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Modelling of Energy Demand in the Building and Construction Sector of the Nigerian Economy

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Abstract The construction sector in Nigeria includes activities involving building of residential, commercial, industrial and administrative buildings. It also involves construction of roads, bridges, canals, airports, sea ports, power and energy facilities, irrigation and water supply facilities, pipelines, and railways. In 2010, value added in this sector was ₦394 billion amounting to 1.4% of the Gross Domestic Product of ₦ 2,9108.0 billion. In the same year, the total final energy consumption by the sector was about 32,500 TOE representing 0.11% of the total final energy demand in all the country's economic sectors. With the aspiration of the country to achieve the Millennium Development Goals as well as transit from an agrarian economy to one of the most developed countries in the world by 2020, the country's' infrastructure would be substantially increased. This requires timely energy supply and other inputs. Planning for secured supply of energy in the building and construction sector requires estimation of the energy demand in the sector. The energy demand estimation was carried out using the Model for Analysis of Energy Demand developed by the International Atomic Energy Agency. Four economic growth scenarios were considered in the analysis with the Reference scenario of 7% growth of GDP per annum showing that total energy demand would amount to about 94.0 Million TOE by 2020 and 191 Million TOE by 2030. The projected energy demand for the building and construction sector accounted for 11.10% and 12.50% of the total final energy demand in 2020 and 2030 respectively. A major challenge is how to supply the energy in a sustainable manner.

Keywords Energy demand modelling, Building and construction sector, Nigerian economy

1. Introduction

The construction sector in Nigeria includes activities involving building of residential, commercial (warehouses, schools, retail stores), industrial and administrative buildings. It also involves construction of roads, bridges, canals, airports, sea ports, power and energy infrastructures and facilities, irrigation and water supply facilities, pipelines, and railways. Despite the high rate of urban development, the construction is now only 1.4 per cent of the Gross Domestic Product (GDP).

Nigeria's government ambition to be among the top 20 most developed countries in the world by year 2020 would necessitate creating much-needed housing, improving public services, developing its tourism sector, improving transport links, creating new jobs and eradicating poverty. All these requirements can be linked to the construction sector. Nigeria is in dire need of foreign investment to build roads, ports, bridges and airports. The country's railway network is also in great need of an upgrade. Considering roads, in particular, only the capital Abuja and, to a lesser extent, the coastal metropolis of Lagos, has a reasonable road network. Nationwide, road fatalities are one of the most common causes of death.

Energy has been a central concern to human development. The adequate provision of energy is a fundamental component of the conceptual and strategy on sustainable development in Nigeria and indeed the rest of the world. Energy utilization in building and construction is an important area of sustainable construction. Sustainable construction entails sustainability in direct energy use, in the amount of fuel used in obtaining the raw materials, and in the production process and transportation of materials. This study only addresses direct energy usage for building and construction. All energy usage for obtaining the raw materials such as mining of limestone for the manufacture of cement which is a major material used in construction is regarded as energy usage in the mining sector. Energy usage for the processing of raw materials such as cement is taken as energy usage in the manufacturing sector while energy usage for the transport of the materials is regarded energy usage for freight transport.

This paper provides the estimation of the energy demand of the construction sector of the economy, with special attention to the requirement of the National Economic Empowerment and Development Strategy (NEEDS) which is Nigeria's strategy for achieving the Millennium

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Development Goals (MDGs). It also addresses the Vision 20-2020 of Nigeria's government which is aimed at making Nigeria one of the top 20 countries in the world by year 2020 (*NPC, 2011*). Apart from this introductory section, there are five other sections in this paper. Section 3 discusses the methodology for conducting the energy demand estimation. Section 4 discusses the input data and application while Section 5 analyses the results. Some concluding remarks are provided in Section 6.

2. Literature Review

Nigeria's population of approximately 159.25million is urbanising at one of the fastest rates in the world, but construction is now only 1.4 per cent of the Gross Domestic Product (GDP). From 2009 to 2020, only Nigeria and India will enjoy higher growth rates than China in their construction output (*GCPOE 2010*).

The country is potentially endowed with abundant energy resources such as oil, national gas, lignite, and coal, and renewable energy sources such as wood, solar, hydropower, and wind. However, Nigeria suffers from inadequate supply of usable energy due to the rapidly increasing demand, which is typical of a developing economy. The predominantenergy resources for domestic and commercial uses in Nigeria are fuel wood, charcoal, kerosene, cooking gas (LPG) and electricity. Others include biomass such as sawdust, agricultural crop residues and cow dung, all referred to as non-commercials, including fuel wood and charcoal.

The pattern of energy consumption in Nigeria's economy is divided into the various economic sectors which are: industrial, transport, commercial, agricultural, and household sectors (*ECN, 2003*). The household sector accounts for the largest share of energy consumption in the country with about 64%, with energy-consuming activities such as: cooking, lighting, and use of electrical appliances. Out of the 64% of the total energy consumed in the household, cooking accounts for a about 70%, lighting uses up to 3%, hot water boiling takes about 25% and the remaining 2% can be attributed to the use of basic electrical appliances such as televisions air conditioning and pressing irons. The household sector is further divided into sub-sectors namely: urban and rural (*ECN, 2007*).

Among the urban dwellers, kerosene and gas are the major cooking fuels. Large percentage of the people depends on kerosene stoves for domestic cooking, while others use gas and electric cookers. The rural areas have little access to conventional energy such as electricity and petroleum products due to the absence of good road networks and grid connection. Petroleum products such as kerosene and gasoline are purchased in the rural areas at prices very high in excess of their official pump prices, thus discouraging cleaner energy resourcing. The rural population, whose needs are often basic, therefore depends to a large extent on fuel wood as a major traditional source of fuel. It has been estimated that about 86% of rural households in Nigeria depend on fuel wood as their source of energy (*Sambo, 2008*).

Power generation in Nigeria relies on both hydro- and thermal power, thus, electricity is also a consumer of petroleum based fuels such: as fuel oil, natural gas, and diesel oil. The percentage of generation capability from hydro turbines is 34.89%; from gas turbine, 35.27%; and from steam turbines, 29.84%. In 1970, the total electricity consumption stood at 1.27 TWh; this increased to about 4.70 TWh in 1980. However, in 2005, the total electricity consumption had increased to 16.41 TWh. On the generation side, these values of 1.55 TWh in 1970 increased to 7.14 TWh in 1980. By the end of 2005, the achieved total electricity generation was 26.26 TWh (*CBN, 2007*). The incapacity of the electricity subsector to efficiently meet the demand for electricity in the country has been harmful to the nation's economic growth.

The scanty inefficient facilities to boost electricity supply in Nigeria have been major causes of the increasing gap between the demand and the supply of electricity. Nigeria with a total of 14 generating stations (3 hydro and 11 thermal stations) with a total installed capacity of approximated 8,039 MW, not more than 4,500 MW has been generated, and this massively reduced to about 3850MW (2,899.9x10^3toe) as at this report. Based on the report of Lumina Decision Systems, USA, a consulting firm commissioned by the world bank for the purpose of Nigerian Climate Change Assessment study on Low Carbon Plan for the Power Sector in 2011, it indicated that about 109.50 TWh (9,415.31x10^3toe) of electricity was generated through non grid power back-ups (captive generation), making a total of 143.23 TWh of electricity generated/consumed in year 2010 (*World Bank, 2013)*. Electricity utilization in the country is recorded with manufacturing and household taking the highest percentages of 40.6% and 35.3% respectively, services tops next (21.7%), construction (2.3%), mining (0.07%) and agriculture as least with 0.03%.

The construction sector in Nigeria contributed about 2.1% of the Gross Domestic Product of ₦29,108 billion in 2010, whilst the final energy consumed was only 0.11% of the final energy demand of 32.5 million tonnes of oil equivalent (Mtoe) (NBS, 2010).

In June 2010, the World Bank announced that it would invest USD300 million for the overall development of Nigerian roads. Hotels and numerous tourist-related facilities will need to be built if Nigeria is to achieve its target of becoming one of Africa's most desirable tourist destinations. Many existing tourist attractions are in need of major work.

3. Methodology

The analysis of the energy demand and projection was carried out using the International Atomic Energy Agency (IAEA) Model for Analysis of Energy Demand (MAED). The MAED allows for the 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 in the construction sector. Each main sector was subdivided into a maximum of ten user-defined subsectors. This free split of sectors into subsectors allows for a high flexibility in reflecting the industry structure pattern.

The energy demand of the construction sector is driven by the level of economic activity of the subsector evaluated in terms of its value added and the energy intensity of each energy form. The level of economic activity of construction sector is obtained from the data on total GDP and GDP structure.

For each sector the energy demand is calculated separately for three end-use categories:

I. Electricity for specific uses (lighting, motive power, etc.);

II. Thermal uses (water heating, steam generation, furnace and direct heat);

III. Motor fuels for driving of construction equipment such as bulldozers, excavators, etc.

Of the end-use categories of energy demand considered, motor fuels and electricity for specific uses are non-substitutable forms. On the other hand, substitution possibilities exist for the thermal uses, in particular for the displacement of fossil fuels (mainly oil).For non-substitutable forms (i.e. electricity and motor fuels) energy intensities are specified in terms of final energy per unit of value added, and for substitutable forms (thermal uses) in terms of useful energy per unit of value added.

GDP (Y) formation by economic sector and subsector (10^9Naira)

Economic Sector Value Added (VA) for Construction Sector (Ycon):

$$Ycon = Y * \left(PYcon \big/ 100\right) \tag{1}$$

Where, ***PYcon*** is the % shares of GDP contributed by construction sector and ***Y*** is the total GDP.

The values added (VA) of the Construction subsectors ($Y_{co(i)}$) are:

$$Yco(i) = Ycon * \left(PVAco(i) \big/ 100 \right) \tag{2}$$

Where, ***PVAco(i)*** is the % shares of value added of subsector i

Economic sector value added per capita (YconCAP):

$$YconCap = Ycon/PO * 1000 \tag{3}$$

Where, ***PO*** is population size.

Energy intensities for the Construction Sector

Energy intensities of Motor Fuels uses (EI.MF):

$$EI.MFcon = \sum_{i=1}^{NSco} \left(\left(EI.MFco(i) * PVAco(i) \right) \big/ 100 \right) \tag{4.1}$$

Energy intensities of ELectricity, Specific uses (EIELS):

$$EIELScon = \sum_{i=1}^{NSco} \left(\left(EIELSco(i) * PVAco(i) \right) \big/ 100 \right) \tag{4.2}$$

Energy intensities of Thermal Uses (EITU):

$$EI.TUcon = \sum_{i=1}^{NSco} \left(\left(EI.TUco(i) * PVAco(i) \right) \big/ 100 \right) \tag{4.3}$$

Final energy demand for Motor Fuels for the Construction Sector:

Final energy demand for Motor Fuels (MFcon)

$$US.MFco(i) = EI.MFco(i) * Yco(i) * CFI$$

***i=1*(subsector)** (5)

where CF1 is the corresponding conversion factor from TWh to the unit specified.

But

$$Mfcon = US.MFcon \tag{5.1}$$

Therefore

$$Mfcon = \sum_{i=1}^{NScon} US.MFco(i) \tag{5.2}$$

And

$$Mfcon = \sum_{i=1}^{NScon} \left(EIMFco(i) * Yco(i) \right) * CFI \tag{5.3}$$

Final Energy Demand for Electricity for Specific uses for the Construction Sector:

Final energy demand for Electricity for Specific uses (ELScon):

$$USELSco(i) = EIELSco(i) * Yco(i) * CFI$$

***i=1* (subsector)** (6.1)

But

$$ELScon = USELScon \tag{6.2}$$

Therefore

$$ELScon = \sum_{i=1}^{NScon} USELSco(i) \tag{6.3}$$

And

$$ELScon = \sum_{i=1}^{NScon} \left(EIELSco(i) * Yco(i) \right) * CFI \tag{6.4}$$

Useful Energy Demand for Thermal Uses for the Construction Sector:

Useful energy demand for Thermal Uses (TUcon):

$$USTUco(i) = EITUco(i) * Yco(i) * CFI$$

***i=1* (subsector)** (7.1)

But

$$TUcon = USTUcon \quad (7.2)$$

Therefore

$$TUcon = \sum_{i=1}^{NScon} USTUco(i) \quad (7.3)$$

And

$$TUcon = \sum_{i=1}^{NScon} \left(EITUco(i) * Yco(i) \right) * CFI \quad (7.4)$$

Final energy demand of Construction Sector (FINcon):

Total Electricity (ELcon)

$$ELcon = ELScon + ELHcon \quad (8.1)$$

Where, ***ELScon*** is Electricity used and ***ELHcon*** is Thermal Electricity used. Therefore, the

Total Final Energy (FINcon)

$$FINcon = MFcon + Elcon + TFcon + MBcon + SScon + FFcon \quad (8.2)$$

where, ***Mfcon*** is Total Motor Fuel Used; ***ELcon*** is Total Electricity Used; ***TFcon*** is Total Traditional Fuel Used; ***MBcon*** is Total Modern Biomass Usage; ***SScon*** is Total Soft Solar Energy for Thermal usage, and ***FFcon*** is Total Fossil Fuel for thermal usage.

Energy supply infrastructures require long time for planning and construction and are normally of long life spans. Projection of demand and supply strategies needs to be long-term horizons. A twenty-year period has been chosen for this study. Four scenarios were constructed based on the GDP growth rates, namely, a Reference Scenario which represents the most likely future developments of 7%, a High Growth Scenario(10%), Optimistic I Scenario (11.5%) and Optimistic II Scenario (13%) which will launch the country among the top 20 develop countries in the world by the year 2020. The scenarios reflect trends and effects of the government policies and private sector behavour. In the estimation of long run energy demand in the construction sector, the energy demand was first calculated at the useful level and then converted to final energy. Though the MAED model lumps together the useful and final energy demand projections for all industry sub-sectors (agriculture, construction, mining and manufacturing), in this study, we separated energy demand projections for the construction sector from the rest of industry.

4. Input Data and Application

The required information for the base year was collected from documents published by data producing organizations. The remaining data which are mostly related to entrance data for forecasted year was gathered through extensive survey conducted and utilization of stakeholders' points of views. Data requirements for the analysis include the gross domestic product (GDP) for the entire economy and growth rates, sectoral value added and growth rates, total population and population growth rates, energy intensity of each type of energy source, urbanization rates, etc. While the study was conducted for the entire economy only the data that are relevant to this paper are presented and discussed.

Activities in construction require energy consumption. Energy usage in this sector includes motor fuels and electricity in machinery and motors. It also includes thermal energy for heating asphalt for road surfacing. For calculation of motor fuel, electricity and thermal energy consumption, energy intensity and building and construction value added have been used. All the energy forms were first calculated at the useful levels and then converted to final energy.

Data on GDP at 1990 Constant Basic prices was obtained from National Bureau of Statistics (NBS, 2010). Data is provided on quarterly GDP estimates for the four quarters and on annual basis. The annual figures for 2010 are revised versions of the previous estimates using data from 2009 and socio-economic survey conducted in the first quarter of 2010 by the National Bureau of Statistics, in collaboration with Central Bank of Nigeria and National Communication Commission. On aggregate basis, the economy, when measured by the real GDP grew by 8.36% in the fourth quarter of 2010 as against 7.67% in 2009. While the GDP measured at 1990 constant basic prices, was estimated at ₦775.4 billion in 2010, indicating a growth rate of 7.9%. This exceeded the 7.0% recorded in 2009 and the annual growth rate of 6.7% for the period. Sectoral breakdown indicated that the Agricultural Sector had the highest contribution to GDP with 40.84%, this was followed by Service sector with 33.64%, Energy 19.02%, Manufacturing 4.16%, Construction 2.00%. The Mining sector had the lowest contribution to GDP with 0.34%.

Another major input required for the energy demand projection in the construction sector is the intensity of motor fuels, electricity and thermal energy utilization. Spot survey was conducted on some construction companies in the large, medium and small categories in the Federal Capital, Abuja where most of the construction take place at the moment. The survey entailed obtaining the consumption of various energy forms by the construction firms and their annual turnovers in the year. These data were applied to compute the energy consumption per unit of value added in each firm and an average obtained for the surveyed firms. It must be stated that the motor fuels, electricity and thermal energy intensities were obtained separately. Factors that would shape the evolution of energy intensities in the future were analyzed. These include the efficiencies of the technologies, prices and tariffs of energy carriers, energy conservation and efficiency policies.

5. Analysis of Results

The MAED model was used to arrive at the projected estimates of the various parameters that may influence energy demand in the construction sector over the period, based on the four scenarios outlined in the study. Table 1 shows the percentage contribution to the GDP by sectors. While construction accounted for 1.4% of the GDP in 2010, it is projected to account for 5.4%, 5.5%, 5.5% and 5% in the Reference, High Growth, Optimistic I and Optimistic II scenarios respectively by year 2030. These projections were estimates arrived at following consultations with the National Planning Commission.

Improvements in technologies would tend to reduce the energy intensities while increasing tariffs and prices would force the construction companies to embrace cost saving measures which include minimizing cost of fuel for their operations. Moreover, much manual labour is involved presently. It is expected that there would be increased penetration of machinery to replace the manual labour. This will increase the energy intensity. Application of thermal energy (for heating asphalt used in road surfacing), the major source of thermal energy application in the construction sector in Nigeria, is currently done in an inefficient manner. It is expected that the technology for the heating will improve, hence a reduction in thermal energy intensity. Table 2 shows the computed energy intensities in the construction sector in Nigeria.

The electricity demand for the construction sector is given in Table 3. The consumption of electricity will increase from 0.11TWh in the base year to between 12.44 -27.93TWh in 2030 for the Reference and Optimistic II Scenarios. There is a high increase in electricity demand for the first period; the periodic growth between 2010 and 2015 is about 1,800% for the Reference Scenario to 2,700% for the Optimistic II Scenario. This increase is due to the massive infrastructural development expected in several sectors of the economy. More power plants, houses, and roads will be constructed for the country to achieve the MDGs and be able to be among the 20 richest economies by 2020. Subsequently periodic growth decreases with time to about 200% by 2030 for all the scenarios.

The final motor fuels demand projection for the construction sector is shown in Table 4. Thus the need will be about 10 million tonnes of oil equivalent by the 2020 and about 33 million tonnes of oil equivalent in 2030. To achieve the Vision 20-2020, the projected demand will be about 13 million tonnes by 2020 and increase to 46 million tonnes in 2030.

Table 5 shows similar trend for the final thermal fuel demand, with an initial high demand from 2010 to 2015 followed by a steady increase for the rest periods.

Table 1. Percentage Sectoral Contribution to GDP

	2010	2020				2030			
	Base year	**Ref**	**HG**	**Opt I**	**Opt II**	**Ref**	**HG**	**Opt I**	**Opt II**
Agric	42.4	38.0	33.5	33.5	29.0	34.0	27.4	27.4	20.0
Const	1.4	4.5	4.6	4.6	3.9	5.4	5.5	5.5	5.0
Mining	0.4	0.5	0.5	0.5	0.4	0.6	0.6	0.6	0.5
Man	4.3	11.0	12.5	12.5	15.0	14.0	19.5	19.5	23.0
Energy	17.4	11.0	9.7	9.7	20.0	8.0	6.0	6.0	12.5
Services	34.1	35.0	39.2	39.1	31.7	38.0	41.0	41.0	39.0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

*Ref = Reference: HG = High Growth: Opt = Optimistic

Table 2. Energy Intensities in the Construction Sector, kWh/Naira

Energy forms		Motor fuels	Electricity	Thermal energy
2010	**Base year**	0.03	0.018	0.0060
2020	**Ref**	1.31	0.194	0.0050
	HG	1.31	0.194	0.0050
	Opt I	1.35	0.200	0.0045
	Opt II	1.35	0.200	0.0045
2030	**Ref**	1.52	0.203	0.0050
	HG	1.52	0.203	0.0050
	Opt I	1.58	0.220	0.0045
	Opt II	1.58	0.220	0.0045

Table 3. Final Electricity demand projection in TWh

Scenario	2010	2015	2020	2025	2030
Reference	0.11	2.03	4.94	7.27	12.44
High Growth	0.11	2.37	5.69	9.64	19.27
Optimistic I	0.11	2.87	6.31	12.26	23.65
Optimistic II	0.11	3.02	6.85	14.21	27.93

Table 4. Final Motor fuels demand projection, Mtoe

Scenario	2010	2015	2020	2025	2030
Reference	0.14	4.56	9.99	14.91	22.64
High Growth	0.14	4.77	11.34	20.75	34.33
Optimistic I	0.14	4.93	12.47	24.40	44.04
Optimistic II	0.14	5.21	12.79	26.80	46.17

Table 5. Final Thermal fuel demand projection, Mtoe

Scenario	2010	2015	2020	2025	2030
Reference	0.010	0.024	0.056	0.913	0.159
High Growth	0.010	0.029	0.076	0.115	0.276
Optimistic I	0.010	0.034	0.087	0.153	0.345
Optimistic II	0.010	0.040	0.092	0.186	0.394

Table 6. Total final energy in construction, Mtoe

Scenarios	2010	2015	2020	2025	2030
Reference	0.16	4.76	10.47	15.63	23.87
High Growth	0.16	5.00	11.91	21.69	36.26
Optimistic I	0.16	5.21	13.10	25.60	46.42
Optimistic II	0.16	5.50	13.47	28.20	48.96

The total final energy in the construction sector will reach about 24 million tonnes of oil equivalent in the Reference Scenario by 2030, whilst in the fast GDP rate of 13% of the Optimistic II Scenario the total final energy demand will be about 50 million tonnes (Table 6). There is an annual increment of 1.2, 1.8, 2.3 & 2.5 million tonnes of oil equivalent in the Reference, High Growth, Optimistic I & Optimistic II Scenarios, respectively.

6. Discussion

The findings of this study shows that demand of the total final energy in the construction sector will increase remarkably over the study period. Motor fuels will contribute majority of the energy demand with minimal contribution of the thermal fuels. The estimated annual growth rates for the final energy demand are 650, 1,042, 1,363 and 1,444% for the Reference, High Growth, Optimistic I and Optimistic II Scenarios, respectively. Ability to provide the forecast energy in a sustainable manner is an important aspect of sustainable construction.

Improvements in the technical efficiencies of equipment used in construction can reduce energy intensity and hence contribute to sustainable construction. Hence attention needs to paid to energy efficiency and conservation in the sector. Though fossil fuel was considered as the main source of thermal energy usage in construction, in many instances, traditional biomass is utilized as a source of thermal energy to heat asphalt, especially in road maintenance. Traditional biomass would be displaced by biomass in the future.

Use of grid electricity in construction sites is not common. Most construction firms use diesel generators to provide electricity for their construction sites. Our interaction with them indicates that they would prefer grid electricity if it is available as it should be cheaper. Solar energy may become viable in providing lighting in construction sites in place of captive electricity provided for the sites with diesel generators. All these should contribute to sustainable construction.

7. Conclusions

Sustainable construction requires sustainability in energy utilization in the building and construction sector. Hence, direct energy demand and usage in the building and construction sector is investigated in this study. The result shows that the total energy demand in the construction sector will increase remarkably over the study period. The estimated annual growth rates for the final energy demand are 650, 1,042, 1,363 and 1,444% for the Reference, High Growth, Optimistic I and Optimistic II Scenarios, respectively. Motor fuels will contribute the majority of energy demand in the construction sector with minimal contribution from thermal fuels.

It is recommended that improvement in technical efficiencies can be used to reduce energy intensity and to contribute to construction sustainability. Also recommended are modern biomass for thermal fuels and solar energy for lighting to replace fuelwood and diesel generators, in order to achieve sustainable construction.

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