ANNEX 3

Various Biofuels feedstocks and the associated issues- *Prof. B.O. Solomon Nigeria*

- Logistics
- Competition for land
- Impacts on food prices
- Environmental implications

1.0 Bioethanol Feedstocks

There are two broad groups of bioethanol feedstock refered to as the first and second generation feedstock. The majority of the first generation of feedstock for bioethanol production include those that are widely grown and used for food and animal feed, hence the current debate, *"Food or Fuel?"*.

i. Saccharine (Sugar Containing) Materials) } *First Generation Feedstock*
ii. Starchy Materials }
iii. Cellulose Materials → *Second Generation Feedstock*

i. Saccharine (Sugar Containing) Materials - These are the feedstock that are currently being used for the production of sugar, or which has high component of simple sugar. These feedstocks are the easiest to convert to ethanol and they include:

- Sugar Cane
- Sugar Beet
- Sweet Sorghum
- Fruits (e.g. grapes, apple, pineapples, pears, oranges, e.t.c.)

Table 1.0: *Average Fermentable Sugar Content of Some Saccharine Feedstocks*

Feedstocks	**Average Fermentable Sugar Content (%)**
Fruits	
Grapes	15.0
Bananas	13.8
Apples	12.2
Pineapples	11.7

Pears	10.0
Peaches	7.6
Oranges	5.4
Water melons	2.5
Tomatoes	2.0
Sugar beets	15.0
Sweet sorghum	14.0
Sugar cane	10.0 - 15.0
Molasses	50.0 - 55.0

ii. Starchy Materials - These feedstocks are those that are rich in starch, a form of complex sugar. They are in form of grains and tubers. They include:

- Cereals such as Corn (Maize), Guinea Corn (Sorghum), Millet, Wheat, Rice, Barley, e.t.c.
- Cassava
- Potatoes

iii. Cellulose Materials – This is a much more complex sugar polymer found in plant materials crystalline in structure (lignin), and resistant to hydrolysis.Roughly, two-thirds of the dry mass of plant materials are present as cellulose and hemicellulose. Lignin makes up the bulk of the remaining dry mass.

The plant (cellulose) materials used as feedstock include:

- Agricultural plant wastes (e.g. corn cobs, corn stalk, straws, sugar cane bagasse, cotton wastes, e.t.c.),
- Plant wastes from industrial processes (e.g. paper pulp),
- Forest wastes (e.g. chips and sawdust from lumber mills, dead trees, and tree branches)
- Energy crops grown specifically for fuel production, such as switchgrass, Miscanthus, Poplar, and
- Municipal Solid Waste (e.g. old newspapers).

Table 1.0 shows some of the feedstocks, their annual ethanol yield and their greenhouse gas saving effect compared to petrol.

Table 1.1: Some Bioethanol Feedstocks and Their Annual Yield

Crop	Annual Yield (Litres/Hectare)	Greenhouse gas savings (% vs Petrol)	Comments
Miscanthus	7300	37 - 73	Low input perennial grass. Ethanol production depends on development of cellulosic technology.
Switchgrass	3100 – 7600	37 - 73	Low inout perennial grass. Breeding efforts underway to increase yields. Higher biomass production possible with mixed species of perennial grasses.
Poplar	3700 – 6000	51 - 100	Fast growing tree. Completion of genomic sequencing project will aid breeding efforts to increase yields
Sugar Cane	5300 – 6500	87 - 96	Long season annual grass. Newer processing plants burn residues not used for ethanol to generate electricity. Only grows in tropical and subtropical climates.
Sweet sorghum	2500 – 7000	No data	Low input annual grass. Grows in tropical and temperate climates, but highest ethanol yield estimates assume multiple crops per year. Does not store well.
Corn	3100 – 3900	10 - 20	High input annual grass. Only kernels can be processed using available technology. Development of commercial cellulosic technology would allow stover to be used and increase ethanol yield by 1,100 - 2,000 l/ha

Source: *Nature 444 (December 7, 2006): 673 – 676.*

2.0 Feedstock for Biodiesel Production

The feedstocks for biodiesel production are vegetable oils and animal fats, alcohol and catalysts.

2.1 Vegetable Oils and Animal Fats

Biodiesel is produced from vegetable oils, animal fats and recycled greases. These materials contain triglycerides and other components depending on type. Some of the feedstocks are palm oil, coconut oil, canola oil, corn oil, cottonseed oil, flex oil, soy oil, peanut oil, Jatropha oil, sunflower oil, rapeseed oil and algae. Table 5.1 shows oil production averages of some crops.

Table 2.1: *Oil Production Averages of Some Crops*

Plant	**Kg Oil/ha**
Oil palm	5000
Coconut	2260
Jatropha	1590
Rapeseed	1000
Peanut	890
Sunflower	655
Soybean	375
Hemp	305
Corn	145

a. Pretreatment of Feedstock

Free fatty acid levels higher than 0.5% is considered high enough to impede high biodiesel yield. Therefore the pretreatment of high FFA in feedstock is essential before transesterification. The procedure for treating high FFA in feedstock is as follows:

- Measure FFA level (Appendix III)
- i) Add 2.25g methanol and 0.05g H_2SO_4 for each gram of FFA in the oil or fat.

  ii) H_2SO_4 and methanol should be mixed first and then added slowly to the oil
- Agitate for 1 hr at 60 – 65°C

- Let mixture settle. Methanol, water mixture will rise to the top. Decant the methanol, water and H_2SO_4 layer
- Take the bottom fraction and measure new FFA level
- If FFA is >0.5% return to the second step with new FFA level. If FFA is <0.5%, proceed to the next step
- i) Add an amount of methanol equal to 0.217 x [gram of untreated triglyceride]and an amount of sodium methoxide equal to [0.25 + (%FFA)0.19]/100 [gram of untreated triglyceride]

  ii) Mix the sodium methoxide with the methanol and then add to the oil. This corresponds to 6:1molar ratio of methanol to oil for the triglycerides. This ignores any methanol that may have been carried over from the pretreatment.
- Agitate for 1 hr at 60°C.

Example: 100g of 12% FFA animal fat

<u>Step 1</u>

Pretreatment 1

2.25 x 12g = 27.0g methanol

0.05 x 12g =0.6g sulphuric acid (H_2SO_4)

- Mix acid with methanol, then add mixture to fat/oil
- Agitate for 1 hour at 60°C.
- Let it settle and remove the bottom phase
- FFA = 2.5%

<u>Step 2</u>

Pretreatment 2

2.25 x 2.5g = 5.6g of methanol

0.05 x 12g = 0.13g of sulphuric acid (H_2SO_4)

- Mix with oil and agitate for 1 hour at 60°C
- FFA should be <0.5%
- Removal of upper phase is usually optional at this point
- Then add 0.217 x (88) = 19.1g of methanol + [0.25 + (0.5)(0.19)]/100 x 88

b. *Quality of Feedstock*

The general rule is that the closer a feedstock is to containing pure trigylcerides, the easier it will be to convert to biodiesel. Feedstock for biodiesel production contains many possible contaminants such as water, FFA, particles and phospholipids. Each of these contaminants has potential impact on the quality of the final biodiesel product. Table 2.2 offers explanation and the negative impact of these contaminants on biodiesel production.

Table 2.2: *Quality of Feedstock as it Affects the Production of Biodiesel*

Contaminant	Explanation	Impact on Biodiesel Production
Water	• Not even 1% water is tolerable in biodiesel production	• Increases soap production in the final product • Affects the completeness of the transesterification reaction by resulting in poor biodiesel yield
Solids	• Feedstock should be filtered to ensure that no particles enter the processing scheme	Reduces the contact between the oil and the reactants impeding the transesterification process. This will result in low biodiesel yield.
FFA	• The FFA content of feedstock should be less than 0.2% for	• Deactivates the catalyst creating soap and releasing water when converted to esters • Do not seem to impact the final acid value of

	the alkaline-caltalyzed process • The alkali catalyst also serves as caustic stripper and removes the FFAs by converting them to soap that is removed during washing	the biodiesel • Affects the type of biodiesel process used and the yield of fuel from that process
Phosphorous	• Phosphorous levels higher than 10 ppm in the feedstock must be removed to meet the desired quality of biodiesel • The usual biodiesel production process removes the phosphorous and it is either transferred to the glycerol fraction or removed by water washing	• There does not seem to be any effect of the initial phosphorous content of the feedstock on the final phosphorous content of the biodiesel
Iodine value	• The iodine value is a crude but commonly used indicator of the level of saturation of an oil	• Saturation and fatty acid profile do not seem to have much impact on the transesterification process but affect the properties of biodiesel • Saturated fats produce biodiesel fuel with superior oxidative stability, a higher cetane number but poor low temperature properties • Biodiesel from saturated fats is more likely to get at ambient temperature than biodiesel

		from vegetable oils

c. Energy Crops

Energy crops are generally plants, trees or other herbaceous biomass which are grown and harvested specifically for energy production use. Here, they are plants whose oils are used for biodiesel production. A typical biodiesel energy crop is *Jatropha curcas* which is inedible (Figure 5.1). The use of *Jatropha curcas* eliminates the arguments against biodiesel production from edible crops. Jatropha seeds contain 37% vegetable oil that is suitable for biodiesel production. Upon extraction, about 25% of vegetable oil is obtained. Jatropha offers the following advantage in fuel production.

- It costs very little to grow
- It is drought resistant
- It can grow almost everywhere even in sandy, saline or otherwise infertile soil
- It is easy to propagate as a cutting simply pushed into the ground will take root
- It is not invasive or spreading
- It is capable of stabilizing sand dunes, acting as a windbreak and combating desertification
- It naturally repels insects and other animals
- It lives for over fifty (50) years producing seeds all the time
- It does not exhaust the nutrients in the soil
- It does not require expansive crop rotation
- It does not require fertilizer
- It grows quickly and establishes itself easily
- It has a high yield (can yield about 1000 barrels of oil per year per hectare)
- No displacement of food crop is necessary
- It is great for developing countries in terms of energy and jobs
- The biodiesel by-product, glycerine, is profitable in itself

- The waste plant mass after oil extraction can be used as organic fertilizer
- The plant itself recycles 100% of the CO_2 emissions produced by burning the biodiesel

Figure 2.1*: Jatropha Plant and Seeds Obtained from Efugo Farms, Kuje, Abuja.*

ii. Alcohol

Methanol is the most commonly used primary alcohol in biodiesel production although any other alcohol such as ethanol, iso-propanol and butyl can also be used as long as the final product meets the ASTM 6571 specification. The major factor for the choice of an alcohol is the water content. Other issues to consider in the choice of an alcohol include:

- Cost of the alcohol
- The amount of alcohol needed for the reaction
- The ease of recovery and recycling of the alcohol
- Global warming issues
- Need for technical modification of the alcohol such as application at higher operating temperature, longer or slower mixing times or lower mixing speed

The argument for the use of methanol or ethanol in biodiesel production is provided in Table 2.3.

Table 2.3: *Methanol vs Ethanol in Biodiesel Production*

Biodiesel parameter	**Methanol**	**Ethanol**
Recovery and recycling of used alcohol • Minimizes operating cost • Minimizes environmental impact	It is easier to recover because it does not form azeotrope (+)	Considerably more difficult to recover because it forms an azeotrope with water so it is expensive to purify (-)
Toxicity	More toxic (-)	Less toxic (+)
Flammability	Has a flash point of 10°C, which makes it considerably flammable (-)	Has a flash point of 8°C, which makes it considerably flammable (-)
Alcohol quality • A good alcohol is one that is un-denatured and anhydrous	It is un-denatured (+)	It is typically denatured with poisonous material to prevent its abuses, therefore, finding un-denatured ethanol is difficult (-)
Finished biodiesel quality	Higher quality methyl esters (+)	Lower quality ethyl esters because of the slower reaction rate resulting in a somewhat lower level of conversion and higher level of mono- and di-glycerides and also glycerol in the final product (-)

+: advantageous in biodiesel production

-: no advantage in biodiesel production

iii. Catalyst and Neutralizers

Catalysts may be base, acid or enzyme material. Catalysts are required in biodiesel production for the following reasons:

- To initiate the esterification reaction.
- Promote an increase in the solubility to allow the reaction to proceed at a reasonable rate.

The most common catalysts used are strong mineral base such as sodium hydroxide ($NaOH$) and potassium hydroxide (KOH). After the reaction, the base catalyst must be neutralized with a strong mineral acid. Table 5.4 provides an argument for the use of a base or acid catalyst.

Table 2 .4: *Acid vs Base Catalyst*

Catalyst	Advantages	Disadvantages
Acid Catalyst *(e.g. H_2SO_4)*	• More commonly used for the esterification of FFAs >1% to avoid soap formation	• Too slow for industrial processing with slow reaction rates and high alcohol: triglyceride requirements (20:1 or more) • Residence times from 10 minutes to about 2 hours • All acid esterification systems needs to have a water management strategy
Base Catalyst, (e.g. NaOH, KOH)	• Relatively fast with residence times from about 5 minutes to 1 hour depending on temperature, concentration, mixing and alcohol: triglyceride ratio	• Highly hygroscopic • Form chemical water when dissolved in alcohol reactant • Also absorbs water from the air during storage

3.0 Feedstock for Biogas Production

Animal wastes and plant residues are excellent feedstock for biogas production because they are organic compounds that contain carbon and nitrogen in the required proportion. Animal waste such as poultry waste, cattle waste, piggery waste and human excreta are used in biogas production. Crop residues and crops, such as water hyacinth, have also been successfully used as feedstock in biogas production.

3.1 Factors Affecting Biogas Production

The production of biogas is affected and influenced by temperature, composition of the feedstock, pH of the waste and toxicity in the form of ammonia, aromatic compounds, presence of heavy metals and volatile acids. Other factors are loading rate of the feedstock into the digester, retention time of the waste in the digester and the nutrient availability for micro-organisms responsible for the bioconversion (C: N).

a. *Temperature*

Temperature is an important parameter that affects biogas production. This is because it affects the enzymatic activities of the micro-organism responsible for the bioconversion of substrates into gas. Biogas can be produced at the psychophilic (below 20°C), mesophilic (20°C - 40°C) and thermophilic (40°C - 65°C) temperatures. Table 6.1 is the advantages and disadvantages of producing gas at each of these temperatures.

Table 3.1: *Gas Production at the Various Temperatures*

Temperature range	**Advantage(s)**	**Disadvantage(s)**
Psychophilic	None	• Bioconversion is slow and incomplete • Longer detention time is required • Heating of the digester is required
Mesophilic	This temperature corresponds to the ambient temperature of the Tropics and as such no heating is required thus reducing cost of production	Longer detention time may be required to enable complete conversion of the available carbon
Thermophilic	• Higher rate of gas production • Allows heavier organic loading • Lower detention time • Enables the use of comparatively smaller size digesters • Digestion is much more sanitary than digestion at the other temperatures because of the few pathogens that can survive at this temperature • Mechanical transport and handling	Digestion is easily upset at this temperature

	of the digester is easier because the slurry is less viscous	

b. *Total Solid Concentration of Slurry (TS)*

Slurry is diluted by the addition of liquid and concentrated by the addition of slurry solids. Slurries of feedstock used in the anaerobic digestion process to produce biogas are usually classified as low (less than 10% TS) and high (TS greater than 20%).

Low TS

- Slurries of low TS are easier to handle by pumps and pipe works compared to those of high TS.
- If the slurry is too thin, the solid matter separates and falls to the bottom instead of remaining in suspension resulting in reduced gas yield.

High TS

- If the slurry is too thick, the biogas produced is trapped within the slurry and rises to the surface with great difficulty resulting in reduced gas yield.

c. *Retention Time*

Generally, 30 days is considered as a minimum time frame for optimum bacterial decomposition to take place to produce biogas and destroy the toxic pathogens found in waste.

d. *pH*

- The pH value of the slurry in the digester is an important indicator of methanogenic performance. In the absence of any other indicator, pH value alone has been used to check the digester environment.
- Gas will be produced if the pH is between 6.6 and 7.6. Gas production is highest when the pH is between 7.0 and 7.2. Beyond this pH limits, digestion can proceed but with less efficiency.

e. *Loading Rate*

- The quantity of waste that is fed into a digester depends on the capacity of the digester, the temperature at which digestion is taking place, the retention time and the efficiency of bioconversion of the waste into biogas.

- Increasing the loading rate after the optimum value increases the TS concentration of the slurry, which results in an accumulation of some inhibitory compounds that reduce the rate of gas yield.
- In a simple biogas plant, 1.5kg/m^3/day is already quite a high loading rate. Temperature controlled and mechanically stirred large scale plants can be loaded at about 5kg/m^3/day.

f. Carbon- to-Nitrogen Ratio of Slurry

- The microbial population involved in anaerobic digestion requires sufficient nutrient to grow and multiply. Each species require both a source of carbon and nitrogen.
- If there is an insufficient quantity of nitrogen present, the bacteria will be unable to produce the enzymes which are needed to utilize the carbon.
- If there is too much nitrogen, particularly in the form of ammonia, it can inhibit the growth of bacteria.
- An optimum ratio of Carbon-to-Nitrogen (C:N) of between 20:1 and 30:1 is recommended for optimum methanogenic performance.
- A deficiency in the carbon content of animal manure used for anaerobic digestion can be corrected by the addition of plant wastes, which are high in carbon content.

g. Toxicity

Many compounds can be toxic to methanogens if present in sufficient concentration in digesters although some are needed, they quickly become inhibitory. Sources of toxicity in biogas plants are:

- The various salts, heavy metals such as Copper, Zinc and Nickel present in the waste, antibiotics in the feed for animals that produce the waste and ammonia concentrations of the slurry in excess of 3000mg/l.
- Formation of aromatics such as phenol, p-cresol, ethyl phenol, indole and skatole during the microbial degradation of proteins contained in the waste being fed into the digester.
- High concentrations of volatile fatty acids in the digester.

COMPETITION FOR LAND AND IMPACT ON FOOD PRICES

The wealth of the First World today have been attributed to locked down in best utilisation of lands and therefore, whenever there is a major crises in the value of land, there is a serious ripple effect on the whole economy. The crossing of third world countries to first have been reported to solely dependent on the utilisation of the land (http://allafrica.com/stories/200807100235.html). The historical importance of land utilisation mostly for food production had for decades received serious consideration by the world leaders through various initiatives promoting the judicious use, its role of being the platform for planting food crops and other plant materials as made the economics of land for Preferential utilisation very imperative in the spirit of current financial globalisation and domestic monetary policies (Bernanke,2007; Champ and Freeman, 2001; Gali, 2008; Greenspan 2007; Harris, 2008; Isard, 2005; Johnson, 2002; Nayyar,2002; Ocampo, 2005; Phillips, 2008; Soludo, 2000; Soludo and Rao, 2002). Land has also been modelled as a non-depletable resource whose productivity is augmented exogenously (Reilly and Paltsev, 2007).

The recent debate against the adoption of the alternative energy option from renewable plant based resources (Biofuel) because of competition with agricultural land and impact on the food prices required a holistic assessment as argued by Polaski (2008) for the fact that other factors aside the biofuel production such as failure of giving the agricultural sector the importance it deserved during the last decades, unfavorable weather conditions possibly due to the effects of climate change, lack of investments in production capacity and infrastructure, distorted agricultural markets and the dismantling of support policies for domestic markets in developing countries might have contributed to the high food prices experienced globally. Although, Fedoroff and Cohen, (1999) have predicted that the global demand for food is expected to double over the next 50 years meaning more food production centering on the available land and technology. The use of appropriate biotechnological tools and techniques for improving the Plants yield, drought tolerance and multiplication offers a best solution incase of unforeseen adverse environmental conditions. The development of second-generation biofuel based on the conversion of cellulosic resources, such as grasses, sawdust and fast growing trees from non-food sources as rightly suggested and reported by Solomon, *et al*.(1990); Layokun *et al*. (1990); Ojumu, *et al* (2003a&b); Adetunji, (2004) that can help to limit the direct competition between food and biofuel that is associated with most first-generation biofuels should be of priority for sustainability of the biofuel initiative.

The biomass energy resource base of Nigeria is estimated to be about 144 million tonnes per year. The biomass resources of Nigeria consist of wood, forage and shrubs, animal wastes and wastes arising from forestry, agricultural, municipal and industrial activities as well as aquatic biomass. Nigeria's land area is about 79.4 million hectares of which 71.9 million hectares can be considered to be arable. This shows a huge potential for the production of biomass since an estimated 94% of Nigerian households are engaged in crop farming. Nigeria's aggregate annual crop production of 93.3 million tonnes of major crop yields far more quantity of straws, chaff, leaves and other biomass materials. This expanse of arable land holds promise for cropping of energy crops such as Jatropha for biodiesel production. These energy crops are not edible and as such cannot affect the food chain. Nigeria also produces an estimated 285.1 million tonnes of manure from her livestock population of 245.9 million, which can yield about 3 billion cubic meter of biogas annually. This is more than 1.25 million tonnes of fossil fuel oil per annum. Other possible biomass resource base includes aquatic plants such as water hyacinth and municipal wastes, both of which constitute major environmental problems.

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ENVIRONMENTAL ISSUES ASSOCIATED WITH BIOFUELS

Biofuel is acknowledged to have capacity to reduce greenhouse gas compared to fossil fuels, but it is not entirely without environmental concern. Depending on the crop type, carbon balance is not always negative, that is, not in all cases is net carbon reduction achieved. For instance when broad leafed vegetation are cleared and replaced by thin leafed crops, there may be net decrease in the annual carbon absorption from that area of land especially when it is considered that the land is left bare with zero absorption prior to the development of adequate leave canopy by the crop. This bare period may be reduced by raising crop in nurseries before land clearing begins.

1. Emissions

Emissions involve the following:

- Emissions from growing the feedstock (e.g. petrochemicals used in fertilizers).
- Emissions from transporting the feedstock to the factory
- Emissions from processing the feedstock into biodiesel
- Emissions from the change in land use of the area where the fuel feedstock is grown.
- Emissions from transportation of the biofuels from the factory to its point of use
- The amount of carbon dioxide produced at the tail pipe.

2. Environmental Issues

There are various types of environmental issues and questions arising from biofuel production and utilization. Some of the issues are hereby enumerated:

- Greenhouse gas emissions
- Socio-cultural impact

- Economic impact
- Impact on water resources
- Food prices vs biofuel production
- Oil price moderation
- Soil erosion
- Deforestation and biodiversity loss
- Potential for poverty reduction
- Biofuel prices
- Centralized vs decentralized production
- Environmental organizations stance
- Energy efficiency and energy balance of biofuels, etc.
- Health risks arising from the impact of emissions and pathogens on living organisms.

Biofuels and other forms of renewable energy aim to be carbon neutral or even carbon negative. Carbon neutral means that the carbon released during the production and use of biofuels is reabsorbed by the plants. Adequate policies and economic instruments would help to ensure that biofuel commercialization, including the development of new cellulosic technologies, is sustainable. Sustainable biofuel production practices would not hamper food and fibre production nor cause water or environmental problems but would actually enhance soil fertility. Responsible commercialization of biofuel represents an opportunity to enhance sustainable economic prospects in many countries.

Some mainstream environmental groups support biofuels as a significant step toward showing or stopping global climate change however, biofuel production can threaten the environment if it is not done sustainably .These findings have been backed by reports of the UN, the I.P.C.C and other smaller environmental and social groups such as EEB which generally remain negative about biofuels.

Environmental Issues Associated with Different Types of Biofuel

i. Biodiesel

- When land is cleared, vegetable matters that absorb CO_2 will be removed, and there will be more CO_2 arising from emissions from the automobiles used for clearing thereby contributing to environmental pollution.
- Agrochemicals used in the farming of biodiesel crops contribute to environmental pollution.
- Agricultural residues left after isolation of the seeds (e.g. cobs, pods, stems etc) constitute environmental problems.
- During the production of biodiesel, oil spillage in the area is an environmental issue.
- Noise pollution arising from the processing of the biodiesel constitutes environmental pollution.
- Combustion of the biodiesel emits CO_2 and some other gases.
- The presence of oxygen in biodiesel improves combustion and therefore reduces hydrocarbon, carbon monoxide and particulate emissions but oxygenated fuel tend to increase nitrogen oxide emissions.
- Edible crops such as soybean could lead to food crisis when used recklessly for biofuel production.
- Biodiesel is a good solvent that can dissolve certain types of paints, however, lower blends, up to B20, does not.
- Biodiesel has the tendency to dissolve the accumulated sediments in diesel storages and vehicle fuel system tanks, however, lower blends, up to B20, does not..
- Dissolved sediments can block fuel filters and foul the fuel injection.
- Biodiesel may dissolve the fuel filter and the fuel host therefore, special materials should be used for the production of fuel hosts and fuel filters e.g. Teflon and Fibre glass.

ii. ***Bioethanol***

- When land is cleared, vegetable matters that absorb CO_2 will be removed, and there will be CO_2 arising from emissions from the automobiles used for clearing thereby contributing to environmental pollution.
- Agrochemicals used in the farming of bioethanol crops contribute to environmental pollution.
- Agricultural residues left after isolation of bioethanol crops (e.g. corn cobs, cassava and sugar cane peels etc) constitute environmental problems.
- On fermentation of bioethanol, carbon dioxide is released, large quantity of water used for hydrolyses and fermentation.
- During distillation, thermal pollution is encountered.
- Noise pollution is encountered during the crushing of raw materials for bioethanol production.
- Combustion of bioethanol emits carbon dioxide and some other gases
- Bioethanol is a good solvent and can dissolve certain types of paints, however, lower blends, up to E10, does not.
- Bioethanol has the tendency to dissolve the accumulated sediments in diesel storages and vehicle fuel tanks, however, lower blends, up to E10, does not.
- Dissolved sediments can block fuel filters and foul the fuel injection system, however, lower blends, up to E10, does not.
- Bioethanol may dissolve the fuel filter and the fuel hose therefore, special materials should be used for the production of fuel hose and fuel filters e.g. Teflon and Fibre glass, however, lower blends, up to E10, does not.

iii. ***Biogas***

- Land clearing: when land is cleared vegetable that absorb CO_2 will be removed, meaning that there will be more carbon dioxide in the environment.
- The automobile used in clearing will produce emissions that pollute the environment.
- Organic wastes used for biogas production contain pathogens that are harmful to living organisms therefore, proper handling should be ensured.

Mitigations

- Strengthening of the existing National Energy Policy and its Master Plan through an Act of National Assembly parliament for sustainable production and utilization of biofuels.
- Creation of public awareness on safety issues involved in biofuel production and utilization.
- Intensification of research and development into biofuel technology to curb emissions arising from biofuel production and utilization.
- Involvement of the full participation of the community for the development of biofuel production and utilization to avoid socio-cultural conflicts.
- Maintaining biofuel standards of Standard Organization of Nigeria (SON) and Department of Petroleum Resources (DPR).