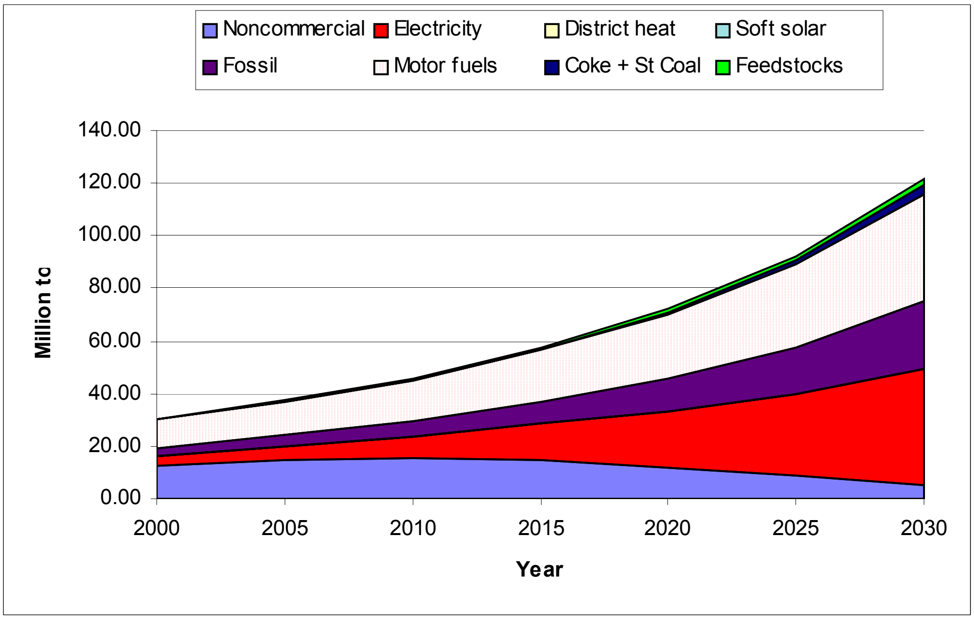

Figure 3.12 Final energy Demand by Energy form.

3.5.6 Final Energy Demand by Sector

Table 3.16 shows the amounts of total final energy demand by the various sectors. For the reference case, the demands will vary over the plan period from 2.84 to 47.88 mtoe, for industry, 9.91 to 28.48 mtoe, for transport, 13.71 to 28.56mtoe for households and 3.97 to 16.33 mtoe for services. All sectors indicate strong positive growths. The fastest growing sector is industry (agriculture, construction, mining and manufacturing) with overall annual growth rates of 9.87%, 14.26% and 16.10% for the reference, high growth and optimistic scenarios. These growths will have been dominated by energy demand in the manufacturing sector, whose energy use far outweighs those of agriculture, construction and mining and due to the fact that each scenario assumed industrialisation of the country with the manufacturing sector as the driver. Figure 3.13 shows the projections of energy demand by sector.

Table 3.16 Final Energy Demand by Sector (Mtoe)

	2000	2005	2010	2015	2020	2025	2030	Overall g.r.
Reference								
Total	30.42	37.27	45.91	57.74	71.99	92.27	121.24	
Industry	2.84	4.37	7.00	11.48	18.69	30.09	47.88	9.87
Transport	9.91	11.30	13.52	16.20	19.46	23.45	28.48	3.58
Households	13.71	16.21	19.15	22.52	24.49	26.36	28.56	2.48
Services	3.97	5.39	6.24	7.54	9.34	12.37	16.33	4.83
High Growth								
Total	30.42	38.03	50.26	72.85	106.81	163.52	256.65	
Industry	2.84	4.97	9.44	19.08	39.50	80.96	155.13	14.26
Transport	9.91	11.36	13.87	17.70	23.64	32.82	46.62	5.30
Households	13.71	16.32	19.85	27.21	32.90	35.87	37.31	3.39
Services	3.97	5.39	7.10	8.86	10.76	13.86	17.59	5.09
Optimistic								
Total	30.42	38.07	51.21	75.38	117.17	198.54	372.41	
Industry	2.84	4.90	9.80	21.20	47.37	107.94	249.96	16.10
Transport	9.91	11.34	14.07	18.52	26.01	39.33	64.44	6.44
Households	13.71	16.44	20.55	26.99	32.73	36.93	39.45	3.59
Services	3.97	5.39	6.78	8.67	11.05	14.34	18.56	5.28

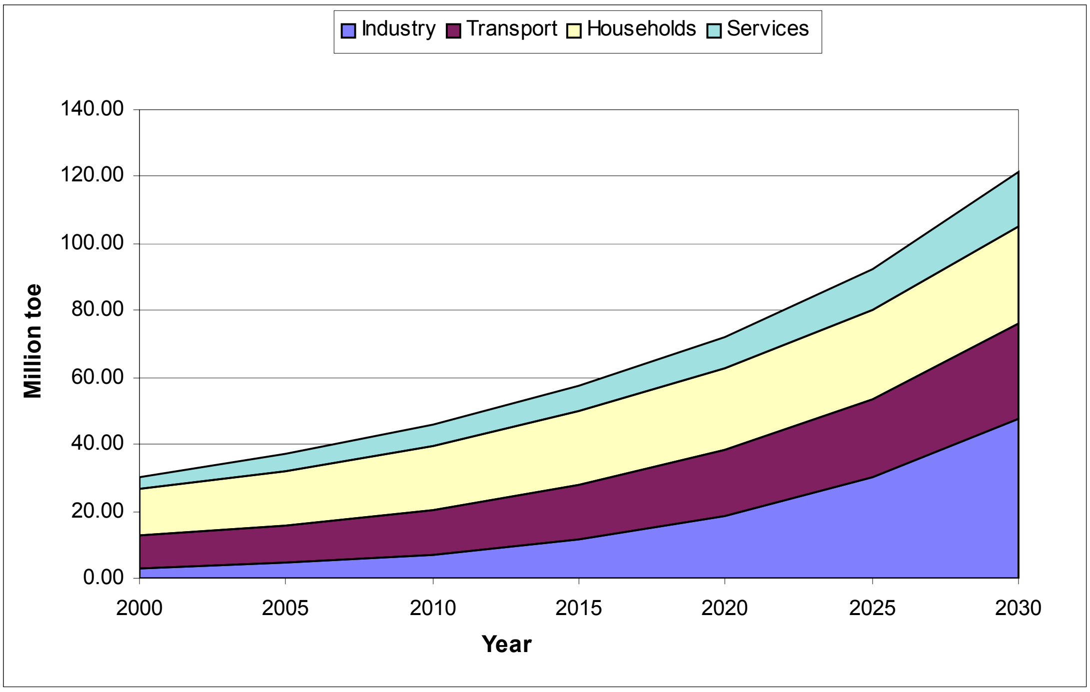

Figure 3.13 Total Final Energy Demand by Sector.

3.5.7 Total and Per Capita Electricity Demand by Scenario

The total and per capita electricity demands by scenario are presented in Table 3.17 and Figure 3.14. Available grid electricity in the base year was 4,230 MW. This is projected to grow to 58,205 MW, 112,846 MW and 159,588 MW by 2030 for the reference, high growth and optimistic scenarios respectively. Electricity consumption per capita is projected to rise to 2167.3, 4201.9 and 5942.4kWh for the reference, high growth and optimistic scenarios respectively from base year value of 321.6kWh. This is in consonance with the country's vision of becoming an industrializing nation by 2030.

Table 3.17 Total and Per Capita Electricity Demand by Scenario

	2000	2005	2010	2015	2020	2025	2030	Overall g.r.
Electricity Demand, MW								
Reference	4230	6453	11370	18397	28277	40872	58205	9.13
High Growth	4230	7134	14884	29676	48877	74471	112846	11.57
Optimistic	4230	7545	17116	33158	55926	90924	159588	12.86
Electricity Demand Per Capita, kWh/cap								
Reference	321.6	426.7	656.8	937.9	1288.6	1680.3	2167.3	6.57
High Growth	321.6	471.7	859.8	1512.9	2227.3	3061.6	4201.9	8.94
Optimistic	321.6	498.9	988.7	1690.4	2548.5	3738.0	5942.4	10.21

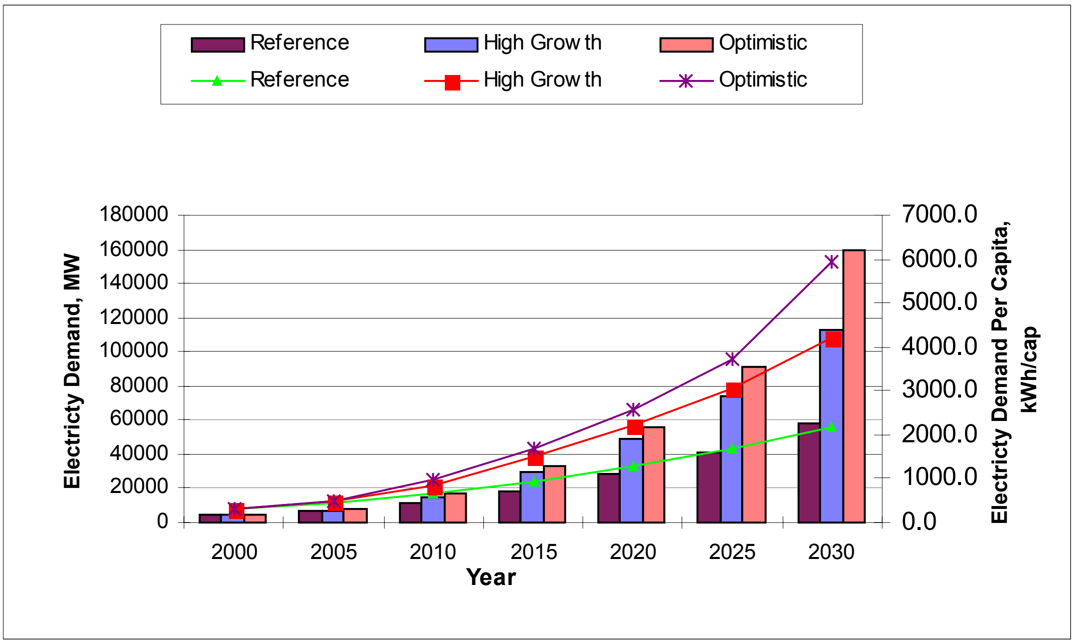

Figure 3.14 total and per Capita Electricity Demand by Scenario

3.5.8 Comparison of Electricity Demand Per Capita with Other Countries

Figure 3.15 shows the base year (2005) values of electricity demand per capita for Nigeria and selected industrializing (middle income) countries, as well as the projected values for Nigeria, by 2030, for the three different scenarios. Nigeria's demand of 5942.4kWh/cap by 2030 for the optimistic scenario is only slightly higher than that of Saudi Arabia in 2005.

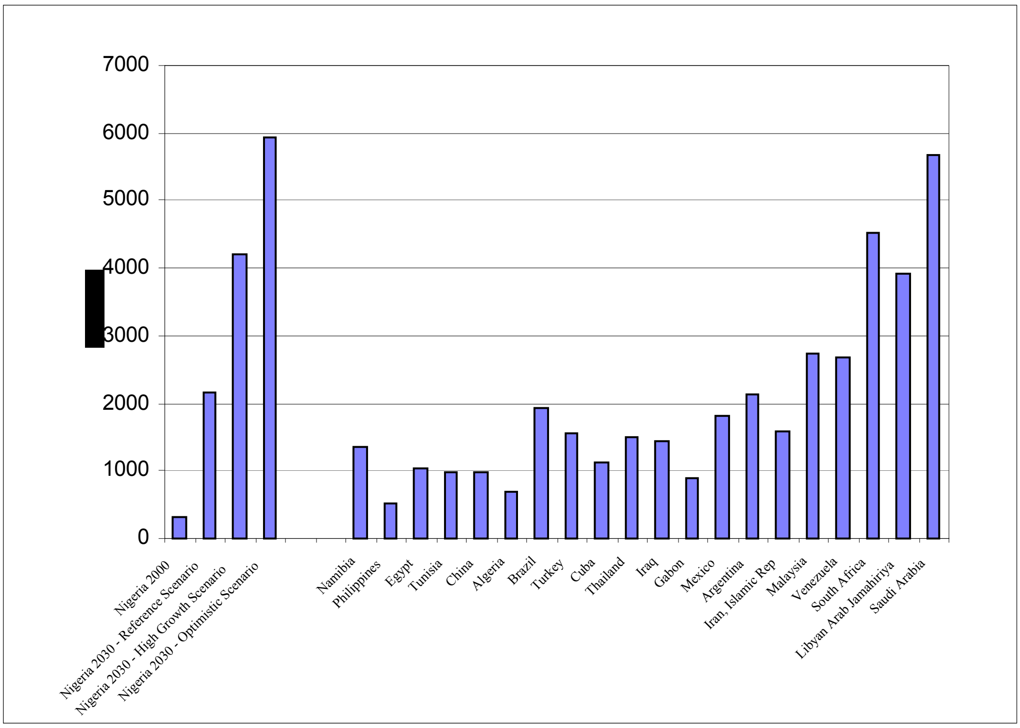

Figure 3.15 Comparison of Year 2005 and Projected per Capita Electricity Consumption for Nigeria with Year 2005 per Capita Electricity Consumption of some middle-income countries

3.5.9 Comparison of Commercial Energy Demand Per Capita with Other Countries

Fig.3.16 shows the base year (2000) values of commercial energy demand per capita for Nigeria and selected industrializing (middle income) countries, as well as the projected values for Nigeria, by 2030, for the three different scenarios. Nigeria's demand of 1564.5kgoe/cap by 2030 for the optimistic scenario is only slightly higher than that of Malaysia in 2005.

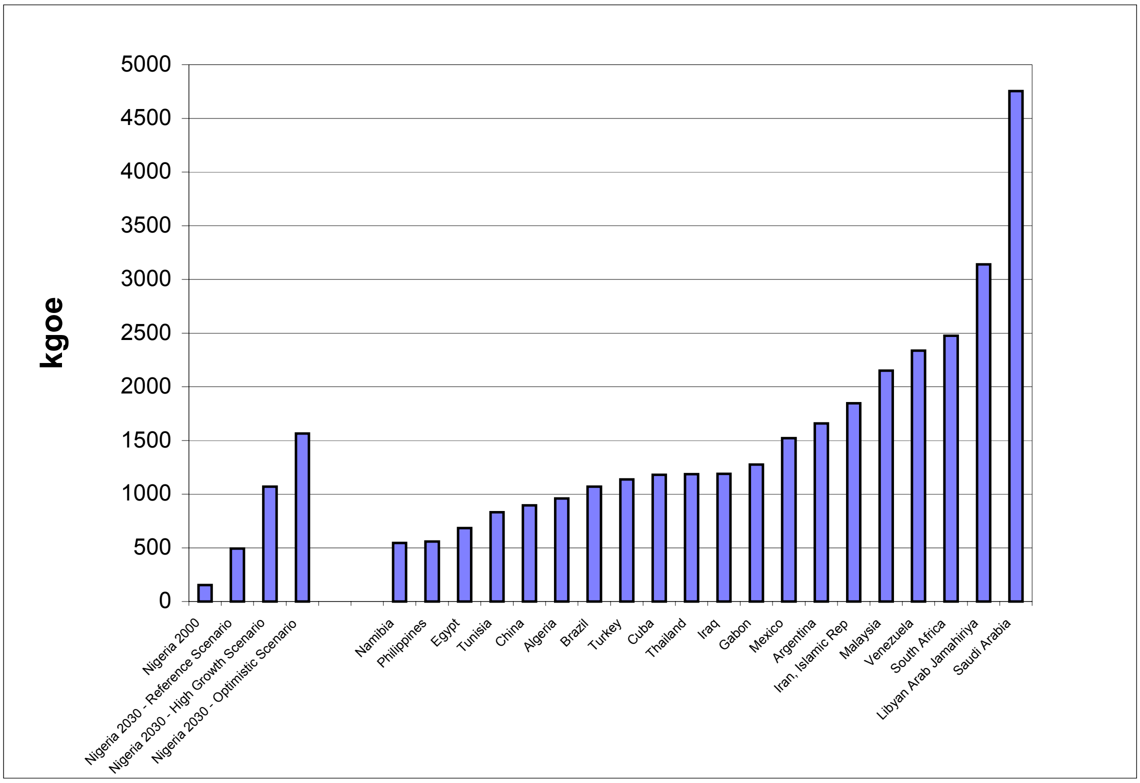

Figure 3.16 Comparison of Year 2000 and the year 2030 Projected per Capita Commercial Energy Consumption for Nigeria with Year 2000 per Capita Energy Consumption of some middle-income countries.

4 ENERGY SUPPLY ANALYSIS AND PLANNING

4.1 Structures of Existing Supply System

4.1.1 Energy Infrastructure

Nigeria is rich in all primary energy resources (oil, gas, coal, uranium, solar,wind, hydro and biomass) as estimated in section 2.4. Main energy flows are shown in Figure 4.1. Fuelwood was the major source of energy in Nigeria accounting for about 37% followed by natural gas at about 34%; crude oil, accounts for 24%; and hydropower, 5%. Coal, solar and other fuels made up the remaining (less than 1%) of the total primary requirements in 2005.

4.1.2 Oil Supply System

The Nigerian oil system includes all processes and activities beginning from crude oil extraction up to the sale of oil products to consumers. The infrastructure include the upstream and the down stream sectors. The down stream sector comprises of the Kaduna, Port Harcourt and Warri refineries, the pipeline; deports and the jetties. The down stream sector are subsidiaries of the Nigerian National Petroleum Corporation (NNPC) which is owned by government. The upstream sector comprises of the oil extraction, transportation and distribution facilities.

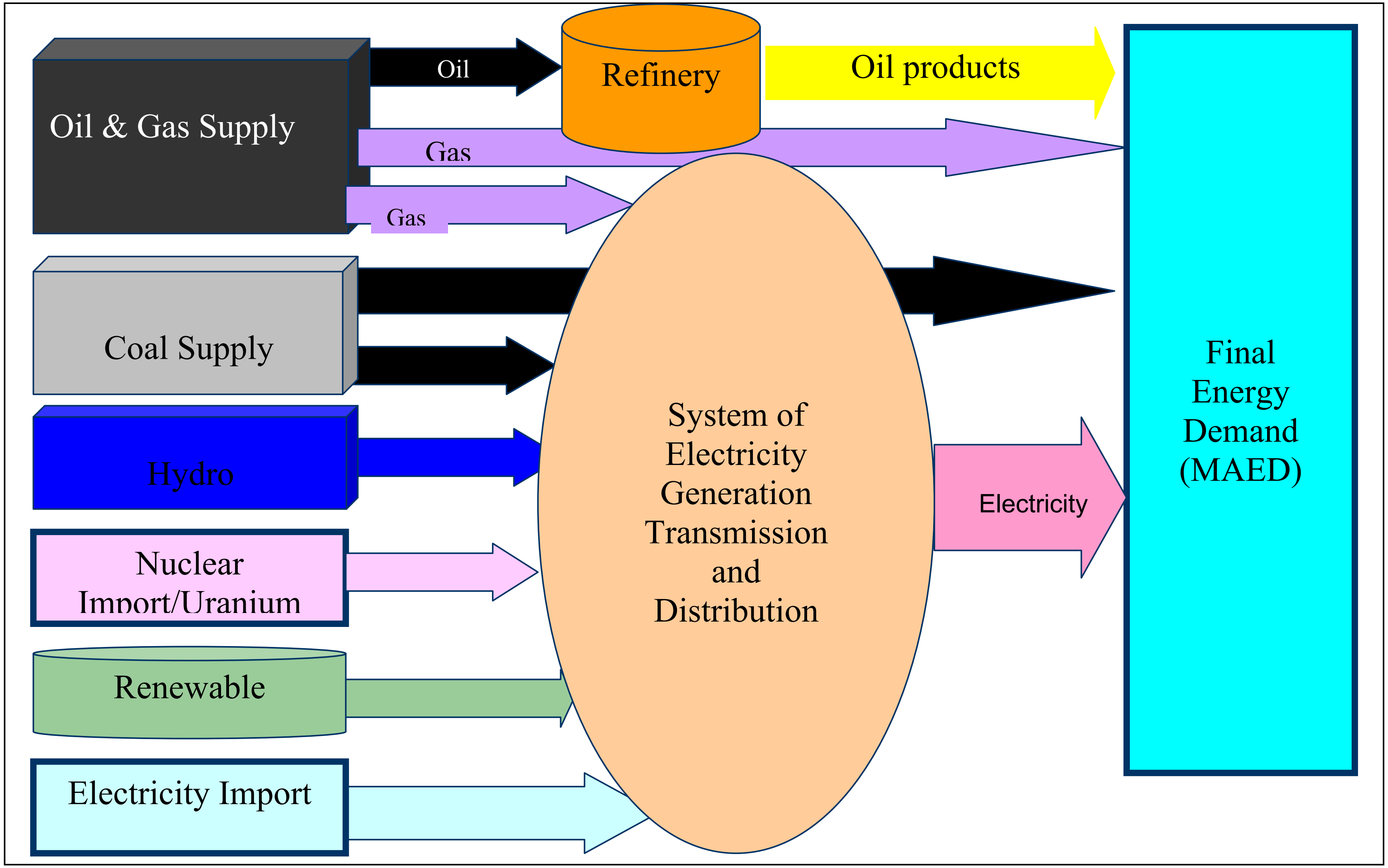

Figure 4.1 Diagram of Main Fuel and Energy Flows

4.1.2.1 Crude Oil Production

Nigeria's proven oil reserves are estimated to be 35.3 billion barrels. Nearly all the country's primary reserves are concentrated in and around the delta of the River Niger but off-shore rigs are also prominent in the well-endowed coastal region. Nigeria is one of the few major oil-producing nations still capable of increasing its oil output. More recently, production has been intermittently interrupted by the demands and actions of the Niger Delta militants.

Nigeria has 606 oil fields in the Niger Delta area, 355 are on-shore while the remaining 251 are offshore. Of these, 193 are currently operational while 23 have been shut in or abandoned as a result of poor outputs or total drying up of the wells. Outside the Niger Delta, a total of 28 exploratory oil wells have been drilled all showing various levels of prospects. These wells include two discovery wells in Anambra State, one discovery well each in Edo State and Upper Benue Trough and Twenty-four (24) wells in the Chad Basin. However, production is yet to commence from any of these wells.

Most of Nigeria's oil fields are small and scattered, and as at 1990, these small unproductive fields accounted for 62.1% of all the production of Nigeria. This contrasts with the sixteen largest fields which produced 37.9% of Nigeria's petroleum at that time. As a result of the numerous small fields, an extensive and well-developed pipeline network has been engineered to transport the crude. Also due to the lack of highly productive fields, money from the jointly operated (with the federal government) companies is constantly directed towards petroleum exploration and production.

Deepwater drilling is an industry that is developing and has potential to strengthen the future for oil extraction in Nigera. This is mainly underwater oil drilling that exists 400 m or more below the surface of the water. By expanding to deep water drilling the possible sources for finding new oil reserves is expanded. Through the introduction of deep water drilling 50% more oil is extracted than before the new forms of retrieving the oil. In Nigeria the deepwater sector still has a large avenue to expand and develop. The amount of oil extracted from Nigeria is expected to expand from 15,000 b/d in 2003 to 1.27 million b/d in 2010. Deepwater drilling for oil is especially attractive to oil companies because the Nigeria ogovernment has very little share in these activities, so it is hard for them to place restrictions and regulations on the companies. Also, the deepwater extraction plants limit the amount of interruptions in production by local militant attacks, seizures due to civil conflicts, and sabotage. These advancements offer more resources and alternatives to extract the oil from the Niger Delta, with hopefully less conflict than the operations on land.

All petroleum production and exploration is taken under the auspices of joint ventures between foreign multi-national corporations and the Nigerian federal government. This joint venture is with the NNPC. Joint ventures account for approximately 95 percent of all crude oil output, while local independent companies operating in marginal fields account for the remaining 5%. Additionally. Five companies are operating in Nigeria and are listed as follows:

- Shell Petroleum Development Company of Nigeria Limited (SPDC): A joint venture operated by Shell accounts for more than forty percent of Nigeria's total oil production

(899,000 barrels per day (b/d)). The joint venture is composed of NNPC (55%), Shell (30%), TotalFinaElf (10%) and Agip (5%). SPDC has more than 100 producing oil fields, and a network of more than 6,000 kilometres of pipelines, flowing through 87 flowstations. SPDC operates 2 coastal oil export terminals. The Shell joint venture produces about 50 percent of Nigeria's total crude.

- Chevron Nigeria Limited (CNL): A joint venture between NNPC (60%) and Chevron (40%) has in the past been the second largest producer (approximately 460,000 b/d), with fields located in the Warri region west of the Niger river and offshore in shallow water. It is reported to aim to increase production to 600,000 b/d.
- Mobil Producing Nigeria Unlimited (MPNU): A joint venture between the NNPC (60%) and Exxon-Mobil (40%) operates in shallow water off Akwa Ibom state in the southeastern delta. ExxonMobil produces around 750,000 b/d of oil in Nigeria. The company plans to invest $11billion in the country's oil sector through 2011, with the hope of increasing production to 1.2 million b/d.
- Nigerian Agip Oil Company Limited (NAOC): A joint venture operated by Agip and owned by the NNPC (60%), Agip (20%) and ConocoPhillips (20%) produces 150,000 b/d mostly from small onshore fields.
- Total Petroleum Nigeria Limited (TPNL): A joint venture between NNPC (60%) and Total produced approximately 125,000 b/d during 1997, both on and offshore. Output at Total's Amenam field reached 120,000 b/d in January 2005. The Amenam field contains reserves of around one billion barrels of oil equivalent. In January 2009, Total plans to bring online its offshore Akpo field (180,000 b/d) and in January 2010, its offshore Usan field (150,000 b/d).

In 2006, total Nigerian oil production, including lease condensates, natural gas liquids and refinery gain, averaged 2.45 million b/d (of which 2.28 million b/d was crude oil; Figure 4.1). If Nigeria could bring back online all oil currently shut-in, EIA estimates that Nigeria could reach crude oil production capacity of three million bpd. With the help of new projects coming online, the Nigerian government hopes to increase oil production capacity to four million bpd by 2010.

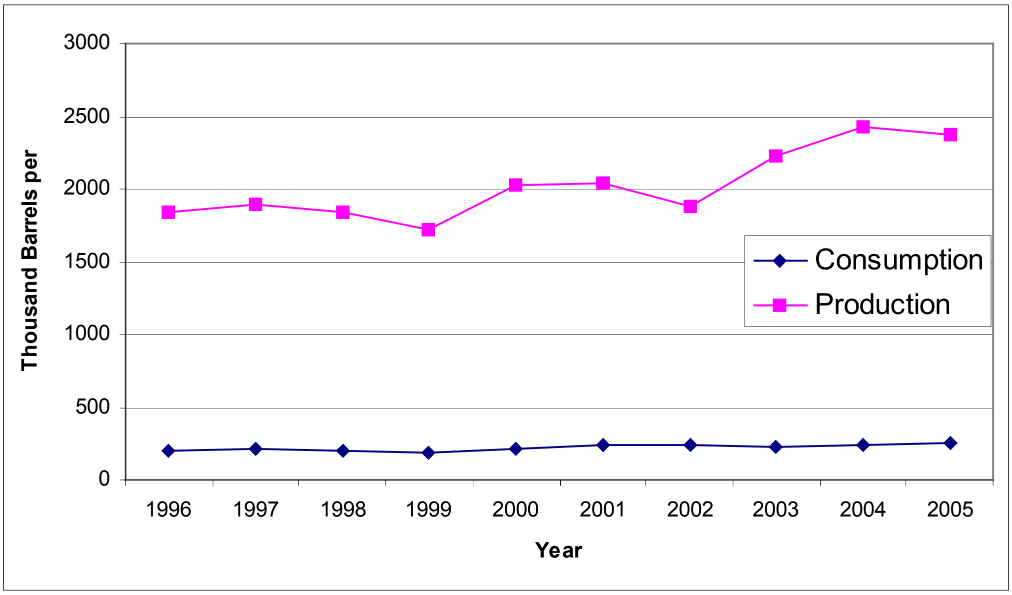

Figure 4.2 Nigeria's Oil Production and Consumption, 1986-2006

The Joint Development Zone (JDZ), shared by Nigeria and neighboring Sao Tome and Principe (STP), contains 23 exploration blocks and could potentially hold up to 14 billion barrels of oil reserves (Figure 4.2). Nigeria and Sao Tome have agreed to split revenues from the blocks on a 60:40 basis, respectively. The International Monetary Fund estimates that Sao Tome and Principe could net more than $700 million per year if oil production output of 80,000 b/d is attained before 2013. Block One is currently the only block in the JDZ undergoing development. The block is controlled by Chevron (51 percent), with partners ExxonMobil (40 percent) and Equity Energy Resources (9 percent). If oil is located, Chevron plans to bring it onstream by 2010. In 2005, JDZ put Blocks 2-6 up for offer. In March 2006, Nigeria and Sao Tome and Principe signed PSCs for three of the blocks.

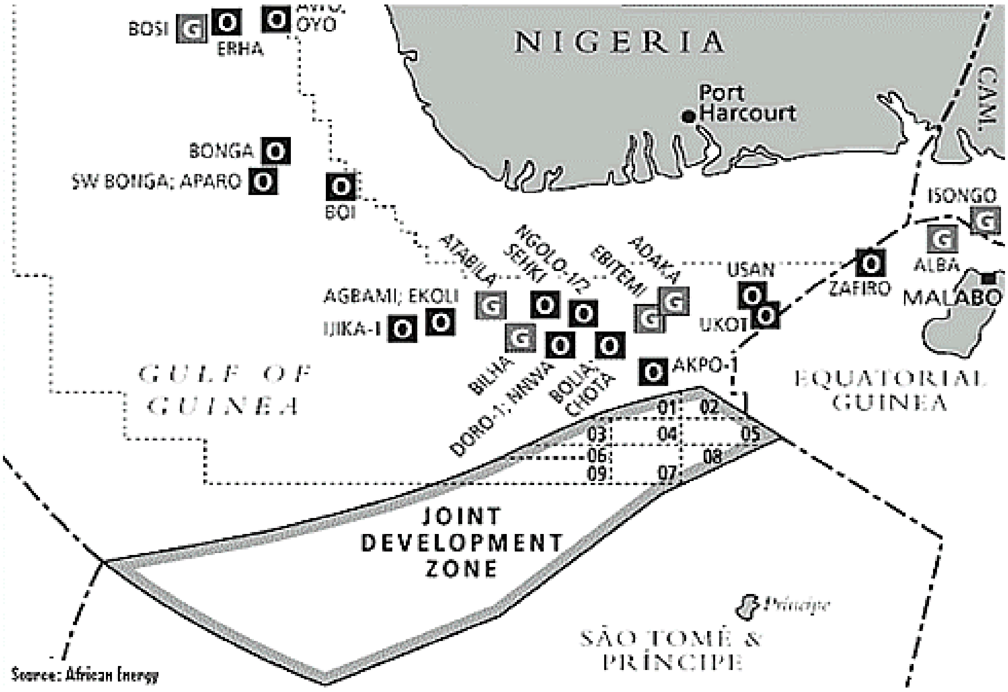

Figure 4.3 Map of Nigeria Sao Tome and Principe Joint Development Zone

4.1.2.2 Refining of Crude oil

Nigeria's total petroleum refining capacity is 445,000 barrels per day (b/d), however, only 240,000 b/d was allotted during the 1990s. Subsequently crude oil production for refineries was reduced further to as little as 75,000 b/d during the 1990s. Table 4.1 shows the output of refined products between 2001-2005. There are four major oil refineries: the Warri Refinery and Petrochemical Plant which can process 125,000 barrels of crude per day, the New Port Harcourt Refinery which can produce 150,000 b/d (there is also an 'Old' Port Harcourt Refinery with negligible production), as well as the Kaduna Refinery with a refined capacity of 110,000 b/d. It is estimated that demand and consumption of petroleum in Nigeria grows at a rate of 12.8% annually. However, petroleum products are unavailable to most Nigerians, because almost all of the oil extracted by the multinational oil companies is refined overseas, while only a limited quantity is supplied to Nigerians themselves.

Nigeria's refining capacity is currently insufficient to meet domestic demand forcing the country to import petroleum products. To increase refining capacity, the Nigerian government is granting permits for building several independently owned refineries. Oando, a leading petroleum-marketing company in Nigeria, is considering building a refinery in Lagos. The refinery would be built in two phases, with each phase providing 180,000 b/d of refining capacity.

Table 4.1 Output of Refined Products by Type 2001–2005 *(1,000 b/d)*

	2001	2002	2003	2004	2005
Gasoline	60.1	90.9	79.6	70.2	40.5
Diesel	50.4	80.0	96.7	95.7	42.1
Kerosene	34.0	47.5	51.7	49.1	27.9
Fuel Oil	59.5	74.8	75.3	76.2	54.1
Others	23.8	13.8	4.1	16.8	10.4

4.1.2.3 Crude Oil Export

Nigeria is the world's eighth largest exporter of crude oil and the country is a major oil exporter to the United States. In 2006, Nigeria's total oil exports reached an estimated 2.15 million bpd. Nigeria shipped approximately one million bpd or 41 percent of its crude exports to the United States in 2006 (Figure 4.3). Additional importers of Nigerian crude oil include Europe (19 percent), South America (7.6 percent), Asia and the Caribbean. Despite shut-in production, major importers of Nigerian crude have experienced little to no decrease in Nigerian crude imports over the past 15 months. The steady exports suggest that the new production capacity additions (approximately 545,000 b/d) have mostly offset shut-in production. Nigeria has six export terminals including Forcados and Bonny (operated by Shell); Escravos and Pennington (Chevron); Qua Iboe (ExxonMobil) and Brass (Agip). According to the *International Crude Oil Market Handbook*, Nigeria's export blends are light, sweet crudes, with gravities ranging from API 29 – 36 degrees and low sulfur contents of 0.05 – 0.2 percent. Forcados Blend is considered one of the best gasoline-producing blends in the world.

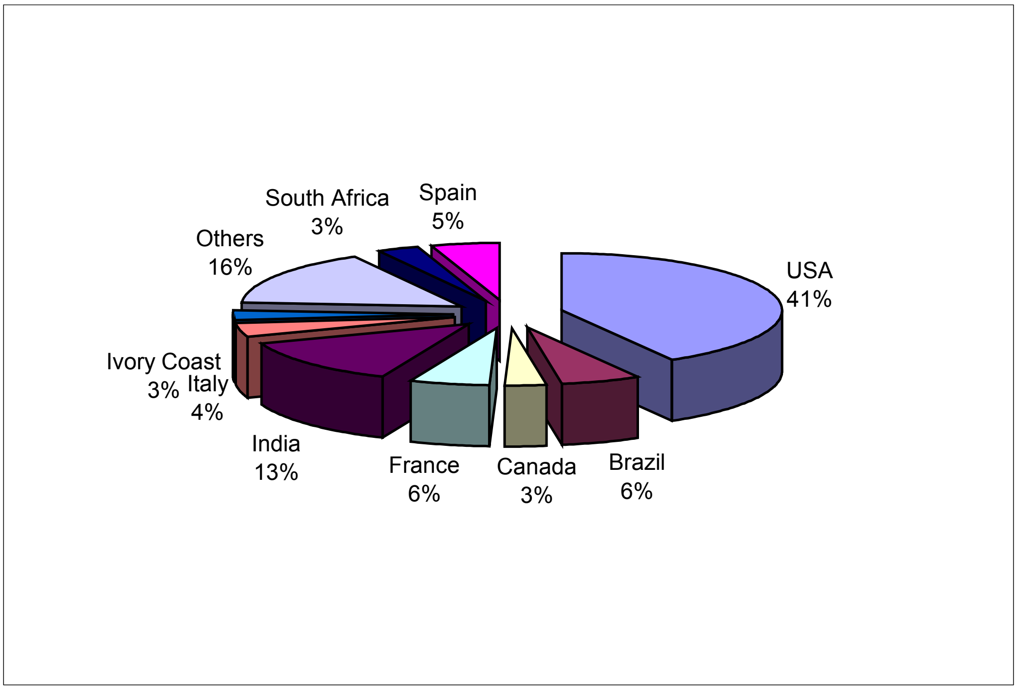

Figure 4.4 Breakouts of Nigeria's Crude Oil Exports, 2006

4.1.2.4 Energy Imports

Petroleum Products

Presently, the will to fully rehabilitate the refineries prior to their privatization seems to be absent. There is therefore an implied preference for importation of petroleum products, which the NNPC handles. The deregulation of products importation, which was started in 1998, is yet to become fully effective. When this happens while the refineries remain un- refurbished, the momentum and share of products imports will further increase, at least in the short-to-medium term. It is however expected that in the long term, following the rehabilitation of existing refineries and establishment of new ones, petroleum products imports will either cease or only be occasional for the supplementation of incidental shortfalls.

Table 4.2 Consumption of Refined Products by Type 2001-2005 in thousands of b/d

	2001	2002	2003	2004	2005
Gasoline	127.84	134.90	136.62	146.05	164.30
Diesel	54.57	46.43	42.03	43.60	40.63
Kerosene	43.35	41.53	31.93	32.80	37.40
Fuel Oil	17.38	15.00	15.00	14.10	10.07

The main ocean receiving facility is the Atlas Cove Jetty. Originally designed to receive products and dispatch them to Mosimi main depot, the terminal is now permanently used for imports.

Liquefied Petroleum Gas (LPG)

The domestic LPG production capacity is grossly inadequate and is unable to meet local demand. For instance, total domestic production in the year 2000 was 105,000t. The estimated demand was 194,300*t* [*Federal Office of Statistics*] and 229,000*t* by this study. Domestic refineries will continue to be unable to meet local demand into the medium term future. The domestic demand will therefore have to be met through linkage to the mixed LPG produced by the Joint Venture Companies for export (Mobil – 200,000*t*/yr, and Chevron) and through imports. The import level will fall with the establishment of new private refineries. The import of LGP has long been deregulated.

Coal

For coal, coking coal is currently imported, as much of the nation's coal resources are not suitable for coking purposes. However, the import level can be reduced with blending of domestic coal with the imported one. Apart from this, there should be no need to import coal for domestic uses. Both the reserves and production capacity are more than adequate to meet domestic needs. The production capacity can be expanded if the need arises.

4.1.3 Gas Supply System

Nigeria had an estimated 182 trillion cubic feet (tcf) of proven natural gas reserves as of January 2007, which makes Nigeria the seventh largest natural gas reserve holder in the world and the largest in Africa. The majority of the natural gas reserves are located in the Niger Delta. In 2004, Nigeria produced 770 billion cubic feet (bcf) of natural gas, while consuming 325 bcf. The government plans to raise earnings from natural gas exports to 50 percent of oil revenues by 2010. However, NNPC estimates that $15 billion in private sector investments is necessary to meet its natural gas development goals by 2010.

Nigeria currently operates eight (8) supply systems namely: the Sapele gas supply systems, which supplies gas to PHCN Power Station at Ogorode, Sapele, the AladIa system, which supplies the Delta Steel Company, Aladja and the Sapele-Oben-Ajaokuta Steel Company and will form the back-bone of a future Northern Pipeline System and the Imo River-Aba system for gas supply to the International Glass industry Limited PZ, Aba Textile Mills and Aba Equitable Industry. The other systems are Obigbo North-Afam system which caters for Power Station at Afam, the Alakiri to Onne Gas pipeline system for supply of gas to the National Fertiliser Company (NAFCON) for fertiliser production; the Alakiri-Afam-lkot Abasi system for gas supply to the Aluminium Smelting Plant (ALSCON) and the Escravos-Lagos Pipeline (ELP), which supplies gas to Egbin Power Plant near Lagos. Subsequent spur lines from the ELP supply the West African Portland Cement (WAPCO) Plants at Sagamu and Ewekoro, PZ Industries at lkorodu, City Gate in lkeja Lagos, NEPA Delta IV at Ughelli, and Warri Refining and Petrochemical Company at Warri. All these facilities comprise 1,100 kilometres of pipelines ranging from 4" to 36" in diameter with an overall design capacity of more than 2 billion standard cubic feet of gas per day (bscf/d), 14 compressor stations and 13 metering stations.

There are plans to integrate all gas transmission systems in the country. It is also planned that extensions of the systems would be made to the far northern states of Borno and Sokoto as well as to the central industrial state of Kano. The resulting highly interconnected system would provide full flexibility and better management of adjustment of supply and demand throughout the country. In the domestic market investment options exist for investors who may wish to do so in gas transmission and distribution joint ventures with the Nigeria gas Company (NGC) for specific projects such as gas-based Independent Power Plants (IPP) and such energy intensive sectors as cement, glass and paper industries.

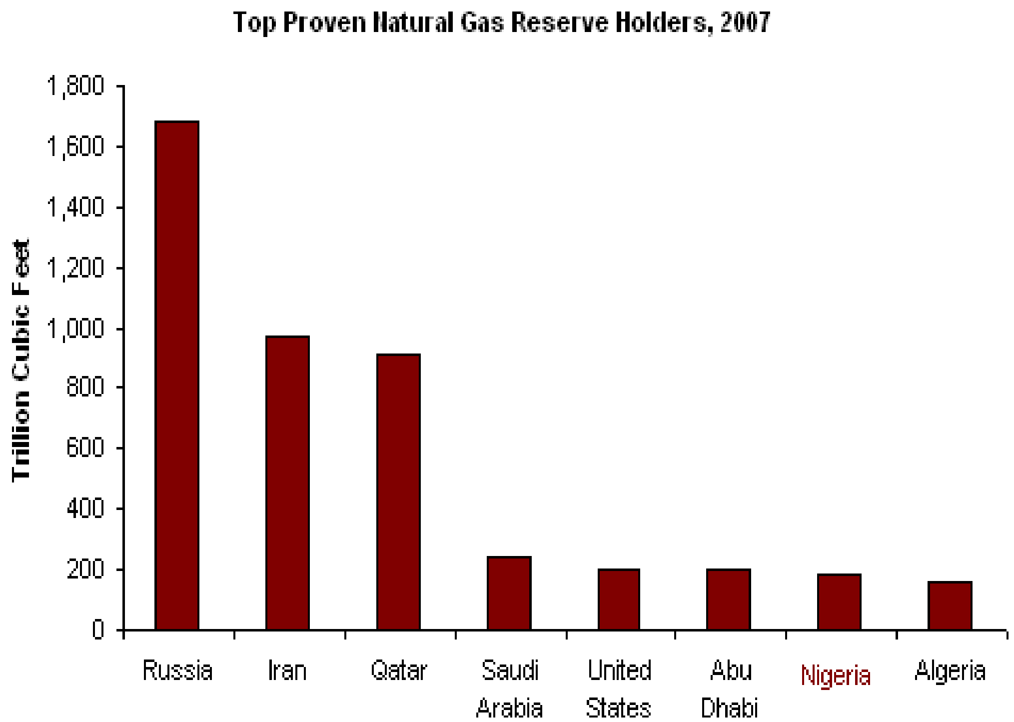

Figure 4.5 Top Natural Gas Reserve Holders, 2007

Because many of Nigeria’s fields lack the infrastructure to produce natural gas, it is flared. According to NNPC, Nigeria flares 40 percent of its annual natural gas production, while the World Bank estimates that Nigeria accounts for 12.5 percent of total flared natural gas in the world. Nigeria is working to end natural gas flaring by 2008. However, there is indication that the target will not be met by the oil producing companies due to funding and poor contractor performance on some projects as barriers to eliminating natural gas flaring.

4.1.3.1 Liquefied Natural Gas LNG

A significant portion of Nigeria's natural gas is processed into LNG. Nigeria's most ambitious natural gas project is the $3.8 billion Nigeria Liquefied Natural Gas (NLNG) facility on Bonny Island. Partners including NNPC, Shell, Total and Agip completed the first phase of the facility in September 1999. In 2006, NLNG completed its fifth train increasing annual production capacity to 17 million tons per year of LNG. NLNG plans to bring a sixth train online in late 2007, raising production capacity to 22 million tons per year. A seventh train could come online in 2011. The facility is currently supplied from dedicated (non-associated) natural gas fields, but it is anticipated that within a few years half of the natural gas feedstock will consist of associated (currently flared) natural gas from existing oil fields.

Additional LNG facilities in Nigeria are also being developed. In January 2005, Chevron announced the possibility of constructing the $7 billion OK-LNG plant at Olokola in western Nigeria. The plant would have an initial capacity of 11 million tons per year and a maximum capacity of 33 million tons per year. In March 2007, NNPC awarded a contract to France-based Technip for construction of the OK-LNG plant. The project includes connecting the LNG plant to oil and natural gas reserves in the Niger Delta through a network of pipelines. OK-LNG is expected to produce its first LNG in 2011. In December 2005, ConocoPhillips, Chevron and Agip met with NNPC to sign a shareholders agreement for the establishment of the $3.5 billion Brass River LNG plant. The project, which includes two LNG trains, could be operational by late 2009 depending on a final investment decision (FID) to be made in 2007.

Chevron is working on the Escravos gas-to-liquids (EGTL) project, which is located in the western Niger Delta, and is expected to have production capacity of 33,000 b/d. Completion of the GTL project was scheduled for 2009. However, in January 2007, work on the EGTL project came to a halt after a breakdown in salary negotiations. A year earlier, the Nigerian government halted the implementation of the EGTL project due to high costs. Plans for the project include linking the Escravos pipeline system with the West African Gas Pipeline (WAGP) for natural gas export to Benin, Togo and Ghana (Figure 4.4).

4.1.3.2 International Pipelines

Progress on the WAGP (Figure 4.6), which will deliver 140 MMcf/d of natural gas to power stations in Ghana, is moving forward. The $590 million, 420-mile pipeline will carry natural gas from Nigeria to Ghana, Togo, and Benin. Operational start-up of the project is expected during 2007, with initial capacity of 200 MMcf/d of natural gas. The pipeline is expected to function at a full capacity of 450 MMcf/d within 15 years. The Multilateral Investment Guarantee Agency (MIGA), and the International Development Association (IDA) are also helping to fund the WAGP by giving $75 million and $50 million, respectively.

Nigeria and Algeria continue to discuss the possibility of constructing a Trans-Saharan Gas Pipeline (TSGP). The 4,023 kilometres pipeline would carry natural gas from oil fields in Nigeria's Delta region to Algeria's Beni Saf export terminal on the Mediterranean. It is estimated that construction of the $7 billion project would take six years. The TSGP is currently in the study phase of development.

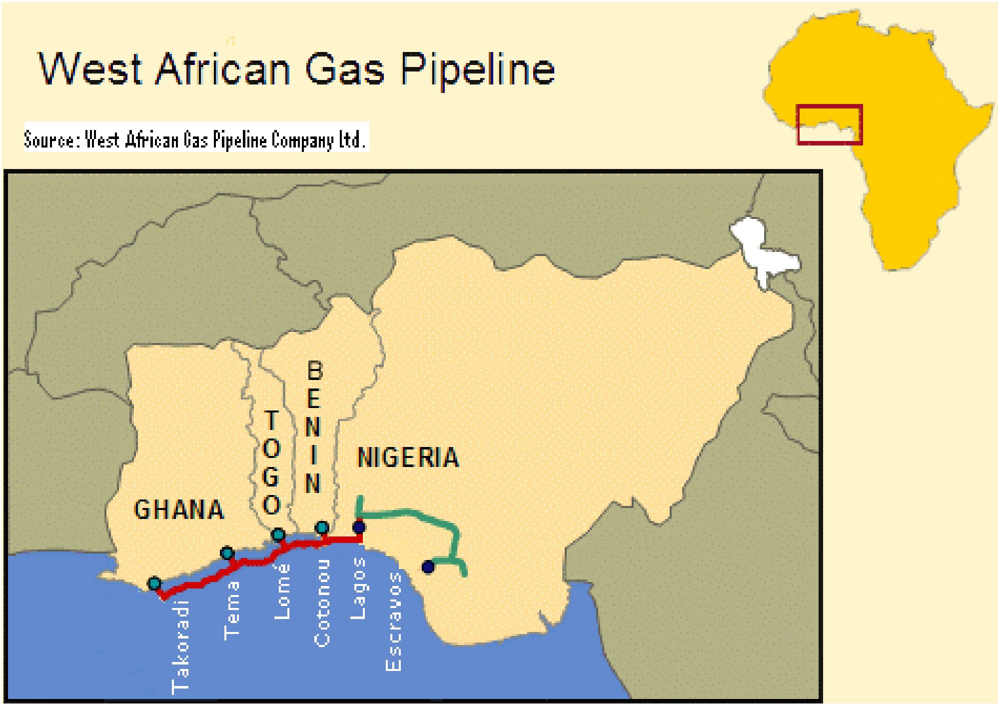

Figure 4.6. Map showing the West African Gas Pipeline

4.1.4 Electricity Supply System

The Nigerian power sector operates well below its estimated capacity, with power outages frequently occurring (Figure 4.7). This has forced commercial and industrial sectors to increasingly use privately operated diesel generators to supply electricity.

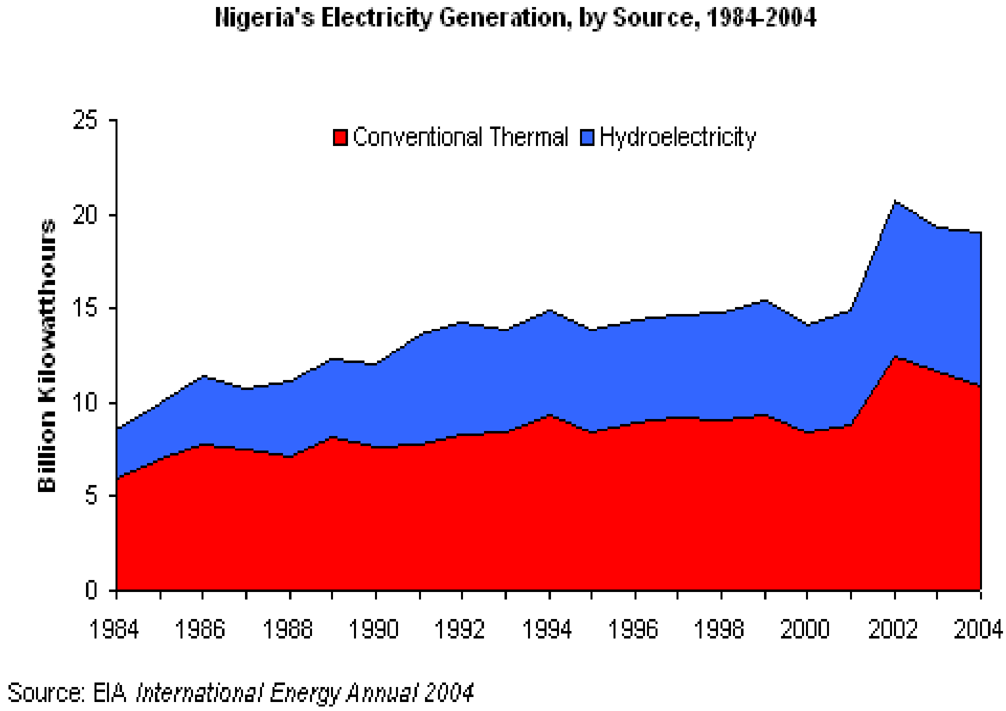

Figure 4.7 Nigeria's Electricity Generation, by Source, 1984-2004.

The present infrastructure for grid connected electric power generation comprises of nine stations. Three of these are hydro-based while the remaining six are thermal stations. The generation infrastructure has a combined total capacity of about 6,000MW, and is solely owned by government under the Power Holding Company of Nigeria (PHCN). Recently, an Independent Power Producer installed a 278MW station in Lagos. Details of the power plants are given in Table 4.5 below. The transmission and distribution system consists of 6,000km of 330kV and 500km of 132kV transmission gridlines, 35,743km of 33kV and over 26,498km of 11kV distribution lines, twenty-two 330/132kV Substations, ninety-one 132/33kV substations and 563 of 33/11kV substations forming a radial network controlled from the National Control Centre in Oshogbo and a supplementary National Control Centre at Shiroro. The transmission facilities are extended to Niger Republic for export of power. The transmission and distribution facilities are, at the moment, solely owned by PHCN.

Table 4.3 Existing Power Plants in Nigeria as at 2005

Plant	Type	Installed Capacity (MW)	Available capacity (MW)
Afam	Thermal	821	230
Delta	Thermal	912	560
Egbin	Thermal	1320	400
Ijora	Thermal	60	20
Sapele	Thermal	420	240
AES	Thermal	270	270
Jebba	Hydro	570	540
Kainji	Hydro	760	590
Shiroro	Hydro	600	600
Total		5733	3450

New thermal power plants will be added to the national grid, some of the power plants were recently commissioned and others are nearing completion. These plants will add about 4000MW of electricity to the national grid (Table 4.4). All the plants are natural gas based. This is in line with government policy of utilizing the abundant gas resources in the country for increased power supply. Figure 4.8 shows the locations of the existing and future gas power plants.

Early this year, Nigeria awarded a contract for the construction of a new hydroelectric project at Mambilla Plateau. Nigeria hopes the Mambilla power station, in the northeastern part of the country, will add 2,600MW to the national grid. The project could be completed by 2012. In addition, China’s EXIM Bank, Su Zhong, and Sino Hydro have committed to funding the Zungeru (750MW) hydroelectric projects.

Table 4.4. New Thermal Power Plants

Thermal Power plant	Capacity (MW)	Status
Alaoji	504	November, 2007
Calabar	561	July, 2007
Egbeme	338	July, 2007
Gbarain	225	July, 2007
Geregu	414	February, 2007
Ibom Power	118	July, 2007
Ihovbor	451	July, 2007
Ikot-Abasi	200	July, 2007
New Sapele	451	July, 2007
Omoku	230	July, 2007
Omotosho	335	April, 2007
Papalanto	335	July, 2007
Total	4162	

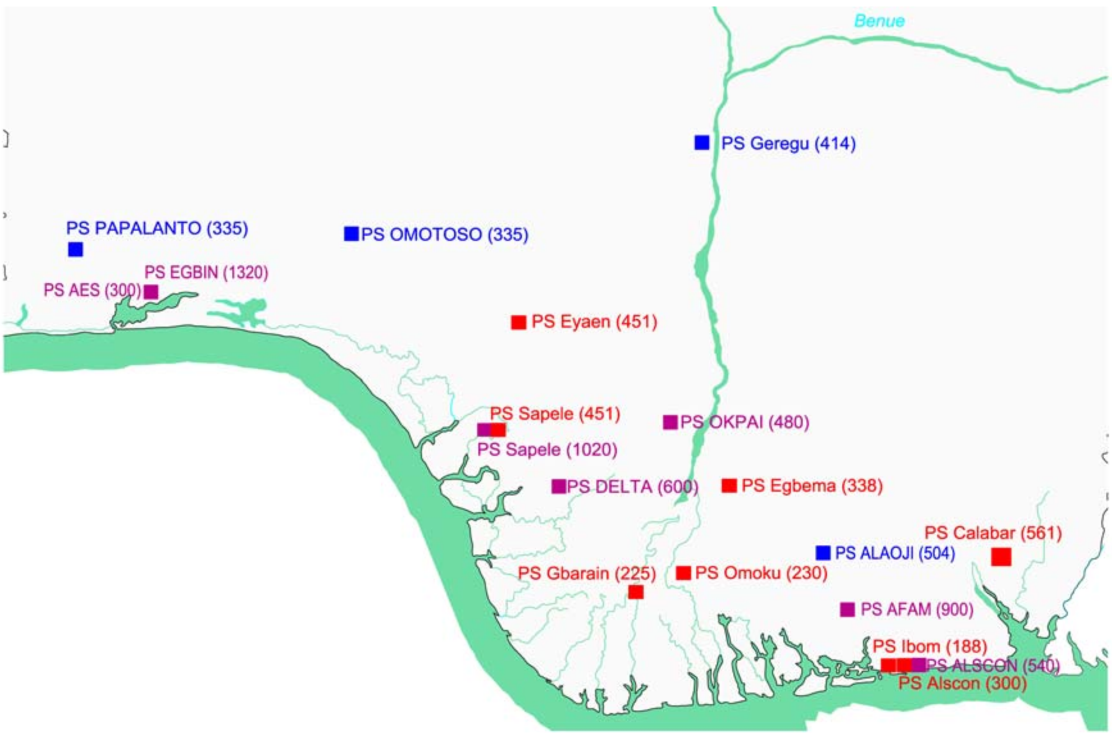

Figure 4.8 Location of Gas Power Plant

4.2 Fuel Prices

4.2.1 Crude Oil

The various streams of crude oil produced in Nigeria are exported in accordance with OPEC quota and at the international prices (Figure. 4.1), while a certain amount is supplied to the domestic refineries at a fixed rate of $35. The principle is to ensure social benefit through subsidy. However, this principle will change in the future in favour of opportunity cost pricing. Crude prices to domestic refineries will be determined by the export prices.

4.2.2 Petroleum Products

Petroleum products supply in Nigeria, over the years, has been made up of the output of domestic refineries and imports, both of which are sold to the consumers at the same subsidized rate. Prior to 1973 when government introduced uniform pricing, petroleum product prices throughout the country varied sharply as the distance from lifting point varied, thus reflecting the transportation costs incurred by the marketers. In consequence of socio-political and equity considerations, the Federal Government, via Decree 9 of 1975 (as amended by Decree 32 of 1989) established uniform prices for petroleum products throughout the country and established the Petroleum Equalization Fund (PEF) under the then Ministry of Petroleum Resources. The purpose of the PEF was to reimburse the marketing companies for any losses suffered by them solely and exclusively because of the sale of petroleum products at uniform prices throughout the country. A PEF tax of ₦1.5 was charged per litre on consumers.

Table 4.5. Cost of Domestic Product in Naira per Barrel of Oil (US$1 ≈ ₦120.00)

	2001	2002	2003	2004	2005
Gasoline	3497.6	4133.5	4133.5	6757.5	10330.7
Diesel	3338.3	4133.5	4134.6	6598.5	13747.0
Kerosene	2702.7	3815.5	3816.6	6598.5	8133.9
Fuel Oil	1907.8	1907.8	1907.8	3339.0	4038.1

Over the last decade petroleum product prices had increased thirty fold, and yet, the final pump price still remained significantly subsidized in order to sustain the marketers' profit margin. Since the prices of petroleum products were fixed by the Government rather than determined by market forces, the price trends had been change, (Table 4.5).

4.2.3 Natural Gas

The prices of natural gas have been set at a low level to encourage the few users who consume natural gas. During the 1970s, power plant, being the major user of natural gas, pays ₦0.50 per thousand standard cubic feet. However, by 1990, discriminatory prices were charged for the resource. Steel companies paid ₦3.0 per 1000 scf while other users paid ₦5.24 per 1000scf. At the instance of the gas producers, the prices were further increased in graduated structure. The minimum price of ₦5.25/1000scf was charged for power generation (electric utility) and Delta Steel Co. All other companies were to pay prices not exceeding ₦8.00/1000scf, the amount depending on the nearness of the consumer to the nearest gas supply. Further revisions of the gas pricing policy have taken place. Power plant still enjoys a subsidized price at about ₦13/1000scf ($0.11/1000scf). However, other industrial consumers enter contracts for delivery prices with the suppliers, and these may be as high as 20 times the price to power generating plants.

4.2.4 Coal Prices

Over the years, the average selling price per tonne of coal at the mines has gradually been on the increase. Three types of coal are currently being sold, namely, run-of-mine coal, washed coal and coking coal. Run-of-mine coal sells for about ₦2000.00 per ton ne($17), while washed coal sells for ₦8000.00/ton ($67) and coking coal costs about ₦25,000.00 per ton ($208). A sector differentiated coal price structure will need to be put in/place. Coal sold to the household and commercial sectors, for cooking, should cost less than industrial and export coals in order to promote coal substitution for fuelwood.

4.2.5 Fuelwood Prices

Fuel wood prices in the country are not uniform. The price is usually a reflection of the local supply and demand situation. Hence, prices are generally higher in the northern part of the country, where fuelwood is relatively scarcer, than in the southern part of the country. An average cost fuelwood is ₦4.00 per kg ($0.03). The price will continue to increase with increasing scarcity.

4.2.6 Electricity Tariffs

Electricity tariff in Nigeria is the sum of energy demand charges (price per kWh consumed) and power demand charges (price per kVA or kW installed). The charges depend on the type of service at the served premises. There are three load classifications by NEPA for the purpose of billing, namely, single-phase service (domestic-small), three- phase service (up to 75kVA) and large three-phase service (above 75kVA).

From 1988 to date, PHCN has come out with six revisions of the electricity tariffs, which have been applied uniformly across the country. Nevertheless, the tariff remains inadequate to cover the cost of power supply. Due to devaluation of the Naira, the tariff in US$ fell drastically in 1988 and has remained below its value in the 1977-1987 decade. The competitive electricity supply industry, which is expected to replace the existing public utility dominated one, with its non-competitive tariff regimes, will have not only cost reflective tariffs on the average, including provision for a reasonable return on investments, but also tariff differentiation according to cost of service, even within the same customer class. In general the future tariff trends will be determined by:

(1) Economic efficiency which seeks to ensure that prices reflect the true economic (or opportunity) cost of supplying energy;

(2) Social equity which is based on social welfare and income distribution consideration;

(3) Energy conservation. This will mean indirect subsidy for very low volume (i.e. low income) consumers, which will be paid for by other consumers, while alternative provisions will be made for the economically less attractive remote rural areas. Not withstanding these special provisions, the tariff structure will be economic and competitive.

4.3 Future Supply System

4.3.1 System of Electricity Supply

Future electricity supply mix of the country will be governed mainly by the utilization of abundant gas resource currently being flared. A major policy target is to end gas flaring by 2008 which means that the over 2 billion scf of gas being flared daily will be utilized, particularly for power generation. Hydropower currently accounts for about 32% of the total installed commercial electrical power capacity but there are still high potentials for large-scale hydropower yet to be harnessed. The first large-scale hydropower station in Nigeria is located at Kainji on the River Niger, with an installed capacity of 760MW and provision for expansion to 1,150MW. A recent estimate for Rivers Kaduna, Benue and Cross River (at Shiroro, Makurdi and Ikom) respectively) indicate their total capacity to be about 4,650MW. Estimate for the rivers on Mambilla Plateau is put at 3,960MW. The total large-scale hydropower resources potential (exploitable) in Nigeria is in excess of 11,000MW.

In addition, potentials for small-scale hydropower plants are fairly well distributed nation wide, in the seven river basins of the country. There are 8 small-scale hydro plants with a total capacity of 37MW, established by NESCO (an IPP), in operation. New sites have been identified and detailed hydrological information is available to show their feasibility. Solar and wind based power supply are also very important and viable renewable sources that will contribute significantly to future electricity supply mix especially for the remote rural communities with low energy demand.

The future additions of electricity generation capacities for the Reference Case expansion plan are presented in Table 4.6 were derived using the MESSAGE tools through the optimization of all the available fuel types. The model was able to select appropriately the introduction of new technologies such coal, and nuclear into the national grid. The solar, wind and the small hydro were modeled as non-grid supply for rural populace, communication gadgets in remote areas, water supply, schools and hospitals in the remote areas of the country.

The case is modeled in such a way that the existing power plants will undergo rehabilitations, while the new ones and the committed ones will be expanded in view of the emergency needs of electricity power supply in the country. In order to meet the demand in all the Scenarios, additional new power plants will have to be constructed.

The plan suggests the development of about 197484MW of power generation capacity over the period 2005 – 2030. By the year 2030, the supply by fuel is projected to be Hydro 21177MW, Small Hydro 275MW, Coal 40981MW, Gas 114038MW, Wind 44745MW, Nuclear 16453MW and Solar 9000MW.

Table 4.6. The Future Additions of Electricity Generation Capacities (MW)

	2010	2015	2020	2025	2030
Coal	0.0	6,392.6	6,515.5	7,305.0	7,815.0
Gas	20,694.8	31,011.8	46,922.5	68,363.4	101,584.8
Hydro	5,756.1	10,961.6	13,478.7	15,112.0	16,167.3
Nuclear	0.0	0.0	8,230.0	9,227.3	9,871.6
Small Hydro	40.2	84.8	140.2	227.0	329.5
Solar	5.4	6.3	34.4	74.8	102.1
Wind	0.0	120.9	4,476.3	5,018.7	5,369.2
Total Supply	26,496.5	48,577.9	79,797.6	105,328.2	141,239.5

4.3.1.1 Coal Energy

Coal fired power plant at Oji, established in 1956, was among the earliest power plant in the country. The decline in coal production as from the 1970s, mainly due to the loss of its traditional market to newly found and more competitive fuel substitutes e.g. diesel for locomotive engines, fuel and gas for power generation led to reduction in the contribution of coal in the nation's energy mix declined from about 70% in the 1960s to less than 1% by late 80s.

Recently, efforts have been made to resuscitate coal production using improved and mechanized system. It is envisaged that the new drive to resuscitate coal production and increase the share of coal in the nation's energy supply mix will result in the return to coal based electricity generation. Already the 30MW Oji coal fired power station is under rehabilitation. With improved coal power technology such as the fluidized bed power technology, the study envisages that coal fire plants will play significant role in the future power supply mix, and will contribute about 17,000MW in 2030.

4.3.1.2 Nuclear Energy

Uranium laden Pyrochlore exist in appreciable quantities on the Jos Plateau as well as around Bauchi and Gombe areas, but there is still no established method of commercial extraction of the uranium. About 617,000km^2 of land area had been covered by aerial radiometric surveys and another 90,000km^2 had been covered by other surveys. Estimate of the actual exploitable quantity of uranium ores has not yet been conducted.

Nuclear power development requires high initial investments, huge industrial infrastructure and skilled manpower for its success. Besides, site evaluation and technical design studies take much longer lead-time for nuclear power plants compared to fossil fuel based power plants. The plant will first depend on imported nuclear fuel pending when the technology becomes matured enough in the country. The study envisaged that nuclear power station can come on stream in 2017 with a 3600MW nuclear power plant, and a further 3600MW could be available for commissioning in 2027.

4.3.1.3 Wind Energy

Electricity based on renewable energy is very attractive; one way to utilize renewable energy is to construct wind power plants, the feasible option for wind energy is wind farms. Wind farms will be constructed along the coastal regions and in the northern part of the country. The estimated capacity of these farms is 4000MW, the estimated investment cost is 1,144 US$/kW for coastal region and 1,200 US$/kW in the northern part, respectively.

4.3.1.4 New Hydro Power Plants

Nigeria has large undeveloped hydropower potential some of these have been shown to be technically and economically viable. Some of these sites are shown in Table 4.7.

Table 4.7 Nigeria's Large Scale Hydropower Potentials

Location	Capacity (MW)
Ikom	730
Lokoja	1050
Zungeru	450
Mambilla	2600
Makurdi	1062
Onitsha	1050
Gurara	300
Dadinkowa	39

In view the huge financial requirement for developing hydropower sites only two large scale hydro projects, Mambilla (1500MW), Zungeru (390MW) and a medium sized hydro project, Dadinkowa (39MW), have been considered as candidate plants.

Table 4.8 Future Installed Electricity Generation Capacity Mix By Fuel (Reference Case), %.

Type	2010	2015	2020	2025	2030
Coal	0.0	9.9	13.8	15.3	15.6
Gas	78.6	48.5	53.5	53.0	59.0
Hydro	21.3	18.9	13.6	10.7	8.6
Nuclear	0.0	9.4	5.3	8.3	6.7
Solar	0.1	13.1	11.0	10.4	8.3
Wind	0.0	0.1	2.9	2.3	1.8

The shares of the different power generation technologies in the total installed capacity are shown in Table 4.8. It may be noted that the share of hydro power in the total installed capacity will decrease from 31.30% in 2005 to about 11% in 2030, while the share of natural gas based power capacity will increase from 68.30% in 2005 to 82.15% in 2010 and thereafter decrease to 62.95 in 2030. The share of oil would increase from 0.4 to 5.02% in the planning period. Coal, which is not used for power generation at all at present, will account for 21.05% in 2030. The installed generation capacity is shown in Figure 4.9.

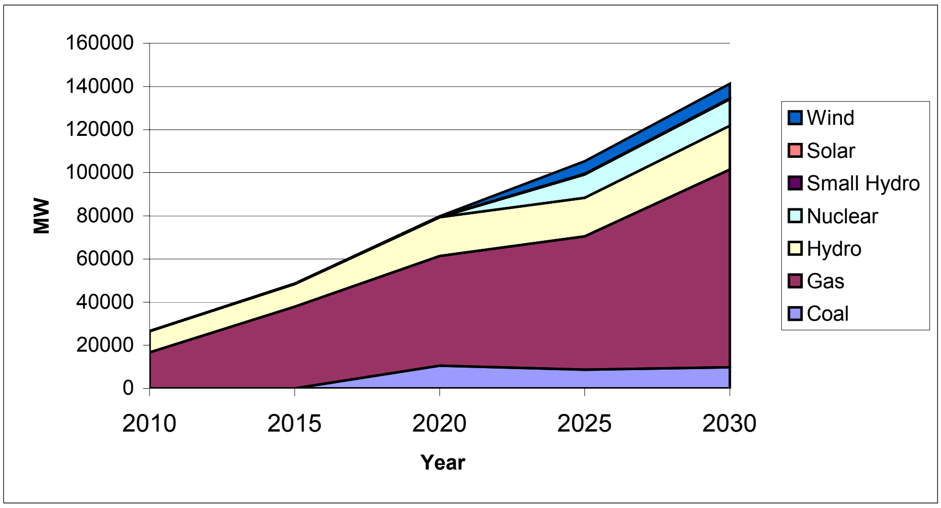

Figure 4.9 Installed Generation Capacities

4.3.2 System of Oil and Gas Supply

The main direction here is that of modernizing the existing refineries.

4.4 Modeling of the Nigeria Energy System

The techniques of representing various technological processes in the energy supply system including those of the existing system and the candidates for future development are modeled in the MESSAGE model. Real life system was applied in the MESSAGE model for the analysis of the energy system. All energy levels and energy forms are specified; energy levels are *useful energy*, *final energy, secondary energy, and primary energy*. Energy forms are *coal, oil, kerosene, electricity* and others, depending on the system complexity and tasks of analysis. Technologies either transform one fuel type or energy form into another form of transport fuels or energy forms from one location in the system into another. Therefore, each technology links one or few fuels or energy forms with either at same level or different level.

4.4.1 System of Oil Supply

The Nigerian system of oil and oil products in the form of the Case Study is shown in Figure 4.10, the system includes imports of oil products. The extraction of crude oil is modeled *crud_extr,* the extraction of oil for export is not considered in this study because we are planning for domestic supply, and however for completeness crude oil export and import have modeled in the case study.

The four existing refineries are modeled separately and like wise the new one. Table 4.9 showed the technologies for petroleum products including their respective investment costs, fixed and variable cost and other features associated with the technologies

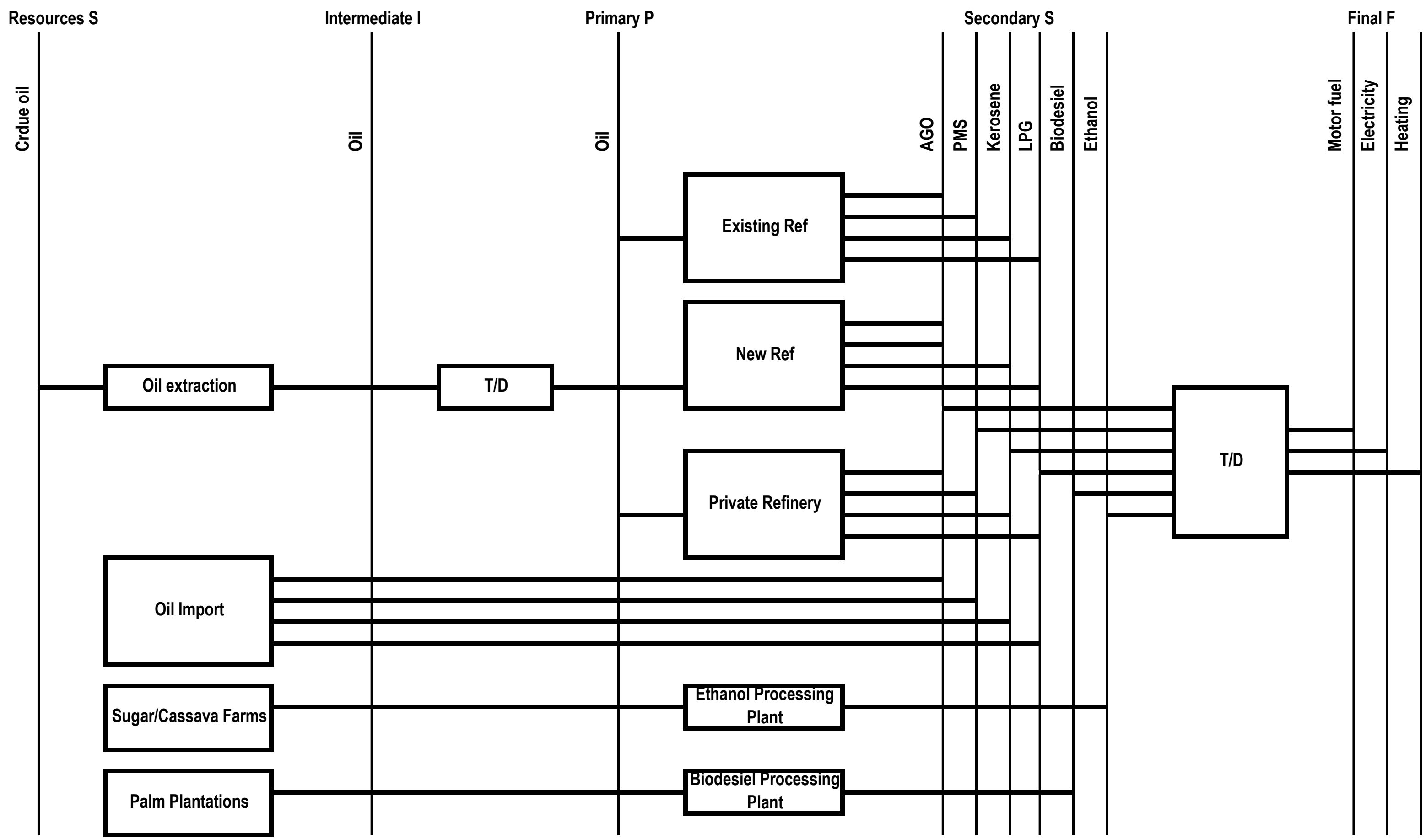

Figure 4.10 Oil Supply System

Table 4.9 Future Installed Electricity Generation Capacity Mix By Fuel (Reference Case), MW.

Technologies Representing System of Petroleum Products and Thermal Fuel Substitutable											
Plant Name	Capacity	Name of technology in the Case Study	First year of Commissioning	First year of operation	Plant factor	Operation time	Plant life	Construction time	Investment cost	Fixed O&M cost	Variable cost
	MWyr		Year	Year	Fraction	Fraction	Year	Year	$ / kW	$ / kW	$ / kWyr
Old Port Harcourt	3966	Oil_ref_1	1978	1978	1	0.9	30	3	2500	350	10
Warri	8264	Oil_ref_3	1978	1988	1	0.9	30	6	3200	300	10
Kaduna	9916	REF_KRPC	1988	1988	1	0.9	30	6	3000	350	10
New Port Harcourt	9916	Oil_ref_2	1991	1991	1	0.9	30	6	3200	330	10
New Oil Refinery	2020	Oil_ref_new	2020	2020	1	0.9	30	6	3700	400	10
Gas Extaction	500000	GasExtra	2000		1	0.9	30	5	1200	200	45
Crude oil Extraction	1666464	CrudeoilExtraction	1968		1	0.9	40	4	1200	240	45
Gas Distribution	1500	Gas-distribution		2015	1	0.9	40	5	600	30	2
Fuelwood preprations	21048	Fuelwood_prep			1	.95			50	10	

4.4.2 System of Fossil Fuel (Substitutable) Supply

The system of fossil fuel (substitutable) shown in Figure 4.11 represent preparation, transportation and distribution of coal, fuelwood and crude oil, and Table 4.9 shows the technologies. The variable cost of technologies representing preparation of fuelwood reflects the price of the prepared fuels. Coal and fuelwood are transported by trucks

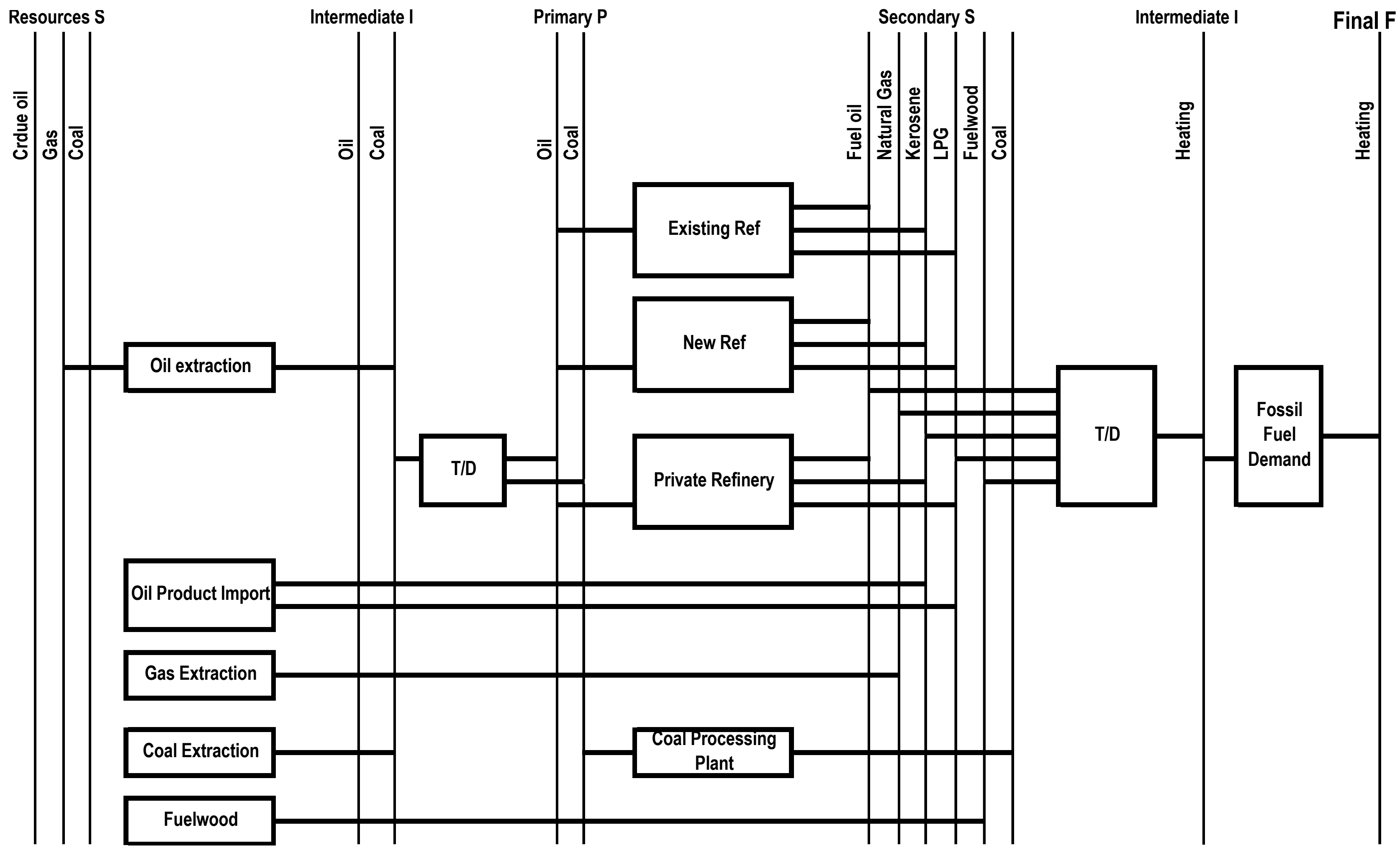

Figure 4.11 System of Fossil fuel (Substitutable) Supply

4.4.3 System of Electricity Generation

The system of electricity generation technologies is shown in Figure 4.12 and the main parameters of technologies producing electricity are summarized in Tables 4.10 and 4.11. Electricity own consumption at power plants was modeled using the additional technology whose input is Electricity for transport at the secondary level and output is at the final level. Electricity flow through technology representing all electricity consumed at power plants for their needs. The electricity flow is represented by the equation:

$$X = \sum_{i=1}^{N} \left(k_{ia} x_{ia} \right) \qquad \text{Equation 1}$$

Where:

X = Electricity flow
k_{ia} = Coefficient of electricity own consumption
x_{ia} = Energy flow
N = Number of power plants in model

The limitation of SO_2 concentrations was also considered in the model. There existing regulations in the Nigeria are not enforced; the international permissible level of SO_2 was used. The SO_2 emission from the thermal power plant is modeled using the equation:

$$\sum_{i=1}^{n} e_i x_i \le Ct \qquad \text{Equation 2}$$

Where:

e_i = SO_2 emission factor
x_i = Amount of fuel
Ct = Permissible concentration of SO_2 in the gas.

Reserved capacity was modeled

Table 4.10 Technologies Representing System of Electricity Generation for Existing Power Plants

Plant Name	Capacity	Name of technology	First year of operation	Plant factor	Operation time	Plant life	Construction time	Investment cost	Fixed O&M cost	Variable cost
	MW		Year	Fraction	Fraction	Year	Year	$ / kW	$ / kW	$ / kWyr
Delta	600	GasPP_Delta	1990	1	0.9	30	4	600.00	34.8	3.000
Afam	821	GasPP_Afa1	1980	1	0.9	30	4	600.00	40	3.000
Egbin	440	GasPP_egb	1987	0.8	0.9	30	3	500.00	30	3.000
Calabar	0.1	GasPP_Cal	1975	1	1	31	2	600.00	60	3.000
Sapele	300	GasPP_sap	1981	1	0.9	30	4	600.00	40	3.000
Omotoso	350	GasPP_omt	2008	1	0.9	30	2	600.00	30	2.000
Olorunsogo 1	1085	GasPP_sog1	2010	1	0.9	30	4	600.00	30	2.000
Geregu	335	GasPP_grg	2010	1	0.9	30	2	600.00	34.8	2.000
Alaoji	346	GasPP_alj	2008	1	0.9	30	4	600.00	34.8	2.000
Niger Delta 7	2586	GasPP_Nd7	2010	1	0.9	30	3	600.00	34.8	2.000
Shiroro	600	hydropp_a	1990	1	0.9	50	5	0.00	5	2
Jebba	540	hydropp_jb_j	1984	1	0.9	50	5	0.00	5	2
Kainji	590	hdropp_knj	1964	1	0.9	50	5	0.00	5	2

Table 4.11 Technologies Representing System of Electricity Generation for Future Power Plants

Plant Name	Capacity	Name of technology	First year of operation	Plant factor	Operation time	Plant life	Construction time	Investment cost	Fixed O&M cost	Variable cost
	MW		Year	Fraction	Fraction	Year	Year	$ / kW	$ / kW	$ / kWyr
Bayelsa	2000	GasPP_bay	2015	1	0.92	30	2	530.00	30	2.
Edo	5000	GasPP_edo	2025	1	0.91	30	2	450.00	73	1
Kano	4000	GasPP_mdg 1	2015	1	0.9	30	2	503.00	34.89	2
Maiduguri	3000	GasPP_mdg 2	2015	1	0.9	30	2.5	450.00	30	4
Mambila	2600	hydropp_mbl	2015	1	0.9	50	5	50.00	5	2
Dadinkowa	39	hydropp_dad	2015	1	0.9	50	4	1682.00	20	5
Lokoja	3500	hydropp_lkj	2015	1	0.9	50	5	1200.00	5	2
Makurdi	1062	hydropp_mkd	2015	1	0.9	50	5	1550.00	25	2
Onitsha	1050	hydropp_ont	2020	1	0.9	50	5	1850.00	5	2
Gurara	300	hydropp_gr	2020	1	0.9	50	3	1200.00	25	2
Zungeru	500	hydropp_zung	2015	1	0.9	50	6	1483.00	20	0.5
Enugu	4000	CoalPP_adv	2020	1	0.9	30	4.5	1200.00	20	2
Gombe	4000	CoalPP_2	2015	1	0.95	30	4	800	31	2
Nuclear	3600	Nuc_PP_1	2015	1	0.9	50	5	2300	60	1
Nuclear II	3600	Nuc_PP_2	2025	1	0.9	50	5	2300	60	1
Solar Thermal	2000	Solar_thermal	2020	1	0.55	20	1	2775	0.1	0.02
Solar PV	5000	Sola_PV_PP	2015	1	0.45	15	1	4160	0.1	
Small Hydro	17.5	Small_hydr_PP	2010	1	0.69	50	3	2735	3	1
Coastal Region	24.5	Wind_PP1	2015	1	0.98	20	0.6	1144	9	0.02
Interior	29.4	Wind_PP2	2015	1	0.98	20	0.5	1200	5	0.02

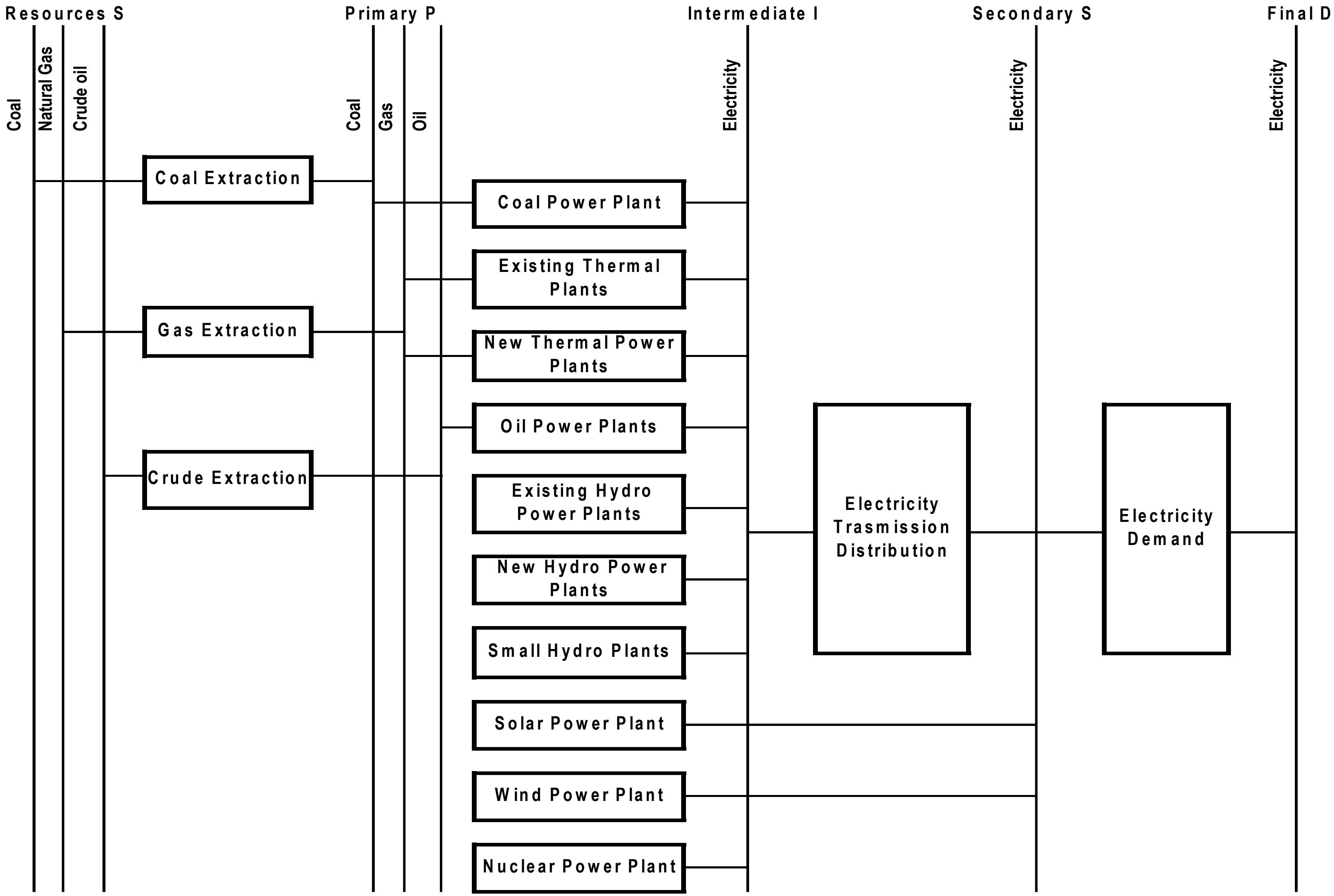

Figure 4.12 System of Electricity Generation

4.4.4 Transmission and Distribution of Electricity

Modeling of electricity transmission and distribution system is presented in Figure 4.12.
The technology " electri_trasm" models electricity transmission to national grid at secondary level while electricity transmission/distribution is modeled as " electri_dist" technology to transmit to the final level. The transmissions losses are 3.5%, the high voltage electricity network has no bottlenecks because it was developed for much higher electricity flows and technology has no constraints on throughput capacity.

5. RESULTS OF NIGERIAN ENERGY SUPPLY ANALYSIS

The three scenarios defined in section 3 have been optimized using the IAEA MESSAGE model in order to determine the optimal sustainable supply in the Nigeria's economy for the next 30 years.

The objectives of the study were:

- To develop an energy and electricity supply projection for Nigeria up to the year 2030 that will be consistent with Nigeria's attaining the standard of an industrializing country;
- To determine the optimal energy supply mix that is consistent with the above first objective;
- To diversify energy and electricity supply sources;
- To enhance the reliability of the energy and electricity supply system;
- To determine the investment requirements to meet the projected energy supply needs.

In order to achieve this, a case study was developed using the High Growth Scenario, while scenario case was developed for Reference and Optimistic Scenarios.

5.1 Electricity Generation

The provisions of the Nigerian National Energy Policy on electricity utilization are:

Policy statements

i. The nation shall make steady and reliable electric power available at all times, at economic rates, for economic, industrial, and social activities of the country.

ii. The nation shall continue to engage intensively in the development of electric power with a view to making reliable electricity available to 75% of the population by the year 2020.

iii. The nation shall promote private sector participation in the electricity sub-sector, while ensuring broad-based participation of Nigerians.

Objectives

i. To provide electricity to all state capitals, local government headquarters as well as other major towns by the year 2010.

ii. To stimulate industrialization in the rural areas in order to minimize rural-urban migration.

iii. To provide reliable and stable power supply to consumers, especially to industries.

iv. To ensure the removal of bottlenecks militating against the utilization of the full capacity of the existing electric power plants.

v. To broaden the energy options for generating electricity.

vi. To attract adequate investment capital, both foreign and domestic**,** for the development of the electricity industry.

vii. To maximize access by Nigerians to the investment opportunities in the electricity industry.

This study being presented in this report was aimed at achieving the above policy statements and objectives.

There were three scenarios developed in the MAED demand study, these were Reference, High Growth and Optimistic Scenarios. The output from the MAED was used in the supply analysis-using MESSAGE. In this study the existing and the committed generating plants were considered.
The following observations were made in respect of the power plants in Figures 5.1, 5.2, and 5.3 for Reference, High Growth and Optimistic Scenarios respectively:

- Existing Power plants for rehabilitation or replacement for both the gas and the hydro to be restored to their original capacities
- Committed power plants would be expanded to meet up with the demand.
- Future plants would be constructed as indicated in Table 4.10 within the study period in order to meet up with the supplies.
- All future gas plants will be designed to have combined cycle gas turbines.
- Nuclear and coal will play greater roles in the later period of the studies.
- The need for electricity importation from the countries benefiting from the West African Gas Pipelines projects in the High Growth and Optimistic Scenarios so as to beef up the supplies is imperative.
- Renewable energy would provide electricity to rural areas where there is no grid and at sensitive places like hospitals and communication installations.
- Coal power plants will come up in the year 2015 and 2020 in the South East and North Central Regions of the country where coal resources are readily available
- Seven new hydropower plants are to take off from 2015 to2020.
- Five new gas power plants would take off from 2015 to 2025, while the renewable energy power plants would come on board from 2010 to 2015.
- The Expansion program of the committed power plants is to start from 2010 to 2015.

As at 2005 electricity generation in Nigeria was mainly from two types of fuels, gas and hydro. Although there are many non-grid supply from various economic sectors of the economy as a result of the epileptic nature of the generation of electricity through the use of oil products and other renewable energy sources. The total installed capacity was 5733MW and the actual production is 4370 MW and was grossly in adequate. The country had nine existing power plants, six from gas and three from hydro. The percentage supply per fuel was 66.34% gas and 33.66% hydro for year 2005 and it is projected to be 72.18% for gas and 13.40% for hydro in the 2030 as shown in figure 5.4

If implemented according to the projection made the supply to the country would be over one hundred and thirty percent of demand at 2030. This is expected to take care of the frequently raised issue of “Suppressed demand” for energy.

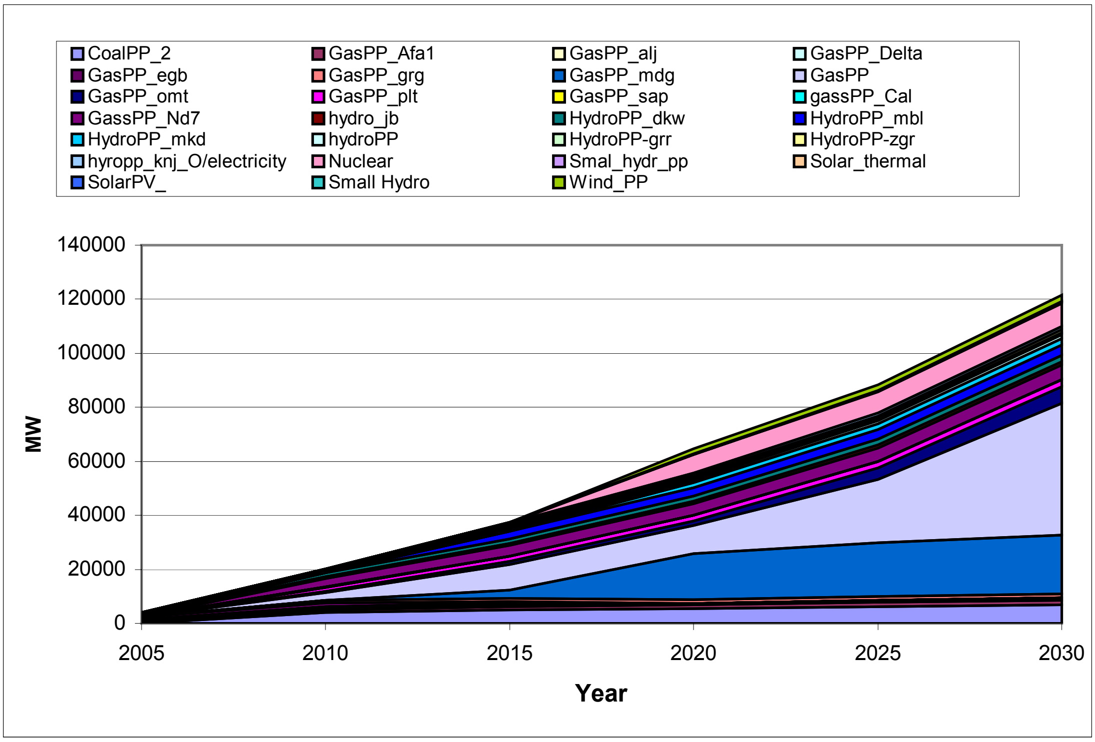

Figure 5.1 Electricity Production by Power Plants (Reference Scenario)

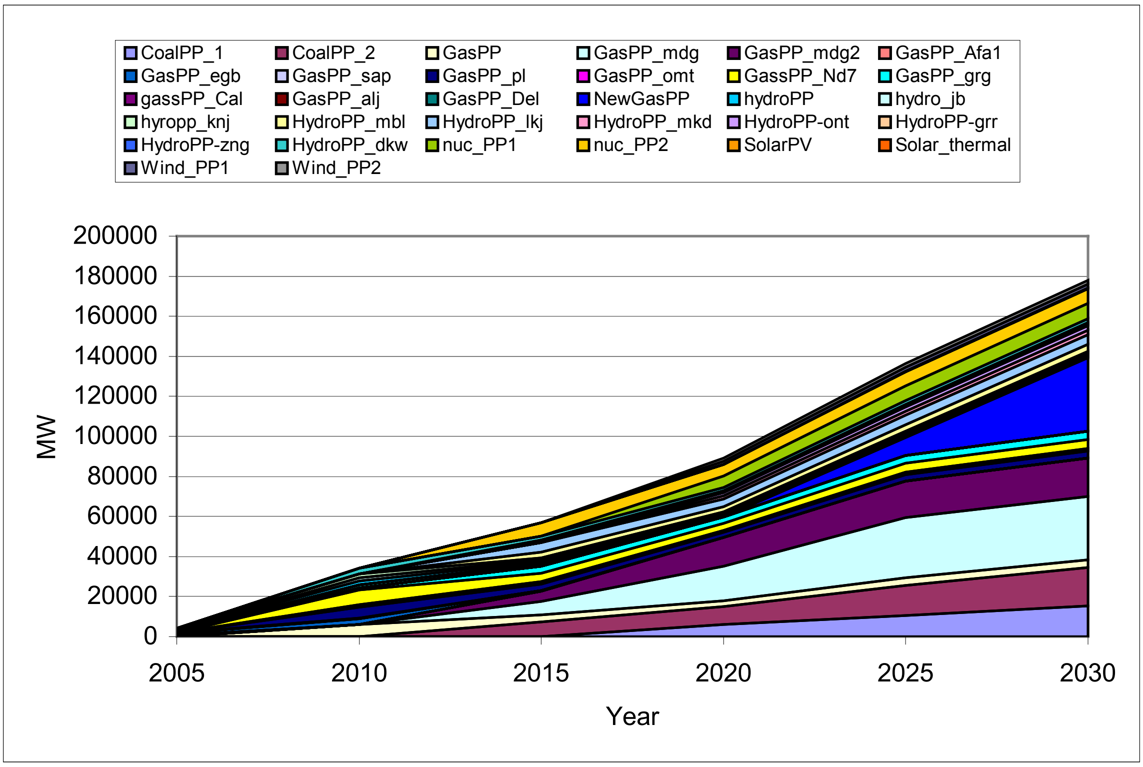

Figure 5.2 Electricity Productions by Power Plants (High Growth Scenario)

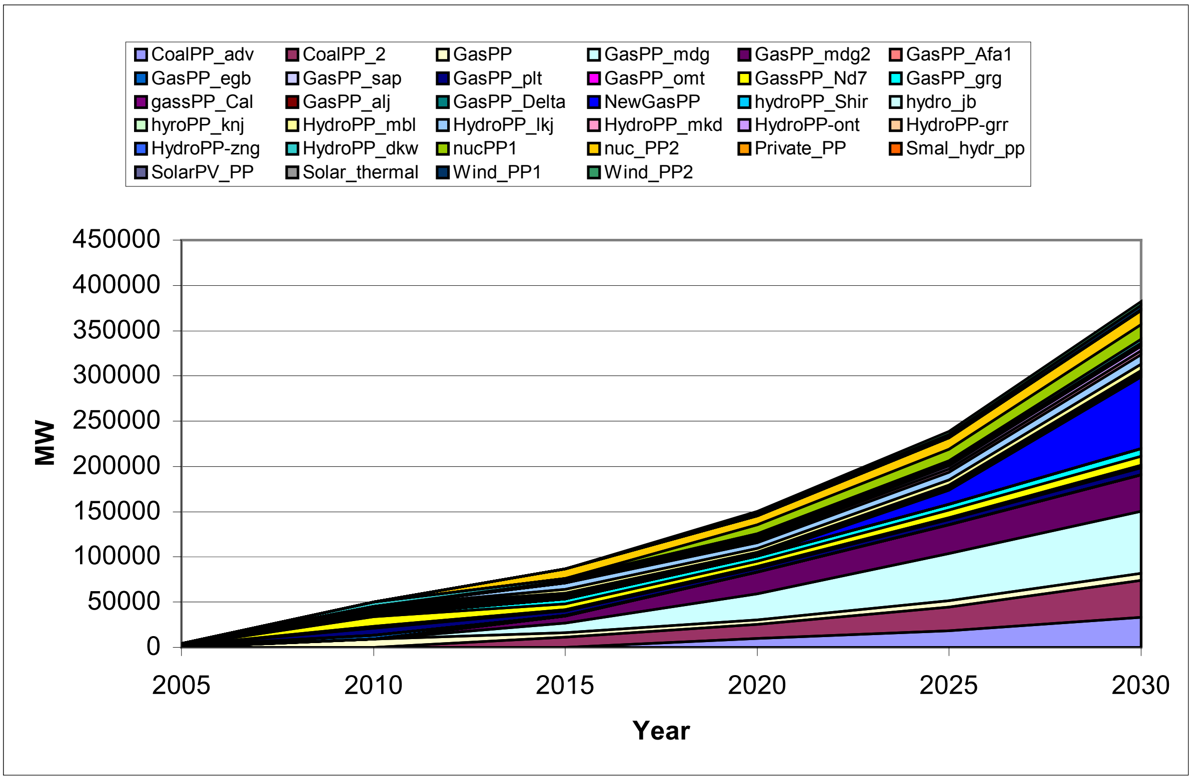

Figure 5.3 Electricity Supply Productions by Power Plant (Optimistic Scenario)

5.2 Electricity Supply Projection by Fuel

As highlighted earlier, the fuel mix for energy production are only two types, the hydro and gas fuels. One of the objectives of the National Energy Policy is to broaden the energy options for generating electricity. Hence the relevance of the use of the highly flexible MESSAGE modeling tool to accomplish this objective. Nigeria is blessed with various energy resources as indicated earlier in the report. The study allows other resources to be tapped for electricity supply. Seven different types of fuels were used for optimization. These are gas, hydro coal, nuclear, small hydro, solar and wind. The contributions of these fuels to electricity generation options have considerably changed the supply of electricity pattern in the country over the period of study.

It is observed that for High Growth Scenario as shown in Figure 5.4 gas is still taking the lead by providing 22826 MW in 2010 to 114,037.8 MW in the year 2030. Coal that is introduced in the year 2015 is taking over from hydro with contribution of 7470 MW by the year 2015 to 40,981 by the year 2030. In the same Scenario, in the year 2030 the contributions of gas is 72.18%, coal is 25.94%, Hydro is 13.40%, Nuclear 10.1%, Small Hydro 0.17% while Solar and Wind are to contribute 0.05% and 2.83% respectively.

Similarly, the electricity projections in the Reference and Optimistic scenarios are shown in Figures 5.4 and 5.7, respectively. The pattern of the supply are similar, however, the supply begins to reduce at 2030 and very high in the year 2020 to 2025 this may not be unconnected to the realization of Nigeria becoming an industrializing economy.

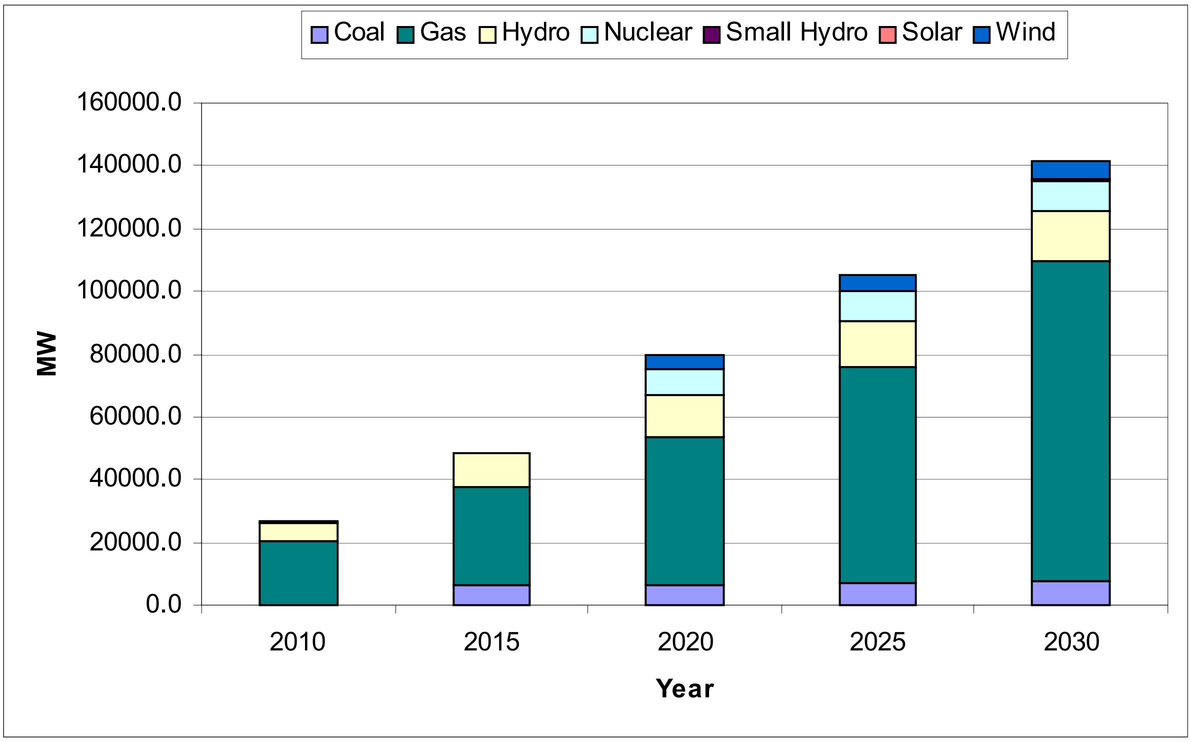

Figure 5.4 Projected Electricity Supply (Reference Scenario)

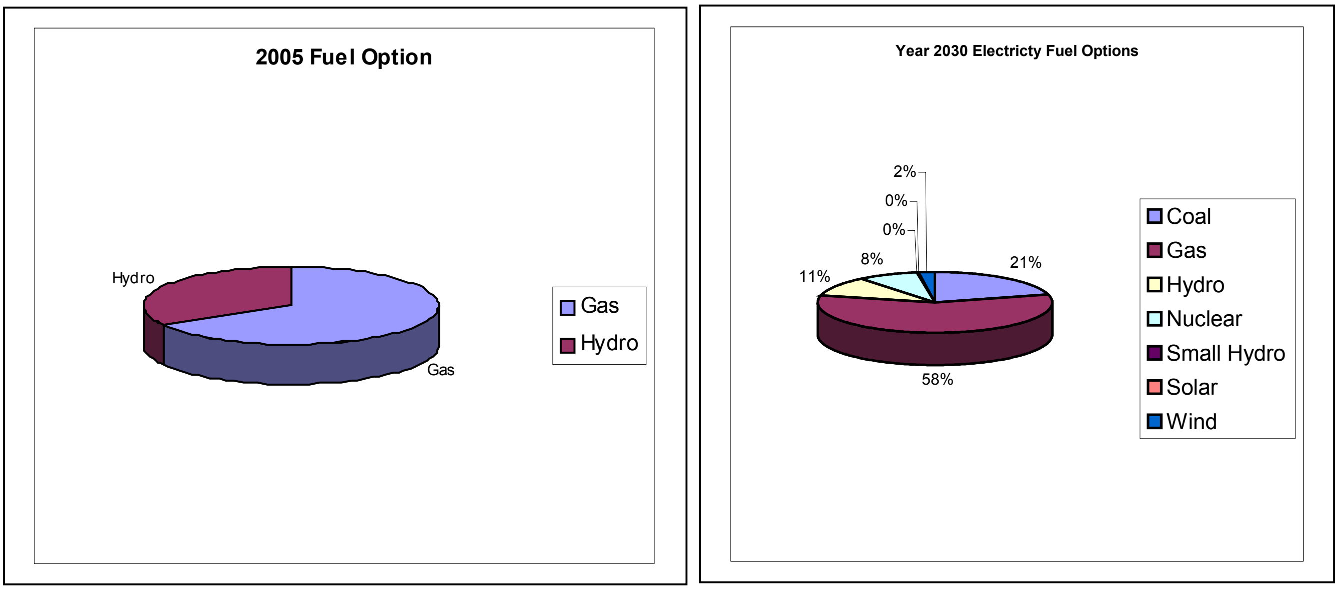

Figure 5.5 Showing Electricity Options in the year 2005 and 2030

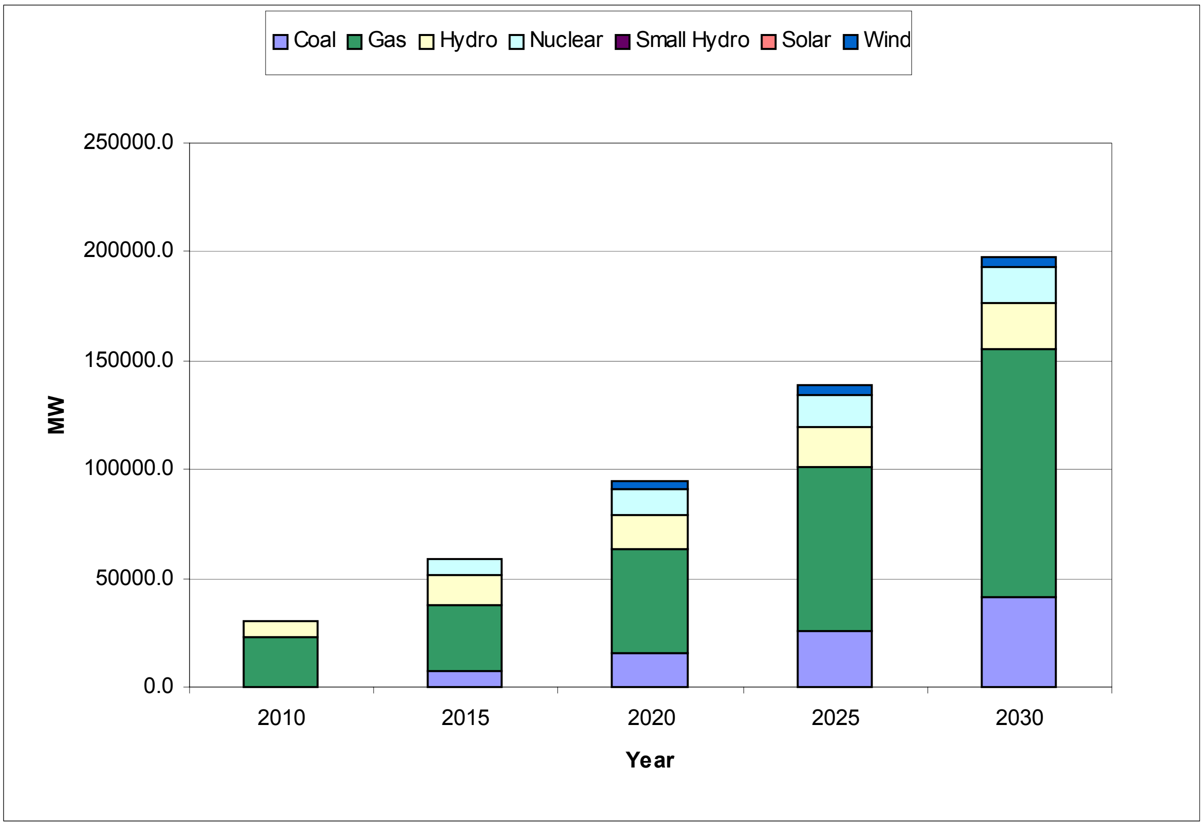

Figure 5.6 Projected Electricity Supply by Fuel Type (High Growth Scenario)

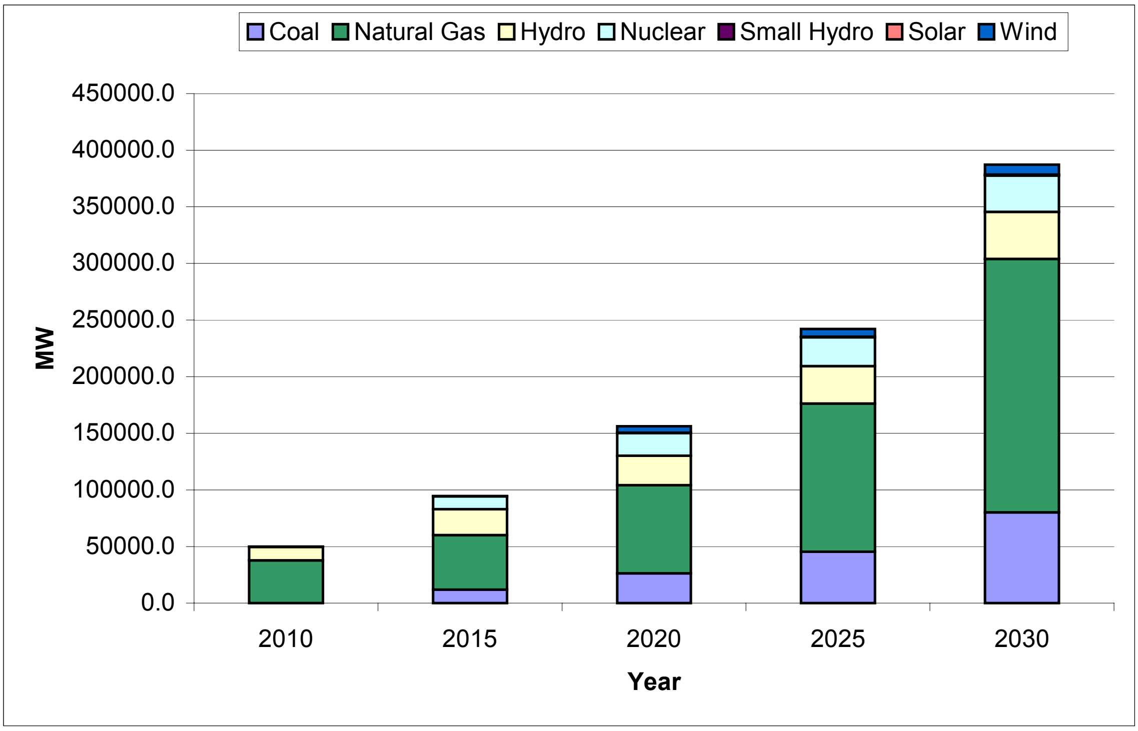

Figure 5.7 Projected Electricity Supply (Optimistic Scenario)

5.3 Total Primary Energy Requirement

In Nigeria oil and gas are dominating the total primary energy. The total primary energy requirements will be growing at the rate of 400% from 2010 to 2030; in the year 2005 gas was contributing 66.346% of electricity supplies and is also contributing 72.18% in the year 2030.

The contribution of oil is much higher in the transport and heat production sectors. The percentages of primary energy in the country's energy mix as at 2030 for High Growth Scenario are coal 12%, natural gas 34%, oil 43%, noncommercial 1%, nuclear 4%, hydro 5% and renewable (solar, small hydro, and wind) 1%. This pattern is similar to the other two scenarios as shown in figures 5.9 and 5.10.

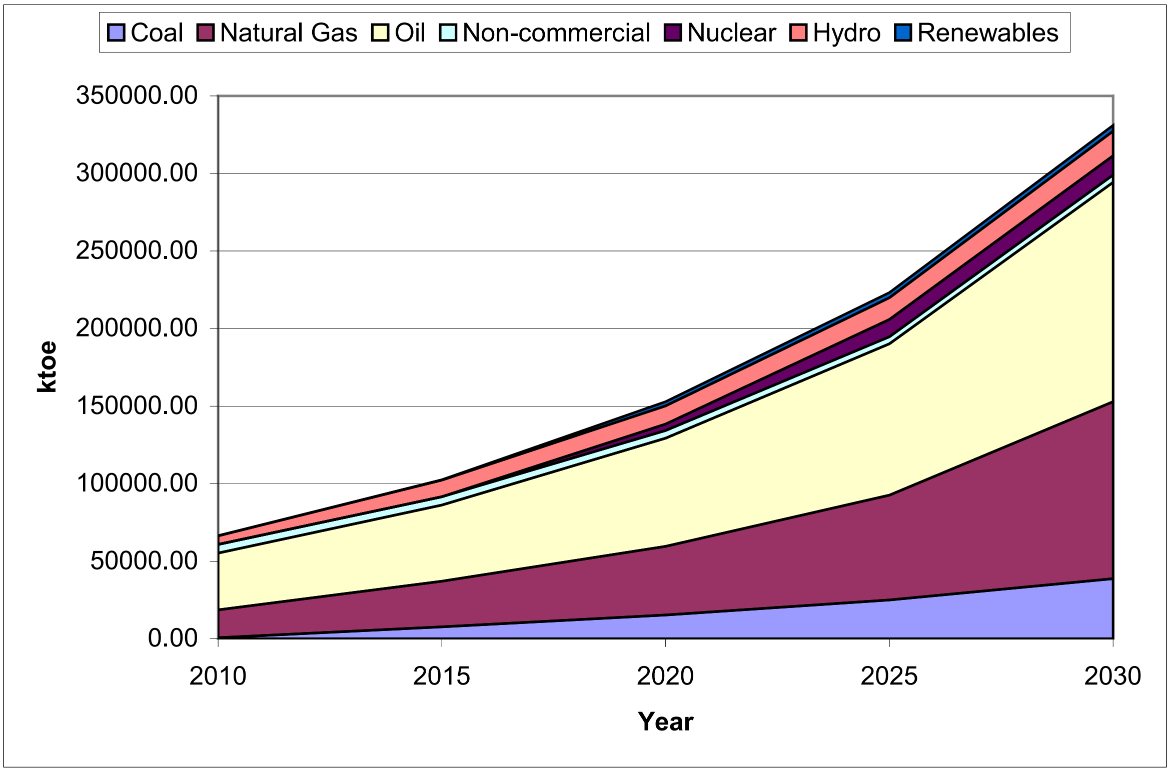

Figure 5.8 Total Primary Energy (Reference Scenario)

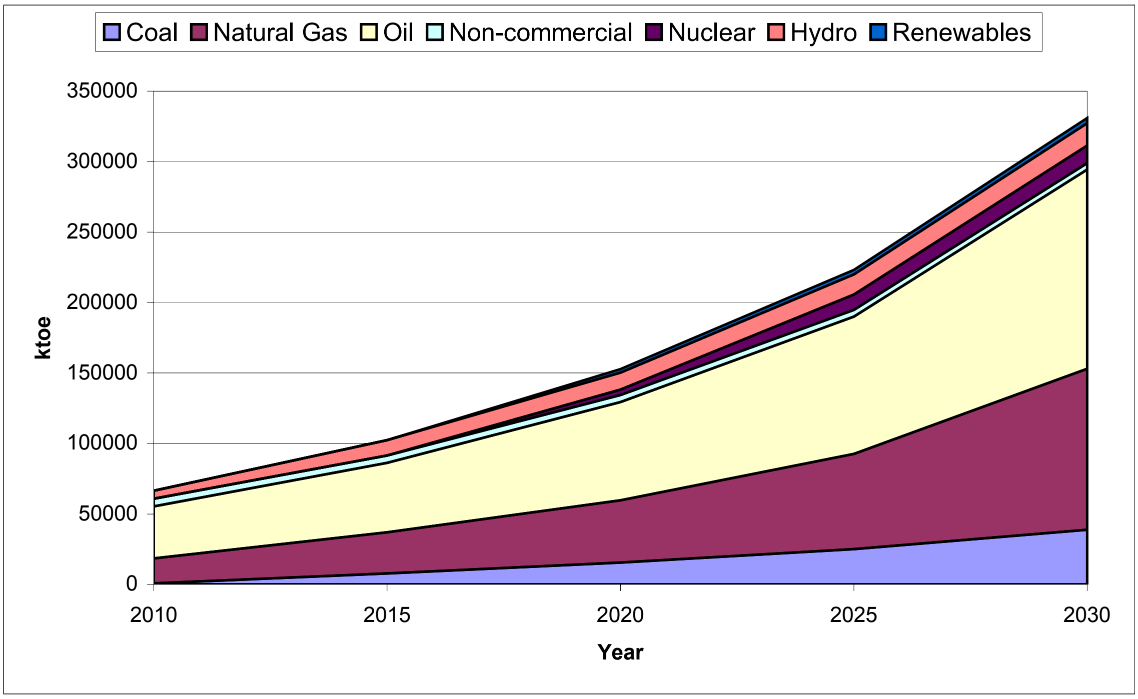

Figure 5.9 Total Primary Energy Requirements (High Growth Scenario)

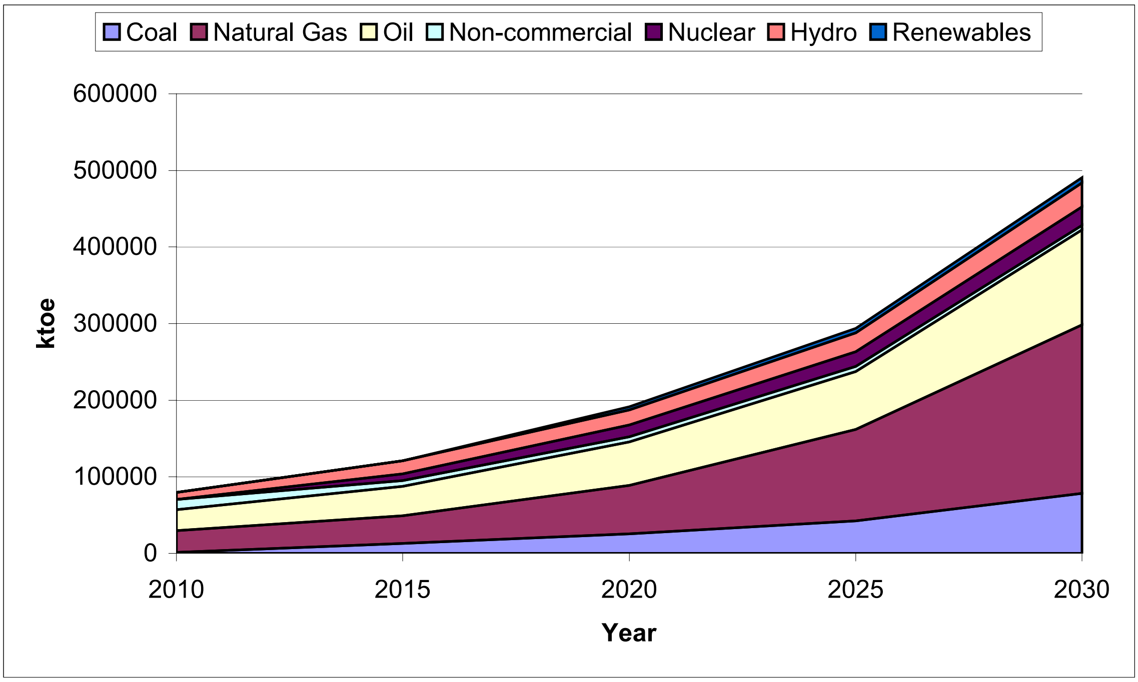

Figure 5.10 Total Primary Energy Requirements (Optimistic Scenario)

5.4 Motor Fuel Projection

The oil industry is the backbone of the Nigerian economy, accounting for over 90% of total foreign exchange revenue. Estimates of the total crude oil reserves vary, but are generally accepted to be about 35 billion barrels, although new offshore discoveries are likely to push this figure to about 40 billion barrels. The refining, petrochemical, and transportation sectors of the oil industry in Nigeria, are controlled by government and indigenous operators and is an area in which government has made considerable investment over the years. The downstream sector is beset by a non-commercial pricing environment and lack of resources to maintain and manage the infrastructure properly.

The focus of the government's policy on the downstream sector can be summarized as follows:

- To maintain self-sufficiency in refining
- To ensure regular and uninterrupted domestic supply of all petroleum products at reasonable prices
- To establish infrastructure for the production of refined products for export.

The downstream sector has been a major problem for the country over the past 3-4 years, as the NNPC has found it impossible to maintain the country's four refineries, and to provide adequate supply of Prime Motor Sprit (PMS), Automotive Gas Oil (AGO) and Dual Purpose Kerosene (DPK) nationwide. The NNPC recently completed the 3rd phase of their national pipeline distribution system; however large segments of the distribution system are in urgent need of maintenance

The oil marketers in the downstream sector in Nigeria are divided into two segments: the majors and the independent Nigerian marketers. Currently, the independent marketers number over 500, with a market share of less than 30%. On the other hand the major marketers are only 6 and include Conoil, African Petroleum, Total, Oando, Texaco and Mobil.

Two of the country's refineries that is those at Kaduna and Warri have petrochemical plants that utilize refinery by-products to produce polypropylene, linear alkyl benzene, and a host of other products. It is recognized that for an olefin-based petrochemicals plant to be viable in Nigeria, it must be developed by cracking natural gas liquids in the olefins plant.

In modeling the oil products production (PMS, AGO, DPK, LPG and Fuel Oil), the four existing refineries were considered for either complete refurbishment or replacement to the their original capacities. The old Port Harcourt refinery that was built in 1978 is virtually out of operation, as it has not functioned since 2004. The model scrapped it because of old age. The city of Port Harcourt being in the heart of the oil producing areas, it will be cheaper to replace the refinery at the same venue, as many supporting infrastructureexist close by. It is observed that with the rehabilitation of the existing refineries and constructing new ones from 2015, import of petroleum products will seize by the year 2025. None of the existing refineries will be expanded, however new refineries are expected to start coming up by the year 2015 Figures 5.11- 5.32 refers.

The supply patterns showed over 30% over supply at 2030 and about 70% in the years 2015 and 2025.

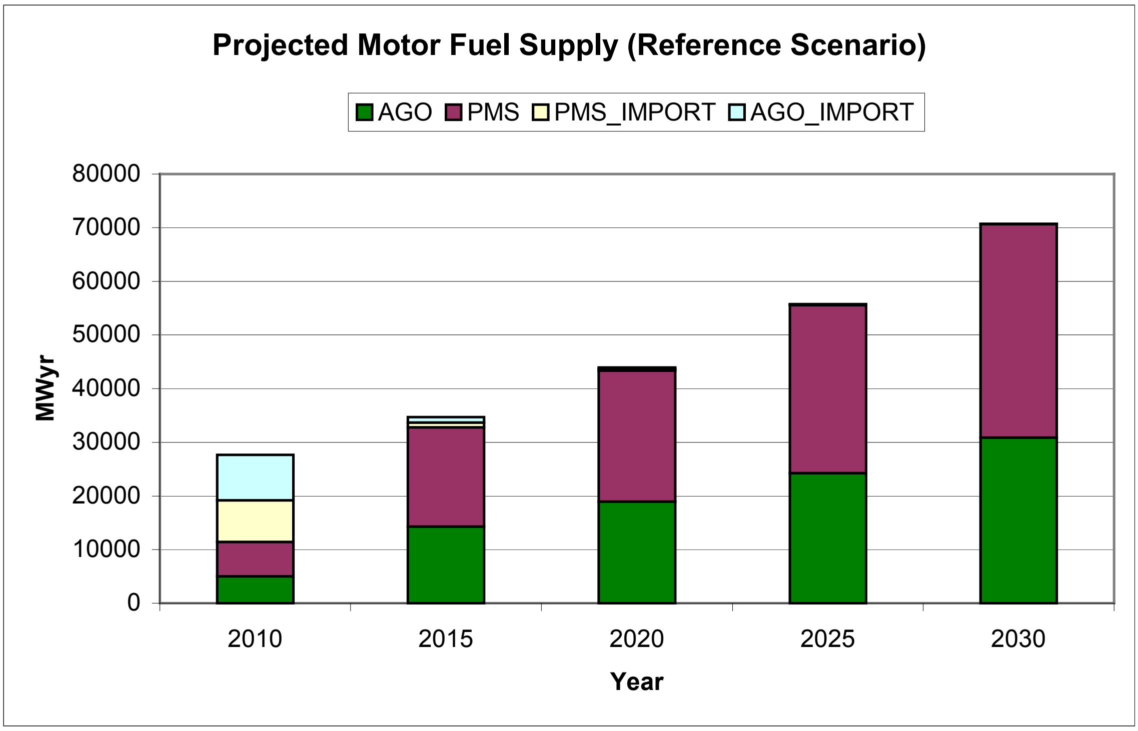

Figure 5.11 Motor Fuel Production by Refineries (Reference Scenario)

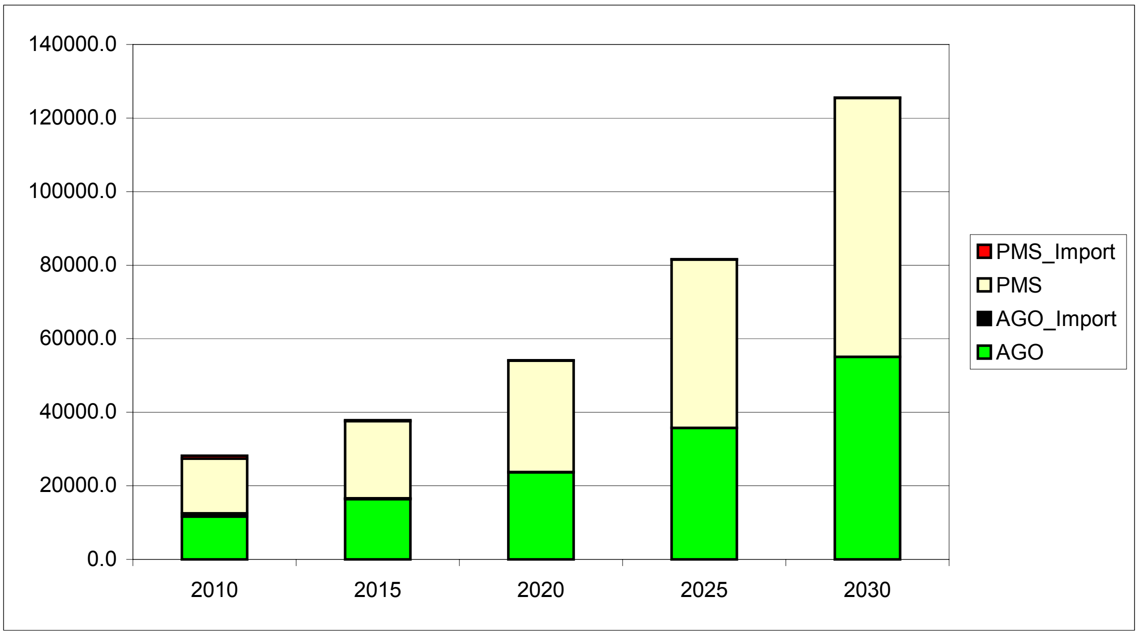

Figure 5.12 Projected Motor Fuel Supply (High Growth Scenario)

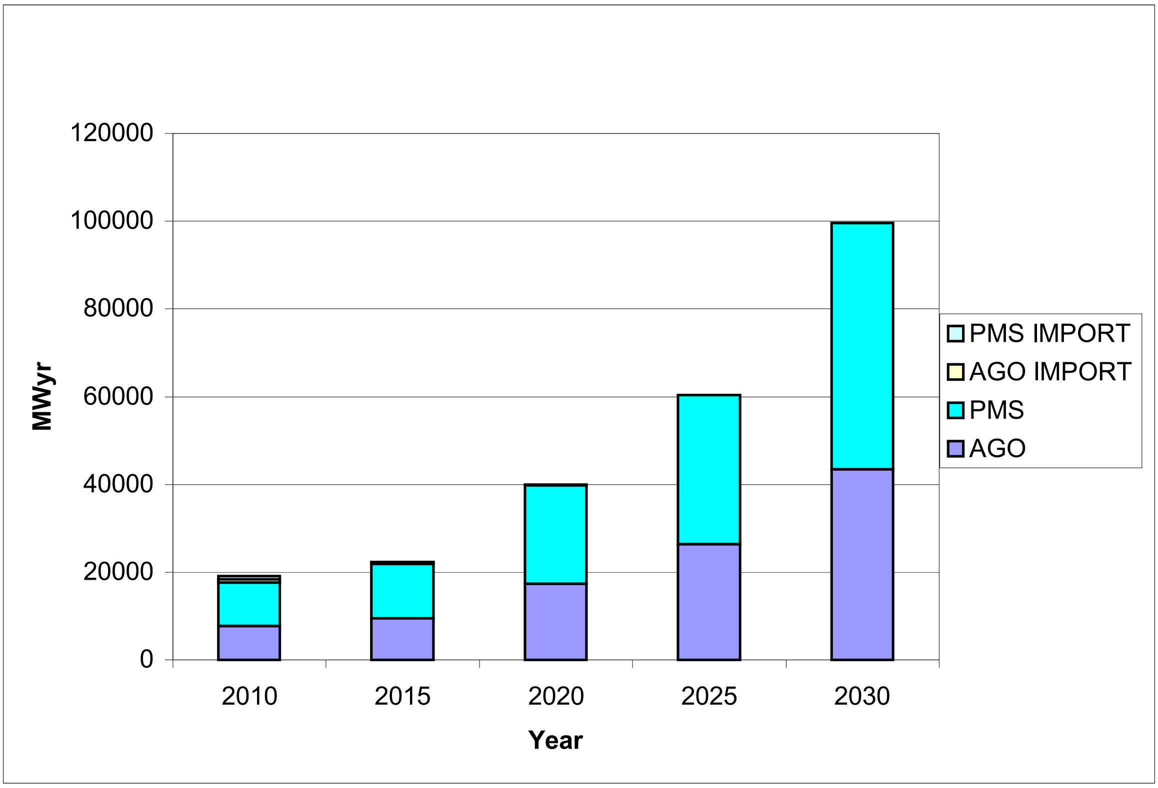

Figure 5.13 Projected Motor Fuel Supply (Optimistic Scenario)

5.5 Projected Substitutable Thermal Fuel

The thermal substitutable fuel is modeled in such a way that any of the fuel types can be substituted with another one for heat production in all the sectors of the economy. These fuel types are gas, coal, fuel oil, DPK, LPG, fuelwood and electricity.

Fuelwood is modelled in such a way as to satisfy the NEP, which provides that:

i. The nation shall promote the use of alternative energy sources to fuelwood.

ii. The nation shall promote improved efficiency in the use of fuelwood.

iii. The use of wood as a fuel shall be de-emphasized in the nation's energy mix.

iv. The nation shall intensify efforts to increase the percentage of land mass covered by forests in the country.

Objectives

i. To conserve the forest resources of the nation.

ii. To greatly reduce the percentage contribution of fuelwood consumption in the domestic, agricultural and industrial sectors of the economy.

iii. To arrest the ecological problems of desert encroachment**,** soil erosion and deforestation.

iv. To facilitate the use of alternative energy resources to fuelwood.

v. To reduce health hazards arising from fuelwood combustion.

Hence while other fuel types are increasing over the study period in all the Scenarios, the use of fuelwood, referred to as noncommercial fuel in the model, is decreasing.

Electricity is not included in this model. In the base year there was no useful record of how much electricity was utilized for thermal purposes in all the economic sectors. However the demand for electricity supplied has covered electricity for all types of utilizations.

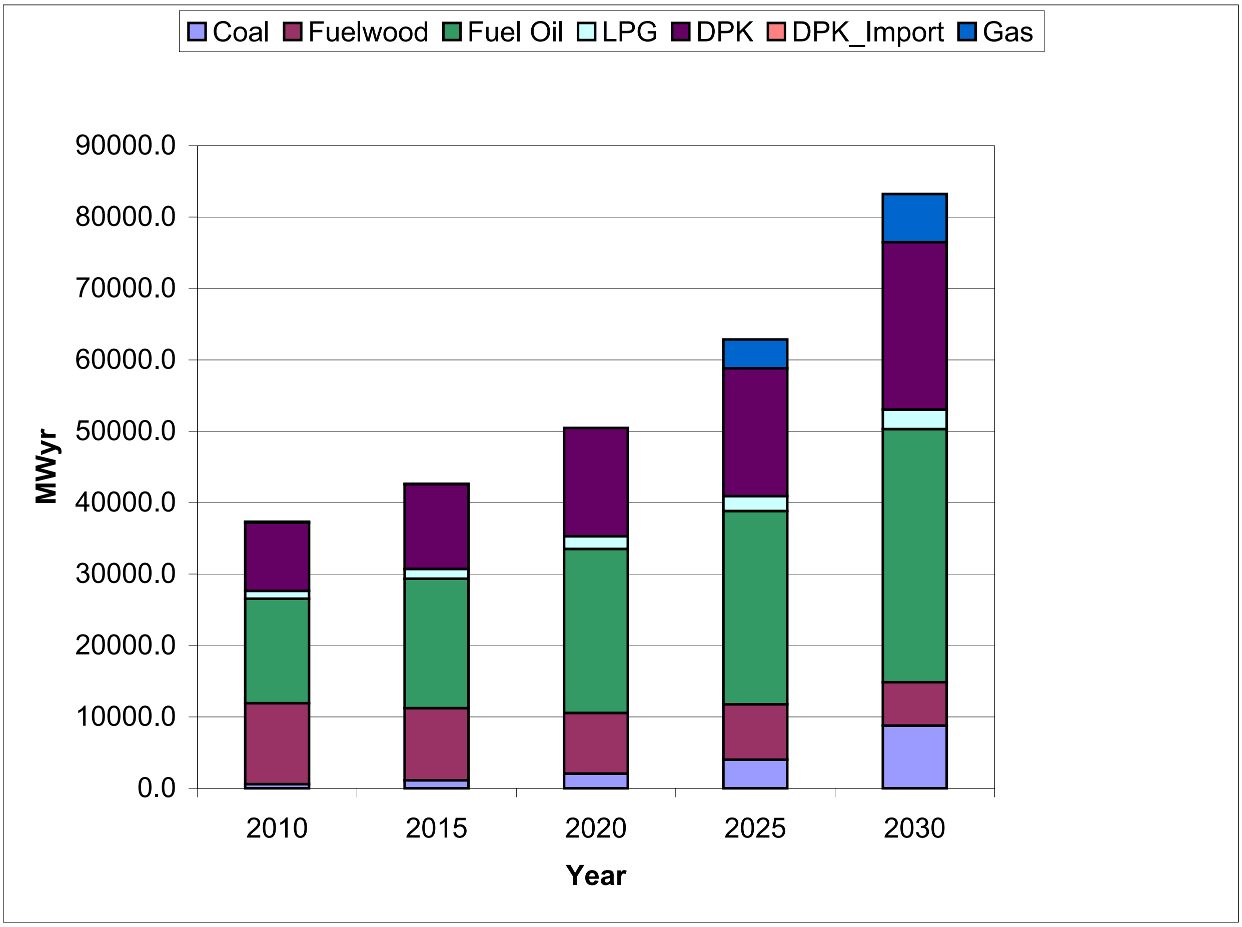

Figure 5.14 Projected Thermal Fuel Substitutable (Reference Scenario)

Figures 5.14 - 5.16 are the outputs from the thermal fuel substitutable model for the Reference, High Growth and Optimistic Scenarios. It could be observed that fuelwood, which is mostly used for residential thermal production, and fuel oil for industrial applications, play major roles in year 2010. As the country moves out of the agrarian economy in the years

2020 to 2030 the use of fuelwood and other non-commercials diminishes while fuel oil continues to grow as more and more industries are built. Coal is introduced in the residential and services sectors as coal briquettes take over from fuelwood and other noncommercial fuels.

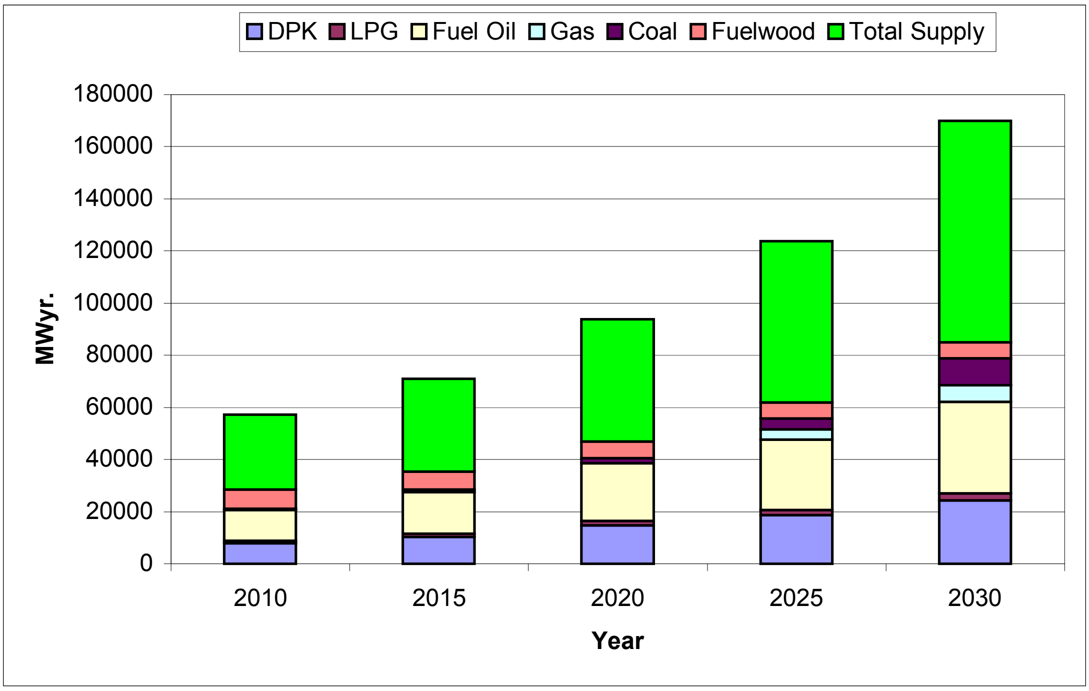

Figure 5.15 Projected Substitutable Thermal Fuel Supply (High Growth Scenario)

The use of natural gas is emphasized in the year 2025 in the residential and services sectors as well as the industrial and other sectors of the economy. Hence, natural gas competes with coal and fuelwood. However it could further be observed by 2030 in the Optimistic Scenario, the use of natural gas for all the economic sectors is acceptable as it has the highest contributions.

Kerosene (DPK) consumption is growing with time and this may not be unconnected with the simplicity and availability of improved kerosene stoves used in the rural areas and some areas of the urban and peri- urban areas in the country. The use of LPG is declining because of the cost of gas cookers, gas bottles and the production of LPG in our refineries.

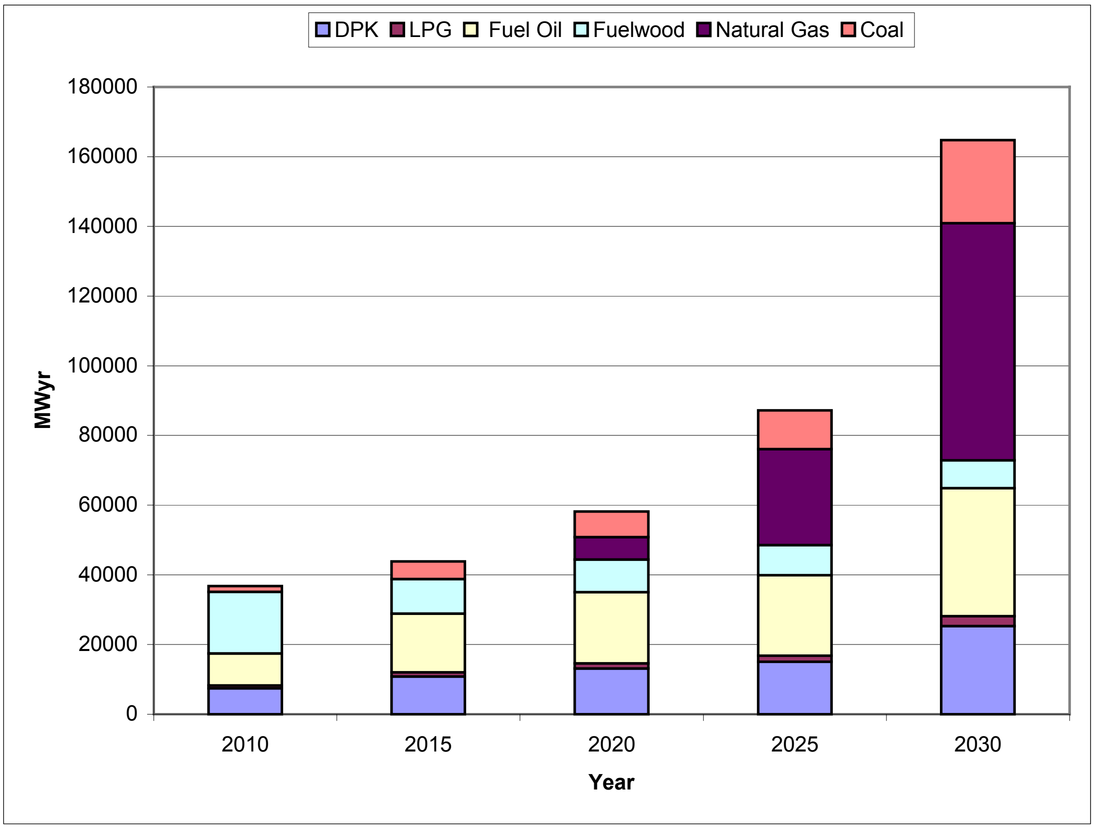

Figure 5.16 Projected Thermal Fuel Substitutable (Optimistic Scenario)

5.6 Environmental Impact Analysis

The exploration and exploitation of fossil fuels - coal, oil and natural gas - have led to air and water pollution, land degradation, deforestation and the attendant erosion menace experienced in a number of developing countries including Nigeria. The combustion of fossil fuels has been identified as the major contributor to global warming due to the emissions of green house gases (CO_2, NO_x, SO_2). Similarly the exploitation of nuclear energy resources requires high degree of security and safety.

Oil spillage has been a common occurrence in the petroleum industry and it has made significant adverse effects on fisheries and marine life in the affected areas. Given the pollution experience of this country from the exploration and exploitation of fossil fuels, environmental considerations were incorporated into the National Energy Policy and in the National Energy Masterplan with a view to evolving ways and means of mitigating energy related environmental pollutions. The use of fuelwood and other noncommercial energy types is causing serious environmental problems in the country. These probem are desert encroachment in the northern part of the country, loss of soil fertility and soil erosions in the southern part of the country

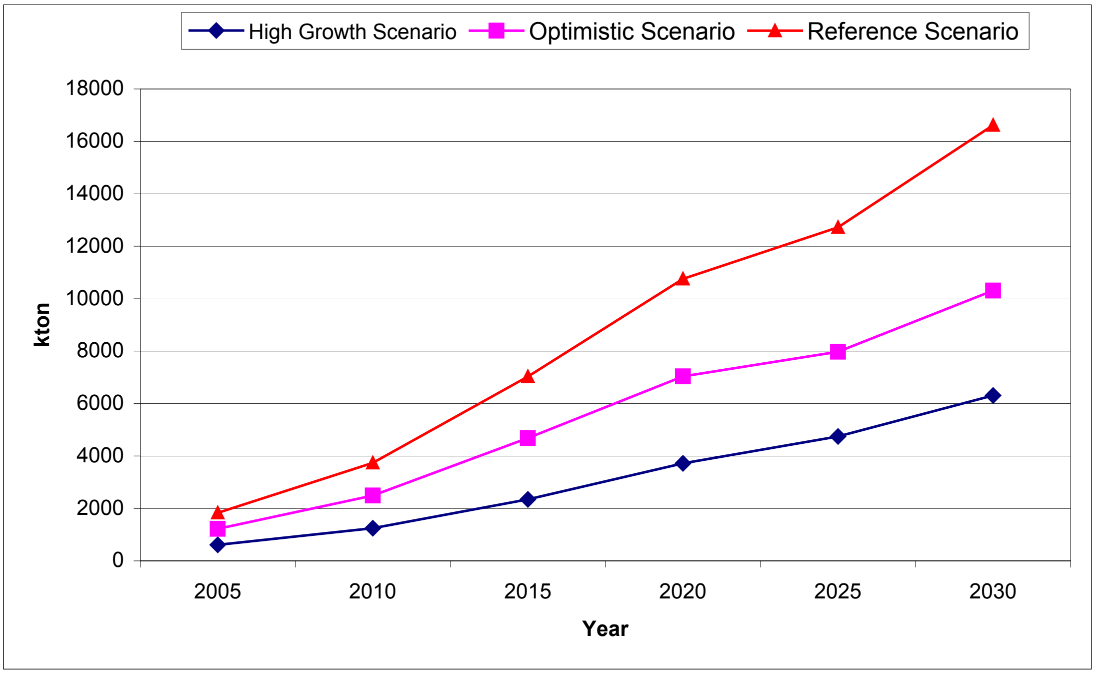

Figure 5.17 NO_x Emissions related to Fuel Combustion Processes

In order to arrest the outlined environmental issues, the green house gas (GHG) emissions were modelled in each scenario.

The deforestation and soil erosion issues were addressed in the thermal subsitutable fuel model in all the scenarios. It could be observed in Figure 5.14 Refrence Scenario, fuelwood is contrubuting 39.2% in the year 2010 in the subsitutable energy mix while in 2030 in the Optimistic Scenario fuelwood is contrubuting 4.8%. This shows the reduction in the use of noncommercial fuel thereby enhancing the desertification and erosion controls.

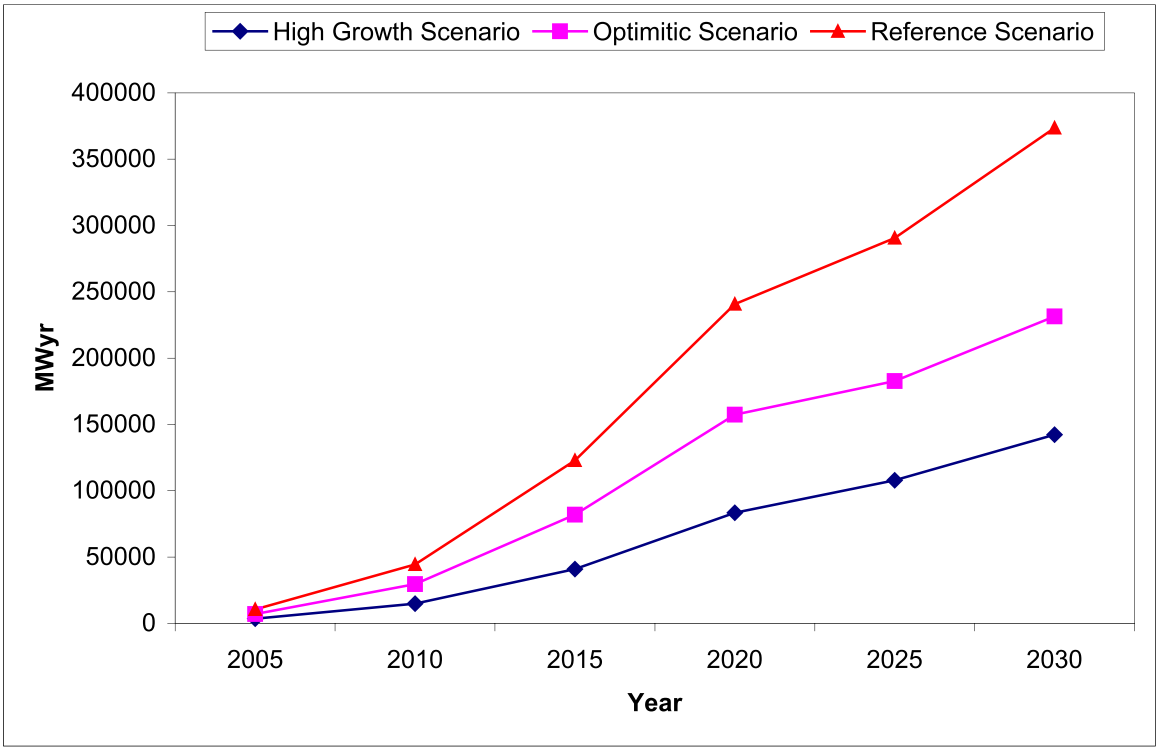

Figure 5.18. CO_2 Related to Fuel combustion Processes.

In modeling associated environmental issues the national energy strategies along with the economic aspect and the energy balance of the country have been considered. The evolution of CO_2, NO_x, SO_2 emission was determined in each scenario without imposing any limits. Figure 5.17 and 5.19 showed the SO_2 and NO_x emissions while the total CO_2 emission is shown in Figure 5.18.

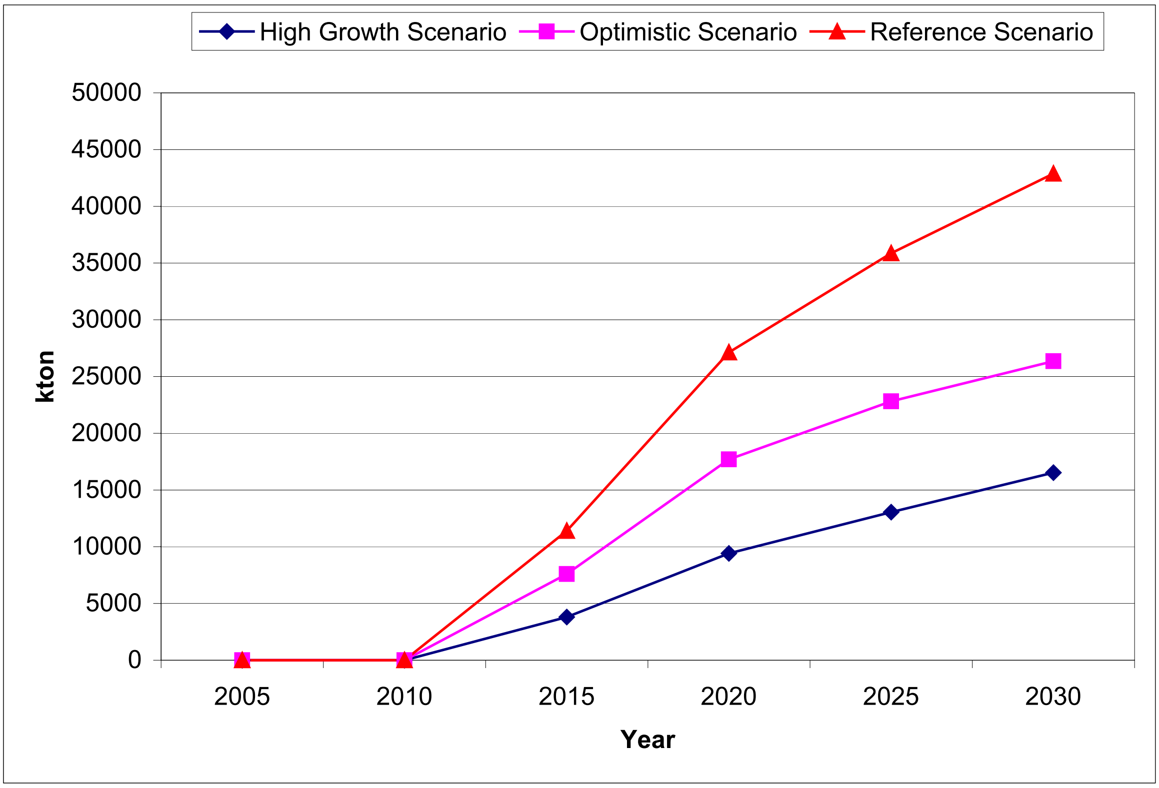

Figure 5.19 SO_2 Emissions related to Fuel Combustion Processes

To further control emissions, CO_2, NO_x, and the flue gas desulphurization equipment must be provided in the rehabilitations of the existing power plants and refineries while incorporating flue gas desulphurization equipment into proposed power plants and refineries. Similarly stabilization of SO2 emissions could be achieved by the installations of flue gas cleaning devices in all the existing and proposed power plants and refineries.

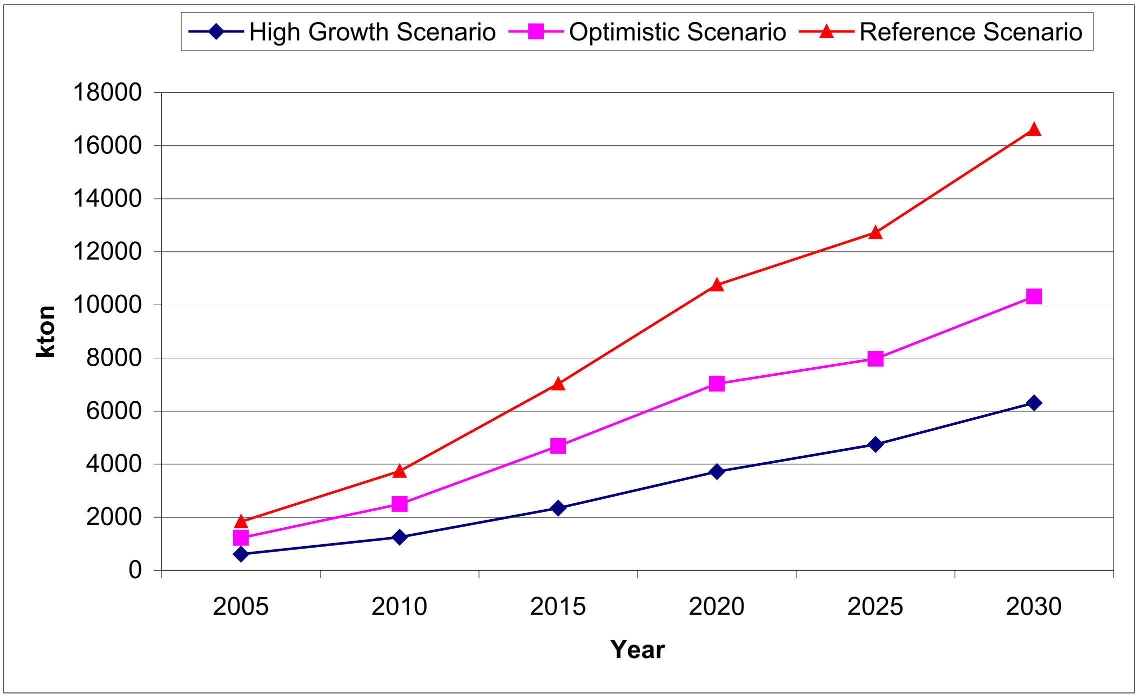

Figure 5.20 NO_x Emissions Related to Combustion Processes

5.7 Investment Requirements

The Nigeria's case study was modeled to project electricity, motor fuels, thermal substitutable fuel supplies and environmental emissions. In accessing the investment costs consideration is given to expansion/replacements of technologies for the supply of electricity, petroleum products, natural gas and coal as well as the use of renewable energies.

5.7.1 Electricity Investment Requirements

Table 5.1 shows the periodic new installations per scenario over the 25-year study period. There is an increase in the projected supply in the Reference Scenario for all the period. An annual capacity expansion of 5485 MW is needed for 25-year study period. Similar pattern of increment is also observed with an annual capacity expansion of 7734 and 15325 MW for the High Growth and Optimistic Scenario, respectively. This increase in the supply will results in very high investment costs in all the scenarios.

Table 5.1 Periodic New Installations per Scenario (MW)

	2010	2015	2020	2025	2030
Reference Scenario (MW)	22387	22081	31219	25530.	35911
High Growth Scenario (MW)	26033	28913	35658	43775	58994
Optimistic Scenario (MW)	45764	44701	61500	86042	145130

Table 5.2 gives the cumulative investment as well as cumulative operation costs (fixed and variable O & M costs) over the next 25 years for all three scenarios, cost of fuel was not included. In the reference scenario the cumulative investment cost for capacity addition is 126 billion US$ and the operational cost is calculated to be US$ 10.69 billion. Comparing it with High Growth Scenario that is targeted to industrializing the country by year 2020 is US$232.05 billion, which makes it US$106.05 billion over the cumulative investment in the Reference Scenario. Similarly the system operation cost for high growth scenario is US$13.74 billion, which is slightly higher than that of Reference Scenario. This may be attributed to the use of more efficient technologies. The investment and operational cost in the Optimistic Scenario is higher than the Reference Scenarios with about US$350 billion.

Table. 5.2 Cumulative Investment and Operation Costs per Scenario

Scenario	Investment Cost (bill US$)	Operation Cost (bill US$)	Cumulative Cost (bill US$)
Reference	126.21	10.69	136.90
High growth	232.05	13.74	245.79
Optimistic	459.77	24.85	484.62

The total investment and operational cost for Reference Scenario is US136.90 billion while US245.79 billion and US$484.62 billion is for High Growth and Optimistic Scenarios respectively. None of these scenarios could be achieved without serious funding from both the government and local and international investors.

With the establishment of the Nigerian Electricity Regulatory Commission that oversees and regulate the supply in the country things would move positively in achieving the objective. Other issues such as political will and stability are needed couple with the sensitization of foreign investors on the potentials of the country in the power sector. Figure 5.21 is showing the graphical view of the investment and operational cost per scenario.

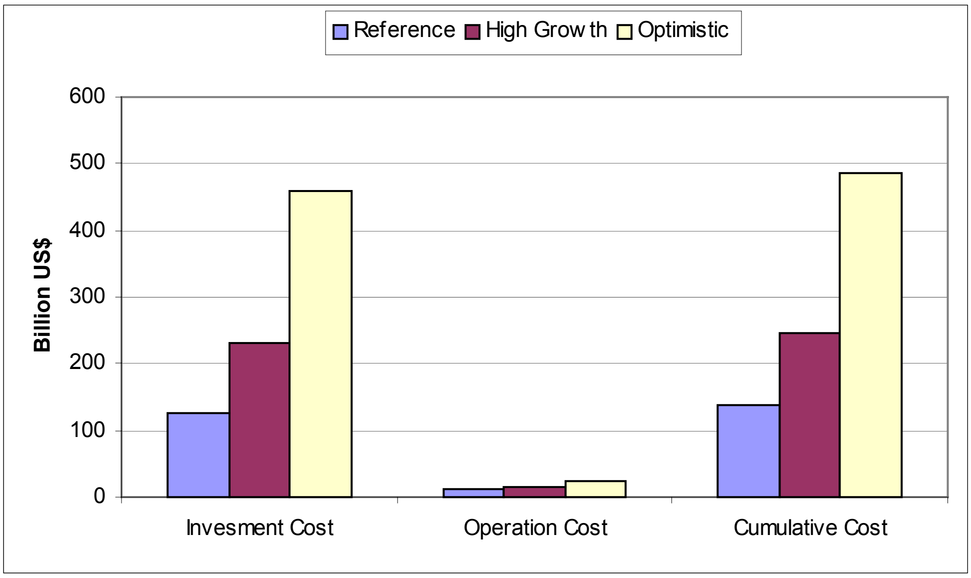

Figure 5.21 Cumulative Investments and Operational Costs

5.7.2 Refinery Investment Requirements

Figure 5.22 give the cumulative investments and cumulative system operation costs (i.e. O & M and fuel) over 25 years period for all the scenarios. Investment cost (capital cost) was calculated based on a 5-year period at a cost of $25,000.00 per barrel per day. Construction of pipeline and storage capacity was not included. However the cost of constructing a 1km of pipeline is $2 million. In the Reference Scenario, the investment for capacity additions for the 25-year period was about $42 billion. The operation cost which include all the production and maintenance cost excluding the taxes was about $153 billion for the whole period. Fuel cost is the cost of crude oil and is calculated at an average of $100 per barrel will be about $1195 billion. The cumulative cost will be about $300 billion for the Reference Scenario.

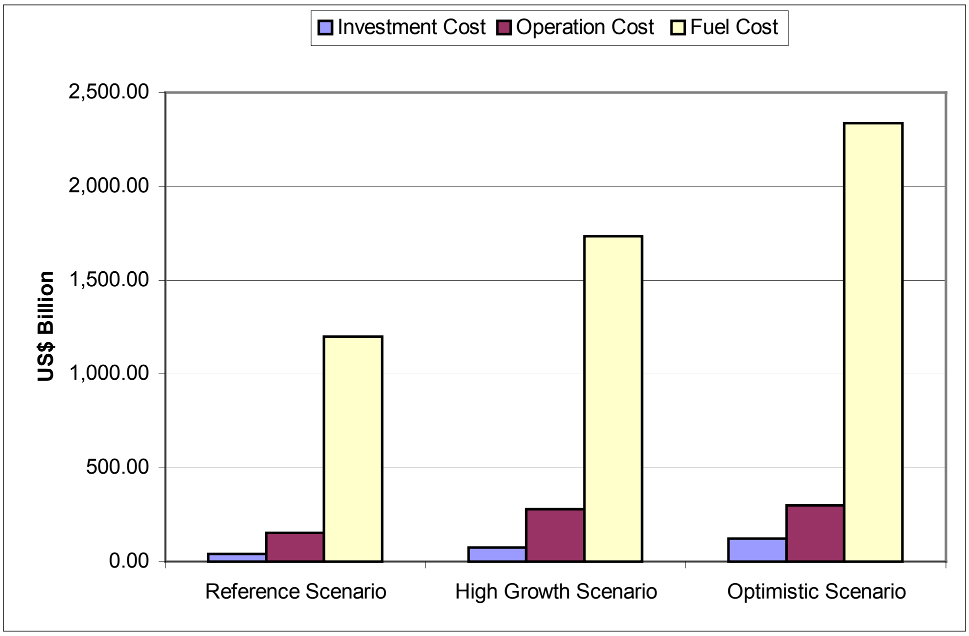

Figure 5.22 Refinery Cumulative Investment, Operation and Fuel Cost over the next 25 years

If fuel demand grows to the levels as envisaged in the High Growth and Optimistic Scenarios (Figure 5.23), the cumulative investments required for building refinery capacity will be about $75 billion and $125 billion for the High Growth and Optimistic Scenarios respectively.

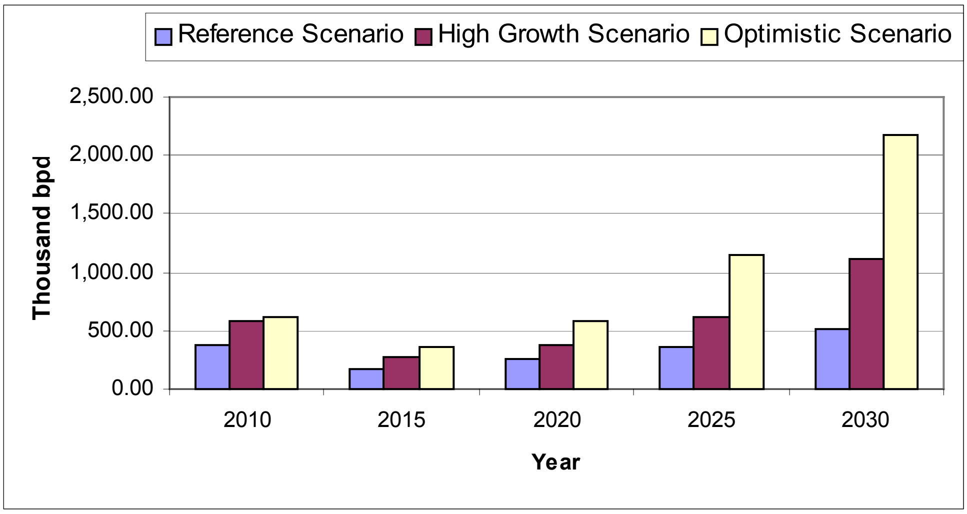

Figure 5.23 Periodic Refinery Addition Capacity (thousand barrels per day)

Comparison of the periodic investment for the Reference Scenario shows that, there is more investment cost in the first period (2010) than second period (2015), and this is due to economic starting growth as projected and the renovation of the existing 450,000 bpd refinery capacity by 2010 capacity (the cost of renovation is not included) (Figures, 5.23). There is an increase in investment cost in the fourth period of the study, and is due to attainment of industrial growth as envisaged in the economic growth as shown in Figure 5.24.

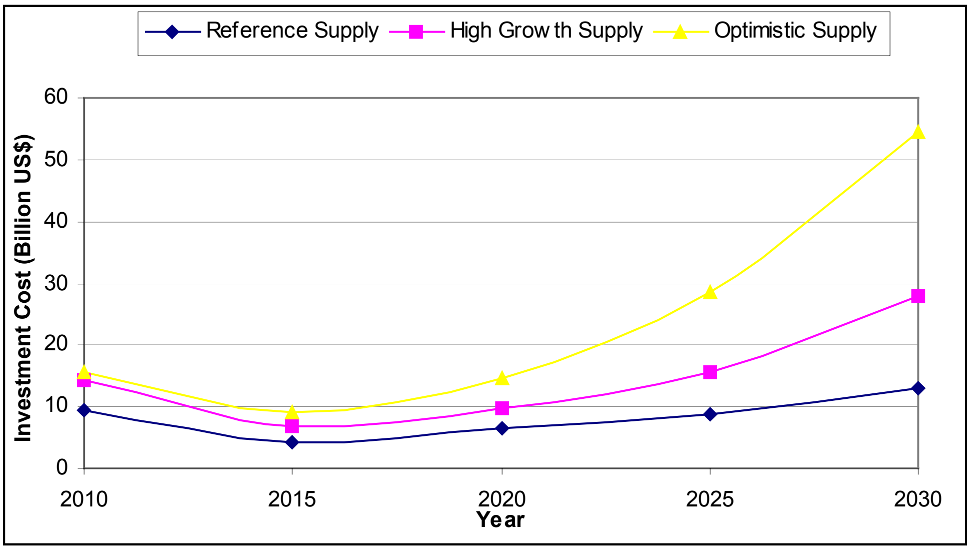

Figure 5.24 Periodic Investment (5 years) of the Plan Refineries

5.7.3 Thermal Substitutable Requirement

Figure 5.25 gives the cumulative investments and O&M cost over 25 years period for all the scenarios for the refinement of coal to coal-briquette. The overall cost for Reference Scenario was $900 million; the overall cost for High Growth and Optimistic Scenario is $1000 million and $2600 million, respectively.

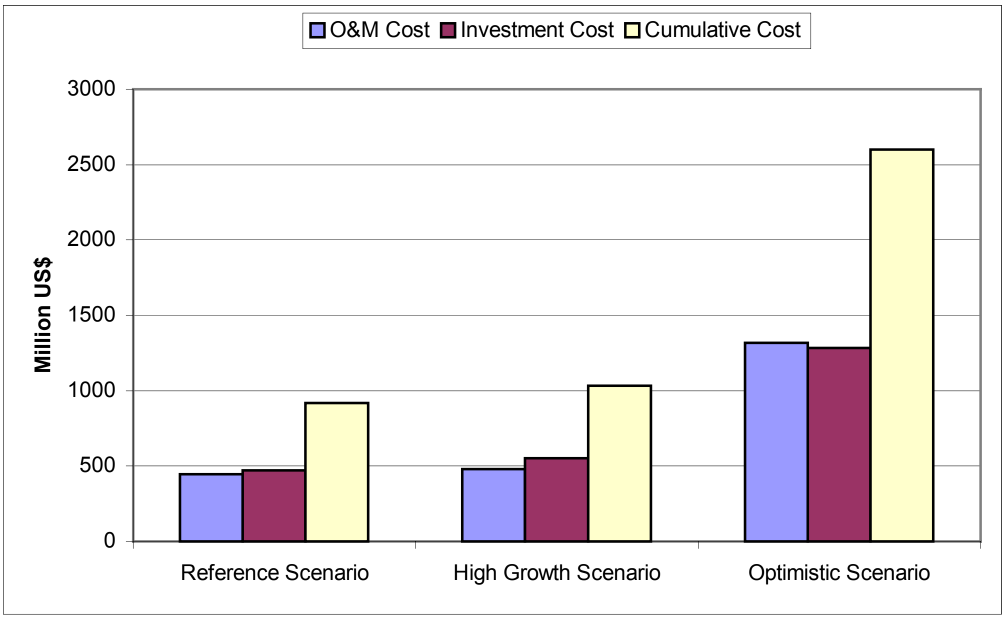

Figure 5.25 Cumulative Investment, O&M Cost for Coal

The periodic investment cost for Reference and High Growth Scenarios is similar between 2010-2020 (Figure 5.26). There is higher investment for the three scenarios after 2020, and this is due to the demand and substitution of fuelwood by the coal-briquettes.

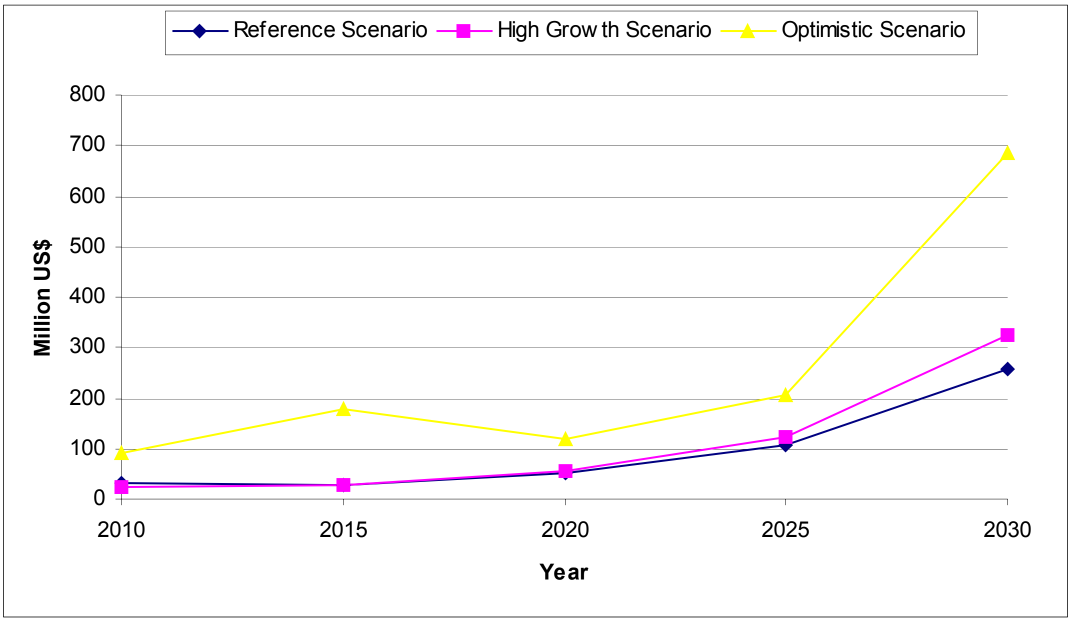

Figure 5.26 Periodic Investment Cost of Coal (TCE)

Figure 5.27 gives the periodic investment of liquefied natural gas. LNG will be contributing for domestic thermal heating mix as from 2020 in the Optimistic Scenario and 2025 for the Reference and High Growth Scenarios. Nigeria will require 202 billion CFG by 2030 annually for the Reference Scenario. The requirement for High Growth and Optimistic Scenarios in 2030 is 224 and 2,265 billion CFG, respectively. At $6.7 per CFG the investment cost for the Reference Scenario is about $1 billion in 2025.

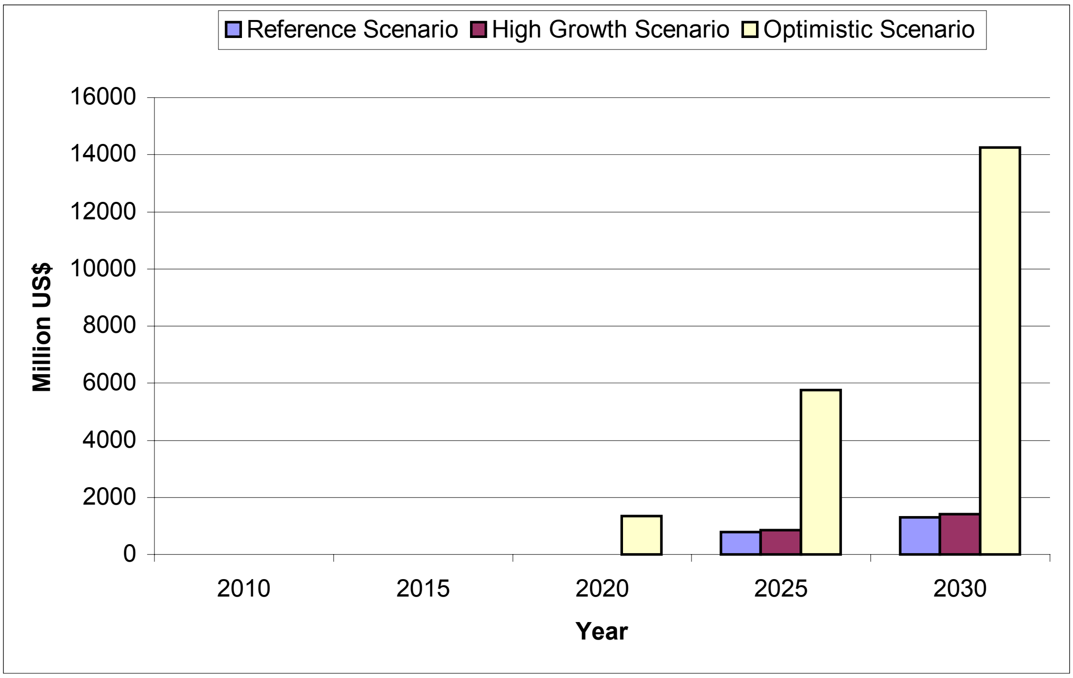

Figure 5.27 Investment Cost of Natural Gas

Figure 5.28 show the operation and maintenance cost for the fuelwood. The fuelwood cost was measured base on $5 per tonne for the development of forest energy. There is a decrease in the O&M of the fuelwood for the Reference and High Growth Scenarios. However, there is an increase in the O&M in the Optimistic Scenario. Fuelwood will be substituted with other environmental friendly alternative sources like coal-briquette and natural gas.

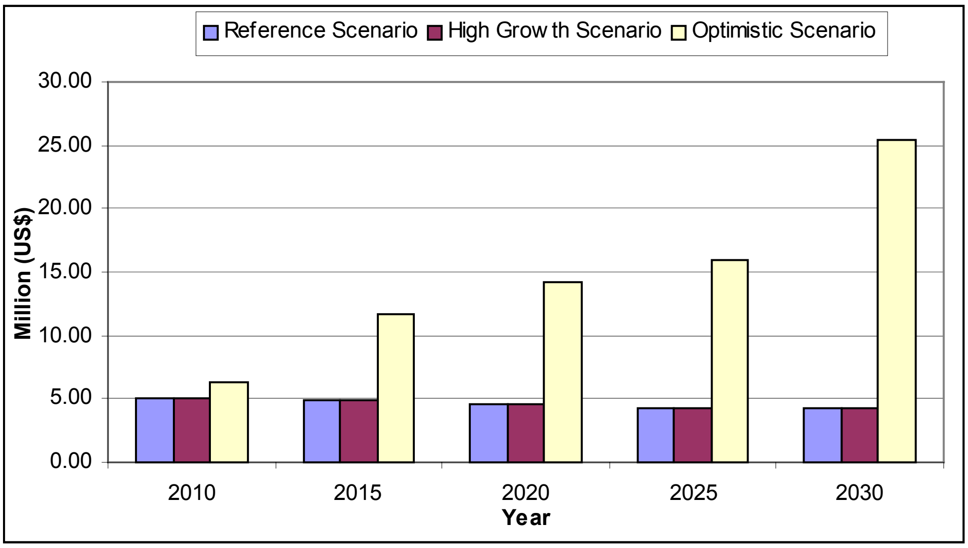

Figure 5.28 Operation and Maintenance Cost of Fuelwood

5.8 Sensitivity Analysis

Sensitivity analysis was carried out for discount rate and capital cost, fuel cost and fuel cost escalations were not included in the analyses.

5.8.1 Refinery Technologies

In order to study the effect of discount rate, investment cost of the refineries and O&M (including the fuel cost) on the oil refinery expansion, various sensitivity analyses were performed including the option for fuel import and fuel subsidy by the government. The results of these sensitivity analyses are described below.

Discount Rate
Sensitivity analysis were performed on the refinery expansion program by increasing the discount rate for both investment and the operating cost from the three scenarios at 10%, 11%, 12% and 13%. The refinery expansion remains unchanged for all the scenarios.

Capital Cost of refineries
Sensitivity analysis is conducted for capital cost by increasing the cost of building refineries. It was found that there is no change in the least cost refinery expansion plan up 30% higher capital cost of the refineries. It is cheaper to refine oil than to import it.

5.8.2 Electricity Power Plant Technologies

Sensitivity analysis was also carried out for the power system expansion programme; the results of these sensitivity analyses are described below.

Discount Rate
Sensitivity analysis on the generation expansion programme was performed, by increasing the discount rate for both capital and operation cost from 10% to 11%, 12%, 13% and 14%.

- The power generation expansion programme remains unchanged for the Reference Scenario
- The power generation expansion programme remains unchanged up to 13% for the High Growth Scenario. However, at a discount of 14% the gas power plant expansion in Maiduguri shifted to 15 years later, and the nuclear power plant I and II were shifted to 2025.
- The power generation expansion programme remains unchanged up to 12% for the Optimistic Scenario. However, there was shift of 10 years for the gas power in Maiduguri, whilst the two nuclear power plants were deferred.

Capital Cost of Power Plant
Sensitivity analysis is conducted for capital cost by increasing the cost of building power plants. It was found that there is no change in the least cost gas and hydro power plants expansion plan up to 30% higher capital cost of the construction. However, nuclear power plant I and II were delayed.

6 CONCLUSIONS

The assessment of energy options and strategies for Nigeria was carried out to give detailed energy demand and supply and their environmental consequences for achieving a sustainable economic growth. IAEA modeling tools were used for conducting of the studies, the study analyses the entire energy system of the country including: the analysis of future evolution of energy and electricity demand by sector and by energy form, the system of energy and electricity supply, the roles of coal, nuclear and new and renewable energy resources in meeting the overall energy and electricity demand. The environmental impacts of the electricity supply system for three economic growth scenarios were also studied.

In carrying out the studies, valuable experience and know-how have been acquired for future application.

6.1 Energy and Electricity Demand Projections

Total Final Energy Demand: The total final energy demand will grow from 30.42 Mtoe in the base year to 120.28, 256.81 and 373.22Mtoe in 2030, for the reference, high growth and optimistic scenarios, respectively. The growth rates of the total final energy demand over the period 2000-2030 are 4.7%, 7.4% and 8.7% p.a., for the reference, high growth and optimistic scenarios respectively.

Of the total final energy demand of 30.42mtoe in the base year, commercial energy constituted 17.72mtoe or 58.24%, while non-commercial energy (fuelwood and charcoal) constituted the balance of 12.70Mtoe (41.76%). By 2030, the share of commercial energy would have risen significantly to 96.36%, 97.92% and 98.61% for the reference, high growth and optimistic scenarios, respectively.

Energy Demand by Sector: For the reference case, the demands will vary over the plan period from 2.84 to 47.88Mtoe, for industry, 9.91 to 28.48toe, for transport, 13.71 to 28.56Mtoe for households and 3.97 to 16.33Mtoe for services. The fastest growing sector is industry (agriculture, construction, mining and manufacturing) with overall annual growth rates of 9.87%, 14.26% and 16.10% for the reference, high growth and optimistic scenarios.

Electricity Demand: Available grid electricity in the base year was 4,230 MW. This is projected to grow to 58,205 MW, 112,846 MW and 159,588 MW by 2030 for the reference, high growth and optimistic scenarios respectively.

Electricity Demand per Capita: Electricity consumption per capita is projected to rise to 2167.3, 4201.9 and 5942.4kWh for the reference, high growth and optimistic scenarios respectively from base year value of 321.6kWh. This is in consonance with the country's vision of becoming an industrializing nation by 2030.

6.2 Energy Supply Analysis

In order to meet the projected energy demand, it is expected that the country will continue to import petroleum products at the initial stage up to the time the existing refineries are rehabilitated and new ones constructed. The total primary energy requirements are projected to increase from 36,420MWyr in 2005 to 651,610MWyr in 2030 for the Optimistic Scenario. While total primary energy requirements are projected increased to 220,835MWyr for Reference and 651,609MWyr for High Growth Scenarios.

The contribution of oil is much higher in the transport and heat production sectors while gas contributes the highest in electricity generation. Two new technologies have been introduced in the power sector from the year 2015; these are coal and nuclear energy technologies.

The supply patterns in the country have been classified into the following:

I. Electricity generation projection;
II. Motor fuels supply projection;
III. Thermal fuels supply projection;
IV. Environmental impact analysis from the supply technologies;

Tables 6.1, 6.2, 6.3 and 6.4 below shows the energy supplies changed from the base year in 2005 to the year 2030 for optimistic Scenario.

Table 6.1 Motor Fuels Supply for the year 2030 (Optimistic Scenario) in Mwyr

	2005	20360
AGO	4718	43520
PMS	6040	56079
AGO Import	7966	5.8
PMS Import	7279	503

Table 6.2 showing Electricity Supply for the year 2030 (Optimistic Scenario) in MWyr

	2005	2030
Coal	0	16439
Gas	2593	49903
Hydro	1512	9267
Nuclear	0	7200
Solar	4	37
Wind	0	1958

Table 6.3 Thermal fuel Substitutable Supply for the year 2030 (Optimistic Scenario) in MWyr

	2005	2030
DPK	3912	25320
LPG	378	2846
Fuel oil	4341	36749
Fuelwood	21085	7927
Natural Gas	0	68097
Coal	0	23815

Table 6.4 Total Primary Energy Supply for the year 2030 (Optimistic Scenario) in MWyr

	2005	2030
Coal	0	104176
Natural Gas	2593	291712
Oil	11224	164524
Non-Commercial	21085	7927
Nuclear	0	32264
Hydro	1512	41527
Renewable	4	9480

The supply projections is in excess of demands by more than 30% in all the Scenarios, however a lot of effort is required from government at all levels to see to the actualization of these projections. The involvement of both foreign and local entrepreneurs is very crucial, hence the need for legislations that will facilitate the implementation of the projected energy supplies.
The infrastructure to be put in place must conform to international environmental laws in order to fully address the problems of environmental concerns. It is noted that the rehabilitation of the exiting power plants and oil refineries must be fast tracked in order to immediately restore the normal supply of both the electricity and petroleum products.

The issue of felling trees for producing fuelwood must be addressed with fuel substitutable or commercial fuel in order to check the menace of desert encroachments and soil erosion that is threatening our environments. Therefore fast tracking the use of more efficient kerosene stoves and constructing coal briquette industries with its corresponding stoves for use by semi urban and rural populace is suggested.

Along with the rehabilitation of the existing power plants, the need for the expansion of the committed power plants become necessary in order to meet the required demands and to achieve the government target of industrializing the country by 2020. New power plants have to be built to meet the projected yearly capacity additions. Similar efforts have to be undertaken to upgrade and expand the transmission and distributions network in the country.

The gas and oil sector also require a radical approach in order to meet the demand. The provision of infrastructure such as refineries, gas distribution line, and depots for the storage of 90 day strategic reserves have to be facilitated as indicated in the supply projection.

6.3 Additional Capacity and Investment Requirements.

The supply patterns in the country have been classified into the following:

I. *Electricity Generation Projection:* A total of 137130MW for the Reference, 193375MW for High Growth, and 383139MW for Optimistic Scenarios were projected as capacity addition for the period of study while annual capacity additions Projection of 5485MW, 7735MW, and 15325MW for Reference, High Growth and Optimistic Scenarios respectively. The total investment requirement is $126.21 billion, $232.05billion, and $459.77 for Reference, High Growth and Optimistic Scenarios, respectively. Translating into annual investment requirements of $5.45 billion, $9.28 billion, and $18.39 billion for the three Scenarios.

II. *Oil Supply Projection*: The projection of oil supply for the three scenarios are 4.15 million, 6.88 million and 10.14 million barrels per day for Reference, High Growth and Optimistic Scenarios, respectively by 2030. These represent an annual building of 165,680, 275,180 and 405,570 barrel per day refineries over 25-year period for Reference, High Growth and Optimistic Scenarios, respectively. A total of $41.58 billion, $73.97 billion and $122.05 billion is required for the investment cost of new refineries for the Reference, High Growth and Optimistic Scenarios, respectively. These represent an annual investment of $1.66 billion. $2.96 billion and $4.92 billion for the Reference, High Growth and Optimistic Scenarios, respectively over 25-year period.

III. *Thermal Fuels Supply Projection*: The projection of thermal fuel substitutable includes coal, fuelwood natural gas, kerosene, fuel oil and LPG. However kerosene, fuel oil and LPG are part of the refinery oil supply analysis. A total of 9.4 million, 11.0 million and 25.6 million tonnes of coal is required for the Reference, High Growth and Optimistic Scenarios, respectively for the 25-year period, and the corresponding investment requirement is $477 million, $550 and $1,280 million for the three scenarios. These represent annual additional capacity of 377,688, 441,771 and 1,025,029 tonnes with an annual investment of $19 million, $22 million and $51 million for the three scenarios. The total fuelwood requirement is 92436, 120903 and 294142 tonnes for the Reference, High Growth and Optimistic Scenarios, respectively. These represent an annual requirement of 3,697, 4,839 and 11,765 tonnes. The O&M cost for the fuelwood is $23 million, $30 million and $73 million for the three scenarios. The production of fuelwood will involve the developments of energy forests, shelter for desert encroachment control as well as charcoal production. The total natural gas requirement is 3,315 billion, 3,586 billion and 33, 945 billion CFG tonnes for the Reference, High Growth and Optimistic Scenarios, respectively, and the corresponding total investment cost is $2,085 million, $2,256 million and $21,358 million for the three scenarios.

Hence, the total investment cost requirements are $170.36 billion, $308.83 billion and $604.46 billion for the Reference, High Growth and Optimistic Scenarios respectively.

6.4 Sensitivity Analysis

Sensitivity analysis conducted for the refinery and power plants for 10%, 11%, 12%, 13% and 14% remained unchanged for the refinery expansion for the discount rate and capital cost of the refinery for all the three scenarios. Whilst for the power plant there was a shift in building of one gas plant and the two nuclear plants for all the scenarios.

6.5 Urgent Future Activities Related to the use of MESSAGE Model.

- There is need to complete the studies using the other IAEA's models for financial analysis (FINPLAN) and Environmental Impact analysis (SIMPACTS).

- The idea discussed last year about on-line training should be experimented because of increased requests by member countries and institutions involved in energy planning. It should be supplemented with a few actual training programmes. This way, more people will be reached at a reduced cost.

- There is the need to designate selected countries as Regional Centres for training in Energy Modelling. This will enhance institutional and human capacity building.

- Training on Energy Economics and indicator analysis as they relate to the IAEA Energy Planning Models is required; this is necessary because many of the officers involved in energy modelling are engineers and Scientists who are rarely competent in economics.

- Such training in the field of Energy Economics will enhance their capacity to translate economic policies into energy supply relationships.

- Training and retraining of both new and old officers on the IAEA Energy Planning Models, that is MAED, WASP, MESSAGE, SIMPACTS, FINPLAN etc is required. New officers need to be exposed to the intensive trainings provided by the IAEA to complement local in-house training imparted by the older officers. Older officers need to be continuously trained to keep abreast of developments of new methods and techniques of modelling.

- IAEA support for Modelling laboratory and materials, such as computers, books, Journals and some modelling tools; Energy modelling is not a fully developed field in developing countries. As a result, reference materials are scarce. We rely mainly on materials provided during IAEA trainings. Assistance with more materials would be of benefit to the energy modelling activities.

- Information and yearly updates on Training Schedules for officers on the Energy Planning Models should be made available to member states. The Modelling Teams can take advantage of the training schedules to improve their competencies.

- IAEA support for the training of energy specialists at MSc and PhD levels, especially on IAEA modelling packages is recommended.

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