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TECHNICAL POTENTIAL OF BIOMASS ENERGY IN NIGERIA

S.J. Ojolo
Department of Mechanical Engineering,
University of Lagos, Akoka, Lagos, Nigeria

J.I. Orisaleye
Department of Mechanical Engineering,
Lagos State University, Epe Campus, Lagos, Nigeria
ifeorisaleye@gmail.com

S.O. Ismail
Department of Mechanical Engineering,
University of Lagos, Akoka, Lagos, Nigeria

S.M. Abolarin
National Centre for Energy Efficiency & Conservation,
University of Lagos, Nigeria

ABSTRACT

The role of energy in the development of a nation cannot be underestimated. The current situation of energy in Nigeria reveals that an energy crisis is pending in the country. However, there is an abundance of renewable energy resources in Nigeria most of which have remained untapped. This paper gives an estimate of the technical potential of biomass energy in Nigeria, the technical potential being the part of the theoretical energy which can be harnessed for energy use. The biomass sources considered are agro-residues, livestock wastes, municipal solid wastes and forest residues. It was discovered that contribution of biomass energy in Nigeria is largely from agro-residues, municipal wastes and livestock wastes while forest residues contribute the least. The energy potential is also expected to continue to grow from about 3.2 EJ in 2010 to about 5.5 EJ in 2020 and may reach about 29.8 EJ in 2050.The estimate compares well with forecasted energy demand and will play a great role in future energy supply. Policy formulations have not favoured the development of biomass technologies for efficient utilization of biomass. There is a need to harness this huge energy potential by employing the various biomass technologies and formulating policies to the effect. There is also a need to enhance the development of the agricultural subsector of the economy where the biomass is generated.

Keywords: *Technical Potential, Biomass, Renewable energy, Energy estimate.*

1. INTRODUCTION

Energy plays a very crucial and important role in the economic, social and political development of a nation. Inadequacy of energy supply limits economic growth, restricts socio-economic activities and adversely affects the quality of life. Electrical energy plays a very important role in the technological and socioeconomic development in Nigeria, as with any nation. However, the demand far outstrips the epileptic supply in Nigeria (Sambo, 2008; Sambo, 2009; Kauffmann, 2005). Petroleum, natural gas, and hydroelectricity are Nigeria's major sources of commercial energy; they are slightly outpaced by the largely non-commercial consumption of fuelwood and charcoal (Osaghae, 2009; RECIPES, 2006). There is also a large quantity of coal which is used majorly in thermal power plants for electricity generation (Olise and Nria-Dappa, 2009). Nigeria also has abundant renewable energy which exists in the forms of solar, oceanic, hydro, wind energy and biomass.

A number of studies have assessed the global and regional potential of bioenergy production with the estimates differing considerably (Smeets et al., 2004, Fischer and Schrattenholzer, 2001). Schmidhuber (2006) differentiates between theoretical and technical potential. Theoretical potential is the total amount of energy produced by photosynthesis and it includes vast amounts of biomass that cannot be harvested because it is too inaccessible or because the cost of harvesting would be too high. Technical potential, however, is that part of the theoretical potential that can be harvested in practice and thus harnessed for practical energy use. Several estimates have shown that the technical potential is a relatively small fraction of the theoretical one.

EIA (2010) provides information about the reserves of crude oil, natural gas and coal used in this section for analysis. Nigeria has depended majorly on her large crude oil reserve which is presently put at 37.2 billion barrels of oil as given by the oil and gas journal. The production of crude oil has also been estimated to be about 2.2 million barrels per day. Most of this is exported while 280 thousand barrels of oil is refined per day for consumption within the country. EIA (2010) reports that according to the oil and gas journal, the natural gas proven reserve is estimated to be about 185 trillion cubic feet. In 2008, Nigeria consumed about 430 billion cubic feet mostly for electricity generation. 140 billion cubic feet was vented, 530 billion cubic feet was flared and about 500 billion cubic feet re-injected for enhanced oil recovery. The gross annual consumption of natural gas is put at 1,600 billion cubic feet. The recoverable coal reserves is estimated to be about 210 million short tons with the production being 9 thousand short tons per annum and consumption being about 12 thousand short tons per annum (EIA, 2010).

On the assumption that new oil or gas reserves are not discovered, it is estimated that the crude oil reserves should run out within the next 50 years and the proven natural gas reserves should run out in about 115 years. Since these have been the major energy sources in Nigeria, major steps need to be taken to explore other energy options which hitherto have been neglected in the country which include solar, nuclear and biomass energies. Technologies for exploiting these forms of energy need to be developed in the short term to guarantee security of energy for the country in the event that the predictions tend towards reality.

This paper aims at developing an estimate for the technical potential of biomass resources in Nigeria with consideration of non edible sources such as agricultural wastes in form of agro-residues and livestock wastes, municipal solid wastes and forest residues.

2. METHODOLOGY FOR ESTIMATION OF POTENTIAL OF BIOMASS ENERGY IN NIGERIA

Biomass considered in this study includes residues from major crop produce (agro-residues), livestock wastes, sawdust and municipal wastes. Data used in the analysis were collected from various sources covering the periods between 2000 and 2010. Simple relations for the estimation of the biomass potential were developed for each source; and using the data, the results obtained were extrapolated to year 2050. The technical potential was taken to be the total energy derivable from biomass obtained from the various sources.

2.1. Potential of agro-residues

Agro-residues include all crop residues which would have normally been regarded to as waste. These remains have usually been disposed of by burning or by deposition in dump sites if they are not combustible. The estimate was based on the residue quantity and the amount of energy derivable from each. The estimate for agro-residues (crop residues and wastes) was obtained using

$$E_{AR} = \sum E_i r_i$$

where E_{AR} is the energy potential of agro-residues, E_i is the energy content of each residue considered, and r_i is the annual biomass residue. But,

$$r_i = \alpha_i p_i$$

where α_i is the residue to crop ratio of each produce, and p_i is the annual production rate of the crop. Hence,

$$E_{AR} = \sum E_i \alpha_i p_i$$

The residue to crop ratios were obtained from several sources which include Yevich and Logan (2002), Milbrandt (2009) and FAO (2004). The annual crop production was obtained from CBN (2006).

2.2. Potential of livestock waste

Major livestock available in Nigeria include cattle, sheep, goat, poultry and pigs. Livestock produce wastes which have majorly been used as manure. Greater part of the quantity of livestock wastes are however left in heaps without any useful purpose. Livestock wastes can be converted by anaerobic digestion to biogas which can serve as an efficient and clean fuel.

The livestock estimates were obtained using

$$E_{LW} = \sum w_j Y_j E$$

where E_{LW} is the energy potential of livestock wastes, w_j is the quantity of waste from each livestock in kg, Y_j is the biogas yield of each waste, and E is the energy content of biogas. But

$$w_j = q_j w_{aj}$$

where q_j is the quantity of livestock reared annually and w_{aj} is the annual waste produced per head of livestock. Hence,

$$E_{LW} = \sum q_j w_{aj} Y_j E$$

The population of livestock was estimated from the annual growth rate for each livestock from a study by Mbanasor and Nwosu (2003) which stated that the annual growth rate of cattle, sheep, goat, chicken and pigs were 4.17%, 5.8%, 8.5%, 3.9% and 7.6%, respectively.

Biogas has a calorific value of 15.7 to 29.5 MJ/m^3 (Klass, 1998). Milbrandt (2009) gives the amount waste that can be obtained from each livestock and biogas yield from the wastes.

2.3. Potential of forest residues

Nigeria lies in the tropical region which is dominated by a vast land mass covered forest trees. Felling of these trees and processing them to planks yield enormous amount of residue which include bark, sawdust and mill chips. The energy potential is also estimated using

$$E_{FR} = \sum V \rho_b r_n E_n$$

where E_{FR} is the energy potential of forest residues, V is the annual volume capacity, ρ_b is the bulk density of the residue, r_n is the residue to product ratio and E_n is the energy content of each residue.

As a rule of thumb, a log in a sawmill produces 60 to 70% of useful timber as boards, 20 to 30% as wood chips and 10% as sawdust (INRS, 2008). Aruofor (2000) noted that the available forestry statistics in Nigeria are not only deficient in quality and quantity, but are disjointed and their collection suffer long lags. It was estimated, however, that the capacity of sawmills should be about 4,635,800 m^3 by 1997 with the production or capacity utilization should be 2,000,000 m^3. The bulk density of wood chips is about 290 kg/m^3 and that of sawdust is about 400 kg/m^3. The energy content of sawdust is about 15 MJ/kg and that of wood chips is about 14 MJ/kg (FAO, 1986; Klass, 1998).

According to CBN (2006), the increase in the index in forestry production was 5.5%. It was assumed that the demand for forest products increases at the same rate annually.

2.4. Potential of municipal solid wastes

Considering the demographic projection and the impact on wastes generation, the estimate for the energy potential of MSW is estimated using

$$E_{MW} = w_p P E$$

where E_{MW} is the energy potential of municipal solid waste, w_p is the annual municipal waste generation per person, P is the annual population and E is the energy content of municipal solid waste.

The annual generation of municipal solid wastes in Nigeria is about 29.78×10^9 kg; the main constituents being putrescible materials, papers, plastics/rubbers, textiles and metals (Ojolo et al., 2004). Municipal solid wastes have a heating value of 12.7 MJ/dry kg (Klass, 1998). With an estimated population of about 129 million people in 2005 (RECIPES, 2006), the annual generation of MSW per person in Nigeria is, thus, put at 231.3 kg/year/person, that is about 0.63 kg/person/day, based on the 2005 population estimate. The population statistics for Nigeria from the U.S. Census Department (2010) was used for the demographic information.

3. RESULTS AND DISCUSSION

a. Estimate of energy potential for all biomass sources

Table 1 presents the estimate of energy potential of agro-residues in 2005 and the relative contribution of each residue to the potential. The estimate shows that the annual derivable energy obtainable from agro-residues is about 1.924 EJ. The major contributors to the potential are fruit and vegetable wastes, sorghum stalks, maize residues, rice residues and cassava peels which contribute about 60% of the total annual energy potential. Table 2 shows the five-yearly estimate of energy potential of agro-residues which is based on the 6% annual increase of agricultural produce according to CBN (2006). It is assumed that the increases in annual production of agricultural produce and annual generation of agro-residues are equal. The estimate shows that the energy potential in 2020 will be about 4.6 EJ and could rise to about 26.5 EJ in 2050. Table 3 presents the population estimates of livestock in Nigeria between 2005 and 2050 while Table 4 present the energy potential of livestock wastes in Nigeria between the same periods. The energy estimate shows that the energy potential of livestock wastes in 2020 will be about 346.4 PJ and could increase to about 2.24 EJ in 2050. The wastes from cattle and goat contribute the higher part (>75 %) of the annual energy potential while sheep, poultry and pigs together contribute less than 25 %. Table 5 shows the quantity of forest residues produced in Nigeria in 1997 and the energy from each waste. The 5-yearly energy potentials of forest residues for full and utilized capacities from 2005 to 2050 are shown in Table 6 using the increase in forest production index. The results show that the energy potential of forest residues in 2020 at the current utilized capacity will be about 12.3 PJ and could reach about 62 PJ in 2050. At full capacity however, the energy potential of forest residues in 2020 will be about 28.4 PJ and may reach 142 PJ in 2050. Table 7 presents the population estimates, estimated annual municipal solid wastes generation and energy derivable from the wastes. The municipal solid waste, as well as its energy potential, is assumed to increase with increasing population. The energy potential of municipal solid wastes which could be harnessed is about 534.4 PJ in 2020 and may increase to about 987.1 PJ in 2050.

b. Biomass energy potential versus energy demand

A summary of the results is presented in Table 8 which shows that the total potential of biomass in Nigeria as at 2020 will be about 5.5 EJ and has the potential to increase to about 29.8 EJ by 2050. The results show that forest residues contribute the least to the overall annual biomass energy potential. Agro-residues, livestock wastes and municipal solid wastes together contribute over 99% of the overall biomass potential in the country. Agro-residues are the largest single contributor to the overall biomass potential producing over 75% of the total annual energy potential. Energy commission of Nigeria has forecasted the demand of energy in Nigeria from 2000 to 2030 using the Model for Analysis Energy Demand (MAED) and Wien Automatic System Planning (WASP) package (Sambo, 2008). The total energy demand by sector, assuming a 10% Gross Domestic Product growth, is shown in table 9. The total annual energy demand has been extrapolated to 2050 assuming the average growth rate of 8.3%. The total energy demand and the total energy potential of biomass are compared in Fig. 1. The comparison shows that with efficient utilization, energy from biomass in the form of agro-residues, livestock wastes, forest residues and municipal solid wastes have the potential of meeting the energy demand in the short term as seen between 2005 and 2025. Beyond 2025, the energy demand exceeds the bio-energy potential. This may be due to a predicted rapid increase in population or increased industrial activities within the country.

According to Dayo (2007), fuelwood has constituted over 60% of the annual energy consumption between 1990 and 2005. Assuming a continuing trend, the consideration of fuelwood in the estimate of the biomass potential will enhance the possibility of biomass energy to meeting energy demands in Nigeria as shown in Fig. 1. However, the use of fuelwood for energetic purposes is being discouraged in Nigeria to prevent deforestation which has a negative effect on the environment. Hence, to suffice the demand for energy while stepping down energy from fuelwood, there will be a need to exploit energy crops which can be cultivated in both arable and grass-lands. The cultivation of energy crops will increase the bioenergy potential. There may also be the need to exploit greatly other forms of renewable energy such as solar and wind energy, and hydropower.

c. Policy formulation, application and opportunities for bioenergy in Nigeria

Efficient use of biomass must be assured to be able to utilize the better part of the obtainable bioenergy potential. The conversion processes have been classified into direct combustion; thermochemical processes involving carbonisation, pyrolysis and gasification; and biochemical processes involving fermentation and esterification. Currently, most of the biomass resources are utilized by direct combustion mostly in the rural areas in the country. The effeciency of this method of utilization is between 5 and 15% which is rather inefficient. Other means of conversion should be exploited other than the direct combustion.

Table 10 shows the progress of research and application of biomass technologies in Nigeria. The applications at the domestic and industrial levels have been considered. The Table, derived from investigation, shows that the traditional utilization of biomass, requiring direct combustion of the biomass is used domestically. However, industrially, biomass is not being utilized yet. However, products from other forms of bioenergy conversion routes have not been widely used either domestically or industrially. Researchers are working on other forms of biomass technologies and are also trying to adapt them to the Nigerian situation. Some of them are outlined. Ojolo et al. (2004), Ojolo and Orisaleye (2010), Ismail (2010), Bamgboye and Oniya (2004), Abolarin (2011), Ojolo and Bamgboye (2005) and Enweremadu et al. (2008) have researched into thermochemical conversion of biomass. Research activities in biochemical conversion of biomass have been carried out by Abdulkarim and Maikano (2001), Hussaina (2002) Abdulkareem (2005), Okonko et al. (2009) and Adenipekun and Fasidi (2005). Experiments and investigation of technologies on the production of biodiesel has been carried out by Ogbonnaya (2010).

Energy policies have been made in Nigeria in 1993, 1996 and 2003 (ECN, 2003). However, the policies have not seemed to state exactly how to implement and develop the use of bioenergy in the country but has placed more focus on developing and financing conventional energy. Dayo (2008) also holds this position. The implication of this is the slow development rate of renewable energy in the country. Whilst an energy crisis is pending in the country, there is a need to focus on and pool resources, hence policies, to harness the high potential of renewable energy present in the country. Such policies should also cover the development and modernisation of agriculture, investment in infrastructure and development and commercialisation of biomass technologies.

4. CONCLUSIONS

The study has examined the technical potential of biomass energy in Nigeria. The situation of energy in Nigeria shows that an energy crisis is pending in the country as its oil reserves may not last up to half of a century. It has been found in this study that Nigeria has a large resource base of biomass energy which has hitherto been unharnessed. The biomass sources considered are agro-residues, livestock wastes, municipal solid wastes and forest residues. The biomass energy in Nigeria is contributed to largely by agro-residues, municipal wastes and livestock wastes while forest residues contribute the least. The energy potential is also expected to continue to grow from about 3.2 EJ in 2010 to about 5.5 EJ in 2020 and may reach about 29.8 EJ in 2050. The estimates compare well with the forecasted energy demand up to 2025 but beyond 2025, the comparison is better with consideration of fuelwood. Most of the biomass technologies are still at the development stage and are yet to be applied on industrial scale. Policy formulations have not favoured the development of biomass technologies for efficient utilization of biomass. There is a need to harness this huge energy potential by employing the various biomass technologies and formulating policies to the effect. There is also a need to enhance the development of the agricultural subsector of the economy since biomass is agriculturally generated.

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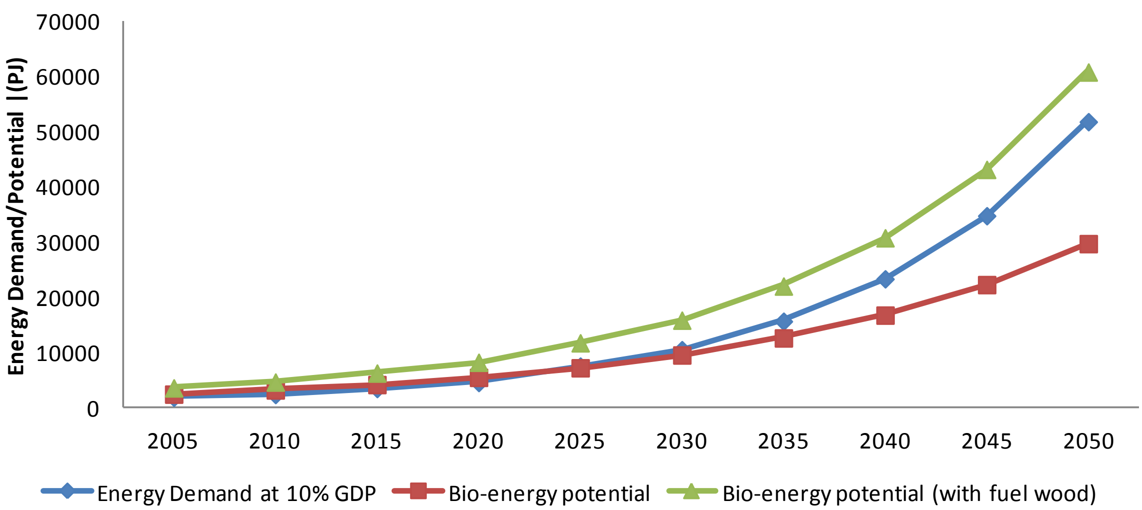

Figure 1: Comparison of Energy Demand at 10% GDP with the Bioenergy potential

Table 1: The estimate for energy potential of Agro-residues obtained in Nigeria in 2005

Agro-residue	Residue to crop ratio range	Assumed residue to crop ratio	Energy content MJ/kg	Annual Crop Production ('000 Tonnes)	Annual residue production ('000 Tonnes)	Annual Energy available (10^{15}J)
Beans	1.58	1.58	12.8	4328.3	6838.7	87.5
Cassava peels	0.4	0.4	16.4	33393.3	13357.3	219.1
Cocoa husks	2	2	17.2	202.6	405.2	7.0
Coconut fibre	1.1	1.1	16.0	216.9	238.6	3.8
Coconut Shells	1.9	1.9	18.0	216.9	412.1	7.4
Coffee husks	0.3 – 1.8	1.2	16.0	230.5	276.6	4.4
Cotton Hulls	0.26	0.26	14.0	536.4	139.5	2.0
Cotton Stalks	3.0 – 5.5	4	16.0	536.4	2145.6	34.3
Fruits and vegetables	2	2	13.1	17866	35732	468.1
Groundnut shells	0.25 – 0.5	0.4	17.4	3350.5	1340.2	23.3
Maize cobs	1.41	1.4	19.5	9503.4	13304.8	259.4
Maize Stalks	0.9 – 4.0	0.8	16.5	9503.4	7602.7	125.4
Palm Empty Fibre Bunch	0.39	0.39	18.1	932.5	363.7	6.6
Palm Fibres	0.2 – 1.1	0.8	11.0	932.5	746.0	8.2
Palm Shells	0.2 – 1.0	0.7	15.0	932.5	652.7	9.8
Plantain	0.25	0.25	17.0	1161.5	290.4	4.9
Potato peels	1.14	1.1	16.4	1528.3	1681.1	27.6
Rice Husks	0.17 – 0.22	0.2	14.6	3713.9	742.8	10.8
Rice Straw	0.8 – 2.5	1.9	11.7	3713.9	7056.4	82.6
Sorghum Stalks	1.5 – 3.7	2.5	18.0	9994.4	24986	449.7
Soyabean	2.1	2.1	16.0	1447.8	3040.4	48.6
Sugar Cane Bagasse	0.05 – 0.2	0.1	8.0	2167	216.7	1.7
Wheat Residue	0.9 – 1.6	1.2	13.9	55.6	66.7	0.9
Yam peels	0.06	0.06	19.4	26700.2	1602.0	31.1
				TOTAL	123238.2	1924.2

Table 2: 5-yearly estimate Energy potential of Agro-Residues

Year	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Energy potential of residue (PJ)	1924.2	2575	3445.9	4611.5	6171.17	8258.4	11051.6	14789.6	19791.8	26485.9

Table 3: 5-yearly population estimate of livestock in Nigeria

Livestock	Annual growth rate (%)	Population (Average million heads)									
		2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cattle	4.17	20.4	25.0	30.7	37.7	46.2	56.6	69.5	85.2	104.6	128.2
Goat	8.5	27.7	41.7	62.6	94.2	141.6	212.9	320.2	481.4	723.9	1088.5
Sheep	5.8	15.9	21.1	27.9	37.0	49.1	65.1	86.3	114.4	151.6	201.0
Poultry	3.9	132.0	159.8	193.5	234.3	283.7	343.5	415.9	503.6	609.8	738.4
Pig	7.6	8.2	11.8	17.1	24.6	35.5	51.2	73.8	106.5	153.6	221.5

Table 4: 5-yearly estimate for energy potential of livestock wastes in Nigeria

Live-stock	Waste (kg/head/day)	Biogas yield (m^3/kg)	Annual Energy produced (10^{15}J)									
			2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cattle	10	0.04	87.9	107.8	132.2	162.2	198.9	244.0	299.3	367.1	450.3	552.4
Goat	2	0.05	29.8	44.8	67.4	101.4	152.5	229.3	344.7	518.4	779.4	1172.0
Sheep	2	0.05	17.1	22.7	30.1	39.9	52.9	70.1	92.9	123.2	163.3	216.5
Poultry	0.1	0.06	8.5	10.3	12.5	15.1	18.3	22.2	26.9	32.5	39.4	47.7
Pig	1.5	0.07	9.3	13.4	19.3	27.8	40.1	57.9	83.5	120.4	173.6	250.4
TOTAL			152.6	199.0	261.5	346.4	462.7	623.4	847.3	1161.6	1606.1	2239.0

Table 5: Energy potential of forest residues in Nigeria (1997)

Forest Residue	Full Capacity			Capacity Utilized		
	Volume (m^3)	Mass ('000 tonnes)	Energy derivable (10^{15} J)	Volume (m^3)	Mass (tonnes)	Energy derivable (10^{15} J)
Sawdust	463,580	185.4	2.7	200,000	80	1.2
Wood Chips	1,390,740	403.3	5.6	600,000	174	2.4
TOTAL			8.3			3.6

Table 6: 5-yearly potential of forest residues at 5.5% increase in production rate (10^{15}J)

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Utilized Capacity	5.5	7.2	9.4	12.3	16.1	21.1	27.5	36.0	47.0	61.5
Full Capacity	12.7	16.6	21.8	28.4	37.2	48.6	63.5	83.0	108.4	141.7

Table 7: Energy potential of Municipal Solid Wastes in Nigeria

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population Estimate ('000,000)	129	150	165	183	202	226	250	279	306	338
MSW estimate ('000,000 tonnes)	29.7	34.5	37.9	42.1	46.4	52.0	57.5	64.2	70.4	77.7
Energy potential (10^{15} J)	376.7	438.1	481.9	534.4	589.9	660.0	730.1	814.8	893.6	987.1

Table 8: Total Biomass Energy Potential in Nigeria

Biomass resource	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Agro-residues	1924.2	2575	3445.9	4611.5	6171.17	8258.4	11051.6	14789.6	19791.8	26485.9
Livestock wastes	152.6	199.0	261.5	346.4	462.7	623.4	847.3	1161.6	1606.1	2239.0
Forest Residue	5.5	7.2	9.4	12.3	16.1	21.1	27.5	36.0	47.0	61.5
Municipal Solid Wastes	376.7	438.1	481.9	534.4	589.9	660.0	730.1	814.8	893.6	987.1
TOTAL (PJ)	2459.0	3219.3	4198.7	5504.6	7239.87	9562.9	12656.5	16802	22338.5	29773.5

Table 9: Total energy demand based on 10% GDP growth rate (mtoe)

Item	2005	2010	2015	2020	2025	2030	Average growth rate (%)
Industry	8.08	12.59	26.03	39.47	92.34	145.21	16.2
Transport	11.7	13.48	16.59	19.7	26.53	33.36	4.7
Household	18.82	22.42	28.01	33.6	33.94	34.27	2.6
Services	6.43	8.38	12.14	15.89	26.95	38	8.7
Total	45.01	56.87	82.77	108.66	179.75	250.84	8.3

Source: Sambo (2008)

Table 10: Progress of Research and Application of Bioenergy as fuel in Nigeria

Conversion route	Research in progress	Domestic Application	Industrial Application
Direct Combustion	✓	✓	×
Gasification	✓	×	×
Pyrolysis	✓	×	×
Anaerobic digestion	✓	×	×
Fermentation	✓	×	×
Biodiesel/Transesterification	✓	×	×