**Towards 2060 Net Zero Emission: Marching the Electricity Demand with Supply in Nigeria Using NECAL 2060**

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# ABSTRACT

The gap between energy demand and supply in Nigeria creates a great hindrance to the country’s sustainable development agenda and the realization of its 2060 net zero emissions. The objective of the study reported in this article was to model the electricity demand and supply using the Nigeria Energy Calculator (NECAL 2050) which develops consistent scenarios of energy supply to meet energy demand projections. The choices that lead in this direction vary, reflecting the different resource endowments and starting points across a very diverse Nigerian energy landscape. For Nigeria to use the enormous potential of its energy resources given its drive to match electricity demand with supply, and its vision towards 2060 net zero agenda, the barriers to achieving these must be eliminated through significant investment in R&D, the building of indigenous human and manufacturing capacities and intensification of the on-going economic reform to create an investor-friendly environment.

**KEYWORDS:** Energy Demand and Supply Projections; Electricity Projections; Energy Resources; 2060 Net Zero Pledge

## INTRODUCTION

Access to a stable and secure supply of energy is a fundamental driver of economic growth. Several Sub-Saharan African countries are amongst the least developed economies in the world. A large proportion of the population in the region lack access to electricity and other modern energy services, while those who have access face frequent outages. More than two-thirds of the population, approximately 600 million people, in Sub-Saharan Africa lacked access to electricity in 2016 (Pappis et al., 2019).

For many developing nations in sub-Saharan Africa, and Nigeria in particular is faced with substantial electricity supply gap (Rapu et al., 2015). For instance, the electricity demand in Nigeria far outstrips the supply, and the supply is epileptic in nature (Sambo, 2008). With the grossly inadequate national grid electricity supply in the country, total installed national grid capacity is far less than the demand and out of this installed capacity the available capacity is barely above half of the installed capacity. As at 2016, percentage of the population with access to electricity in Nigeria was 61%, leaving behind barely 39% without electricity (Pappis et al., 2019). Particularly, the per capita energy consumption is too low for meaningful economic and social development. In spite of this, Nigeria still has a constraint of supplying 70MW of energy to Niger Republic (Ezennaya et al., 2014).

Studies exploring pathways to enhance energy supply, reduce energy demand and GHG emissions in Nigeria are limited and have not really focused on what is economically, technically feasible within the country. In this research, the Nigerian Energy Calculator 2060 is used to examine and compare the energy balances and GHG mitigation potentials for four alternative low carbon scenarios which are possible by 2050 (Dioha et al., 2019). The NECAL 2060 simulates final energy demand and supply, sectoral GHG emissions, per capita GHG emissions, air pollutants as well as policy implications of different scenarios.

## Methodology

Nigeria is one of the 10 counties supported by the UK Government to develop an Energy and Emissions Calculator, one of the tools used to inform the country’s Nationally Determined Contribution (NDC), called Nigeria Energy Calculator 2060 (NECAL2060) (ECN., 2015). The model was developed based on vast literature review and consultations with over one hundred local experts, to ensure that the most accurate assumptions are made and the data used are of high quality (Dioha et al., 2019). Furthermore, the NECAL2060 platform does not ‘recommend’ or ‘prefer’ any one scenario or pathway over the others. It merely provides the user a way to understand the realm of possible scenarios and their implications and post their preferences and choices as a contribution to the debate on sustainable energy development for Nigeria.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** | **2055** | **2060** |
| **Agriculture** | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 |
| **Industry** | 15.7504 | 15.47554 | 18.47636 | 21.33678 | 24.1827 | 27.09347 | 30.20599 | 33.3616 | 36.409 | 39.50053 |
| **Transport** | 0.023062 | 0.034071 | 0.034318 | 0.048948 | 0.067124 | 0.088878 | 0.113441 | 0.141415 | 0.161485 | 0.18244 |
| **Buildings Other** | 17.69975 | 18.02948 | 20.81344 | 23.44145 | 25.11661 | 25.18767 | 30.8924 | 37.57103 | 41.63399 | 45.91275 |
| **Buildings Heat** | 0.001019 | 0.001037 | 0.001147 | 0.001262 | 0.00138 | 0.001501 | 0.001627 | 0.001757 | 0.001891 | 0.002028 |
| **Total** | **33.47563** | **33.54152** | **39.32667** | **44.82985** | **49.36923** | **52.37293** | **61.21482** | **71.07712** | **78.20764** | **85.59898** |

NECAL2060 is a transparent and open source model of energy, GHG emissions (CO2, CH4, N2O, HFCs, PFCs, SF6), and land use. The model also accounts for emissions of air pollutants such as PM10, NOX, SO2, and NMVOC (Non-methane volatile organic com- pounds). It uses a set of existing and future technologies to ensure that energy supply satisfies the varying energy demands. Two versions of the model were developed by the Energy Commission of Nigeria (ECN): the MS Excel-based type and the Web-based type. In this paper, the MS Excel version was employed. As an integrated model, NECAL2060 aims to identify secured pathways for energy supply and demand at minimal or net-zero GHG emissions level from 2015 to 2060.

NECAL2060 is split into six sectors; (i) industry, (ii) building, (iii) transport, (iv) electricity, (v) land use and waste (AFOLU) and, (vi) CO2 removal and other gases. The demand is determined by the user’s choices from each of the demand sectors (industry, building, transport and land-use). Then the user also determines how the energy supply would be and then NECAL2060 compares the demand-supply figures based on the user’s choices. When the supply is higher than demand, it is assumed that the domestic energy resources are sufficient to match the demand (Dioha et al., 2019). In this research, two out of four scenarios were examined and compare for electricity access and low carbon development in Nigeria; the Business-as-Usual (BAU) scenario and Most Ambitious Level (MAL) scenario, targeting utmost determination of GHG removals whilst meeting-up adequate energy supplies for the demand.

## Results

Nigeria’s peak power demand was computed, and projected to 2060 using NECAL2060 with the key power demand drivers, demography, socio-economy and technology. The two selected scenarios, BAU and MAL, were analyzed for the application of power in to agriculture, industries, building heat and building others (specific electricity use, cooling and cooking). The year 2015 was selected the base year in this study on the basis of availability of data that represented the country’s steady economic and energy situation.

Table 1: Peak Power Demand, BAU (GW)

The structure of the nation’s economy and climate change mitigation are the major driving parameters in these selected two scenarios. Projected electricity demand has been translated into demand for grid electricity and peak demand on the bases of assumptions made for T&D losses, auxiliary consumption, load factor and declining non-grid generation.

Fig. 1: Power Peak Demand (GW), BAU.

Table 1 shows the electricity peak demand projections for BAU scenario. It must be emphasized that despite suppressed demand being experienced in the country since 2015 due to inadequate generation, transmission, distribution facilities. Suppressed demand is expected to be non-existent by 2030. From Table 1 above, it indicates ever growing demand as seen in Fig. 1, from 33.5 GW in 2015 to 85.6 GW 2060 for the BAU. Building sector is most demanding with about 53 % compared to industrial sector, 46% while agriculture and transport with insignificant energy demands.

Table 2: Peak Power Demand, MAL (GW)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | 2055 | 2060 |
| Agriculture | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 | 0.001233 |
| Industry | 15.7504 | 15.47554 | 18.93627 | 22.7078 | 26.93474 | 31.45823 | 36.63384 | 42.30853 | 48.49473 | 55.36861 |
| Transport | 0.023062 | 0.034071 | 0.099309 | 0.222201 | 0.341953 | 4.496197 | 8.683085 | 12.98554 | 16.51847 | 19.65411 |
| Buildings Other | 17.69975 | 18.02948 | 18.4252 | 19.36006 | 20.5826 | 22.12842 | 26.29152 | 30.963 | 33.11525 | 35.27584 |
| Buildings Heat | 0.001019 | 0.001037 | 0.001016 | 0.000993 | 0.00097 | 0.000945 | 0.00092 | 0.000893 | 0.000865 | 0.000835 |
| Total | 33.47563 | 33.54152 | 37.46319 | 42.29245 | 47.8615 | 58.08503 | 76.98102 | 96.97782 | 112.1274 | 126.7411 |

Total energy demand from the projected MAL shows active economic activities that supports consumption of clean energy, as seen in Table 2, the consumption of significant electricity by Electric Vehicles (EVs) from 2040, while industry leads in the consumption of electricity from 2030. See Fig. 2.

Fig. 2: Peak Power Demand, MAL

The total energy supplies were computed using same NECAL2060. This is one of the advantages of using the tool; assessment of energy demand whilst generation by optimization, strategic energy supply based on technology application provided which includes both available and future technologies. The tool, simultaneously, assesses the environmental impacts of the energy resources utilized for an exogenously given demand of final energy, targeting net-zero emission at the determined year, 2060 in this case. Nigeria is quite blessed with a lot of resources for electricity generation (Table 3) such as coal, natural gas, fossil oils, hydro and other renewable energy sources.

Table 3: Available Non-renewable sorces of electricity and status of use

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Resource Type** | **Reserves: 2019 (Natural Units)** | **Production Level: 2019 (natural units)** | **Utilization: 2019 (natural units)** |
| 1 | Crude Oil | 37.062 billion barrels | 0.723 billion barrels | Domestic: 0.162 bbd (22%)  Export: 0.561 bbd (78%) |
| 2 | Natural Gas | 203 trillion scf | 2.94 trillion scf | 90%: Utilized – 41% Export  - 16% (Domestic use, power/  Industry/commercial  - 33% Field use  (fuels/gas lift/re-injection)  10%: flared |
| 3 | Coal and lignite | 2.7 billion tonnes | 810,171 tonnes | Not applicable (as at 2015) |
| 4 | Tar Sands | 31 billion barrels of oil equivalent | 0 | Not applicable (as at 2015) |
| 5 | Nuclear Element | Yet to be quantified | 0 | 30kW experimental nuclear reactor |

Table 4: Available renewable sources of electricity and status of use

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Resource Type** | | **Reserves: 2019 (Natural Units)** | | **Production Level: 2019 (natural units)** |
| 1 | Large hydro power | | 24,000MW | | 2,630MW |
| 2 | Small Hydro power | | 3,500MW | | 64.2MW |
| 3 | Solar Energy | | 4.0 kWh/m2/day - 6.5kWh/m2/day  (a) \*210,000 MW solar PV @ 1% of  suitable land  (b) \*88,700 MW CSP @ 1% suitable land | | About 1000MW solar PV off-grid; 1 MW grid connected PV; No solar thermal electricity |
| 4 | Wind | | 3,200 MW at 10m height with wind speeds of 2-4m/s | | Still under search (as at 2015) |
| 5 | Biomass | Fuel wood | 11 million hectares of forest and woodlands | 29,800 PJ\* | Not applicable (as at 2015) |
| Municipal waste | - 18.3 million tonnes in 2005\* | Not applicable (as at 2015) |
| Animal waste | 243 million assorted animals in 2001 | Not applicable (as at 2015) |
| Energy Crops and Agric. waste | 72 million hectares of Agricultural land | Not applicable (as at 2015) |

The Nigeria’s electricity supply, both national grid and off-grid, are presently entirely dependent on fossil based (natural gas, PMS, AGO) fuels about 99 % (Table 5), which are highly polluting and the resources are fast depleting. The current nation’s electricity provision is short of the electricity demand in the country. The present average national grid power generation is about 21 % (7 GW) of the entire electricity consumption as at 2015 to 2020 (Table 1). Growing or sustaining the available national grid capacity has been very difficult due to inadequate supply of natural gas, for instance, for the thermal plants due to either shortage of gas or gas pipelines vandalization, has not allowed full utilization of total installed capacity of 18 GW.

Table 5: Electricity supply, BAU

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | 2055 | 2060 |
| Biomass & Waste CCS | 0 | 0 | 0 | 3.87E-08 | 0.007363 | 0.007363 | 0.007363 | 0.007363 | 0.007363 | 0.007363 |
| Nuclear | 0 | 0 | 0 | 0 | 19.50435 | 31.20696 | 46.81044 | 62.41392 | 62.41392 | 78.0174 |
| Wind | 0.000111 | 0.00036 | 1.014136 | 1.390682 | 2.398041 | 2.516061 | 3.237975 | 4.121431 | 4.945717 | 5.770004 |
| Solar | 0.009529 | 0.963105 | 12.03857 | 21.66943 | 25.41218 | 25.253 | 31.17655 | 37.41186 | 43.64717 | 49.88248 |
| Hydro | 1.562774 | 6.122405 | 8.984029 | 12.80564 | 17.19775 | 23.69449 | 23.46668 | 22.74129 | 24.75353 | 22.28738 |
| Biomass & Waste | 0 | 0 | 0 | 7.550094 | 7.360938 | 8.19022 | 7.300199 | 7.23945 | 7.876351 | 9.125747 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas CCS | 0 | 0 | 0 | 0 | 0.003849 | 0.003849 | 0.003849 | 0.003849 | 0.003849 | 0.003849 |
| Liguid & Gaseous Fossils | 173.2963 | 167.4825 | 158.0391 | 172.6561 | 190.2106 | 207.7372 | 237.9202 | 270.5437 | 295.576 | 309.5511 |
| Net Imports | 0 | 0 | 0 | 0 | 23.54232 | 15.69488 | 7.84744 | 0 | 0 | 0 |
| Total | 174.891 | 174.5683 | 180.0758 | 216.0719 | 285.6374 | 314.304 | 357.7707 | 404.4829 | 439.2239 | 474.6453 |

Fig. 4: Electricity Supply, BAU

Table 5 is a summary of the Electricity supply strategies based on economic activities at business as usual 7% growth rate, demand for electricity is expected to vary from 174.8 TWh in the base year to 474.6 TWh by 2060. Electricity generation in this scenario will be of highly CO2­ ­generation, creating continues global warming at base year, there was a generation of 69 MtCO2 to the atmosphere and it will continue to rise to 130.8 MtCO2 (Fig. 3).

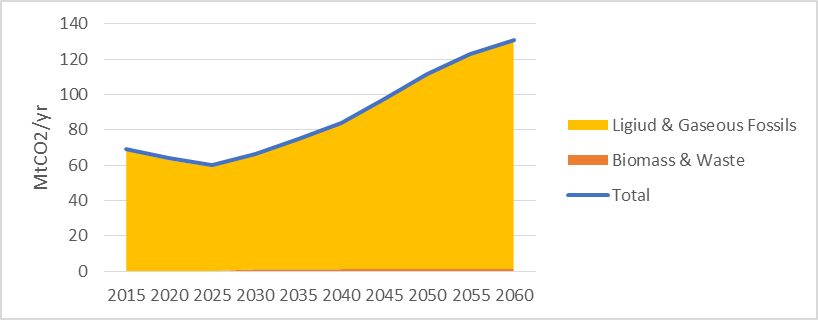


Fig. 3: Emissions from Electricity Generation (MtCO2/yr) BAU

It was also observed that emission of CO2 between 2020 and 2025 would be reduced to 63 MtCO2 and 59.9 MtCO2, respectively. This is based on shot-down of activities during COVID-19, buy it would continue to rise after 2025 due to high involvement of fossils for business activities (Fig. 3). It was also observed that fossil based fuels at base year formed 99 % of the supply while hydro made up the 1 %. By 2030, it is expected that Fossil based electricity generation would be decreased to 67 %, hydro would improve to 6 % and other cleaner fuels would come up such as Solar, 10 %; wind, 1 %; biomass and wastes, 3 %, and by 2060, fossils based generation would be 65 %; hydro, 5 %; wind, 1%, solar, 11 %; biomass and wastes, 2%, this is demonstrated in Fig. . But because of volume of resources utilized, emission would continue to rise (Fig. 3).

Table 6: Electricity supply (TWh/yr), Most Ambitious Level

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | 2055 | 2060 |
| Biomass & Waste CCS | 0 | 0 | 4.54E-08 | 4.39E-08 | 0.007363 | 15.18835 | 30.29511 | 45.3302 | 60.29924 | 75.35835 |
| Nuclear | 0 | 0 | 0 | 0 | 19.50435 | 93.62088 | 179.7311 | 266.1112 | 339.2905 | 407.978 |
| Wind | 0.000111 | 0.00036 | 1.014136 | 6.621789 | 11.9902 | 11.92051 | 16.18987 | 20.60715 | 24.72858 | 28.85001 |
| Solar | 0.009529 | 0.963105 | 48.29371 | 80.1029 | 103.9075 | 137.1768 | 171.471 | 205.7652 | 240.0594 | 274.3536 |
| Hydro | 1.562774 | 6.122403 | 11.27424 | 20.25504 | 29.23583 | 15.24353 | 17.90622 | 21.48742 | 25.06862 | 28.64981 |
| Biomass & Waste | 0 | 0 | 0 | 6.229643 | 16.52636 | 26.34029 | 38.00362 | 49.75517 | 61.58393 | 36.46341 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 30.79296 | 61.58592 | 92.37888 | 123.1718 | 153.9648 |
| Gas CCS | 0 | 0 | 0 | 0 | 0.003849 | 38.4912 | 76.95501 | 56.72141 | 10.10256 | 0 |
| Liguid & Gaseous Fossils | 173.2963 | 167.4825 | 129.0405 | 131.0503 | 137.0718 | 67.24788 | 0 | 0 | 0 | 0 |
| Net Imports | 0 | 0 | 0 | 0 | 23.54232 | 0 | 0 | 0 | 0 | 0 |
| Total | 174.891 | 174.5683 | 189.6226 | 244.2596 | 341.7895 | 436.0224 | 592.1379 | 758.1567 | 884.3047 | 1005.618 |

On electricity supply strategies based on economic activities at Most Ambitious Level (MAL) growth rate, the electricity demand would be faced by the influence of technology advancements, efficiency gains and climate change mitigation, which will impact the drivers of electricity demand such as electricity access, security and climate change mitigation. From Table 6, the demand would rise from 174.8 TWh in 2015 to 1005.6 TWh by 2060.

Fig. 5: Electricity supply, Most Ambitious Level

This scenario is based on providing adequate electricity access based on reduced emissions, targeting net-zero emission by 2060. From Table 6, 2015 being base year energy resources will be the same as BAU in Table 5, but from 2030, fossils would be reduced to 54 % in electricity generation, hydro would increase to 8 % and solar, 33 %; wind, 3 %. By 2040, new technologies would be introduced in the electricity generation, so Fossils would be fueling just 15 %; hydro, 3 %; wind, 3 %; solar, 31 % and Biomass and wastes, 6 %. New technologies like nuclear would generate 21 % of electricity; biomass and wastes with carbon capture and storage (CCS) facility, 3 % and hydrogen technology, 7 %. By 2045, fossil would stop to be used as fuel for electricity except natural gas with CCS facility at about 13 % generation while nuclear would take the lead in fueling electricity generation with about 30 %, hydro, 3 %; wind, 3 %; solar would power substantially with 29 %; biomass and wastes with CCS technology, 5 %; biomass and wastes 6 %; hydrogen technology would also be substantial with about 10 %. By 2050, natural gas with CCS would generate less electricity with just 7 %; nuclear would improve to generate about 35 %; hydro, 3; wind, 3 %; solar 27 %; biomass and wastes with CCS, 6 %; biomass and wastes, 7 %; hydrogen, 12 %. Finally by 2060, fossils would be completely eliminated from the list of resources for electricity generation in the country leaving nuclear to be the major fuel for electricity generation with about 41 %; hydro, 3 %; wind, 3 %; solar, 27 %; biomass with CCS, 7 %; biomass and wastes, 4 %; and hydrogen, 15 %. This scenario would cost less environmental impact by generating least emission. Fig. 6 shows that right after 2025, rate of emission from electricity generation in the country would start reducing and by 2035 and 2040, the value of emission generation rate would be negative, indicating carbon sink.

Fig. 6: Emissions from Electricity Generation (MtCO2/yr), Most Ambitious Level

## Conclusion

Nigeria is endowed with abundant energy resources, the significant ones include fossil, and numerous renewables such as; solar energy, biomass, wind, small and large hydropower with potential for hydrogen fuel, geothermal and ocean energies. However, the main constraints in the rapid development and diffusion of technologies for the exploitation and utilization of these different energy resources in the country are the absence of appropriate policy, regulatory and institutional framework to balance demand with supply that would attract investors. Technical, economic, environmental, and societal energy parameters that affect energy demand and supply and how they interact to determine the quantities of energy demand and supply are of paramount importance for policy development. Therefore, for Nigeria to unleash the enormous potential of its energy resources in its drive to match electricity supply with demand there is need for significant investment in critical areas of research and development, building of indigenous human and bridging the infrastructural gap and the intensification of the on-going economic reform to create an investor friendly environment.

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