Jatropha Curcas:

An Alternative Source of Energy to Meet INDIA's Growing Energy Demand & Effect of EGR on Emissions from Diesel Engine Using Biodiesel Blends.

S.Hariharansudarson

Department of Mechanical Engineering, K.L.N College of Engineering, Sivagangai, (India)

ABSTRACT

This paper presents the Jatropha (Jatropha curcas) is a plant native to Central America and Mexico. A source of oil and other by-products with commercial possible and economic assess. Biofuel produced from Jatropha curcas can be used in a variety of ways to meet India's energy demand, particularly in the rural areas. The purpose of this paper is to feature the treats and the required outcome for biofuel production at a commercial scale in India from Jatropha curcas oil feedstock. The paper covers issues of policy development, sustainability and economics that need to be addressed by India authorities while taking this path toward sustainable biofuel production. The major origin of data for the report was the development of Biofuel Roadmap for India. Bio-diesel is an alternative fuel to diesel and is wide applied in CI engines to cut down exhaust gas expelling which in turn helps in reduction of environmental abasement. The trouble with biodiesel utilization outcome is more prominent NOx discharge when compared to diesel engines. The purpose of this influence is to decrease the NOx emissions with the help of Exhaust Gas Recirculation (EGR). NOx, CO, HC and smoke concentration of the release gas were measured to calculate the emissions. Outcome of the result show decrease in NOx emission with the aid of EGR with little compromise in power yield.

Keywords- *Biodiesel; Diesel engines; EGR; economic assess; Jatropha curcas; Roadmap.*

I. INTRODUCTION

Today, most of the energy we use comes from fossil fuels: petroleum, coal and natural gas. While fossil fuels are still being used today by belowground heat up and force, they are wiped out more quickly than they are created. For that reason, fossil fuels are viewed non-renewable: that is they are not substituted as shortly as we use them. The role of fossil fuel and its associated by-products have posed a great threat to the planet which is currently grappling with the challenges caused by the increasing concentration of green house gases (GHG - particularly as carbon dioxide), and the resulting consequences of global warming, including increased hurricanes and typhoons and other extreme weather events. Thus we have a desperate need for a shift towards

ISBN: 978-93-87793-31-6

green or lower GHG solutions in our way of life. It is widely agreed that the production of transport fuel from biomass, in either liquid or gas form, holds the promise of a lowered net fossil-energy requirement and lowered greenhouse gas (GHG) emissions. However, the future scenario of biofuel production on a sustainable basis over the coming 30 years is not yet clearly defined. However, using non-food biomass feedstock such as *Jatropha curcas* could help to achieve sustainable, very low emission and cost-effective biofuels production through successful development of advanced biofuels technologies. In addition to fuel production, its scope entails a very significant stimulus to the economies of India from creation of many permanent jobs from Jatropha oil production by small holders, and from use of the oil and Jatropha by-products for generating electricity and as a feasible alternative for firewood and charcoal.

In the automobile sector, compression ignition engines consume lot of fuel like diesel at present day and they are preferred prime movers due to excellent drivability and higher thermal efficiency. Besides their advantages, they emit large quantities of discharge gases which contain green house gases and other gases like CO, NOx and smoke etc which cause damage to people's health. Due to these effects, human beings may suffer from various diseases, such as breathing difficulties, skin cancer, lung cancer and poisoning etc.

Hence, there is a need of controlling diesel engine emissions. Several researchers have worked to understand effect of different bio-diesels on exhaust emissions. Research on alternative fuels proves bio-diesel has an assuring effect on reducing emissions of CO2, CO and UBHC for all biodiesel and its blends without any modification on current diesel engines. This is due to the concept that biodiesel has oxygen in its structure and it burns cleanly for the fuel. But it was described that NOx emissions are slightly high in biodiesel and its blends. Availability of high flame temperature and rich oxygen in the combustion chamber is the basic reason behind higher NOx emissions. EGR is one of the most effective means of reducing NOx emissions from compression ignition (CI) engines and is widely used in order to meet the emission standard. EGR is an effective technique where a part of exhaust gas is recirculated to intake so as to decrease the amount of oxygen available for nitrogen and also to reduce flame temperatures which in turn dilutes NOx emissions. The specific heat of the EGR is much higher than fresh air, hence EGR increases the heat capacity (specific heat) of the inlet charge, thus decreasing the temperature rise for the same heat discharge in the combustion chamber. But, EGR application results in higher specific fuel consumption and also more prominent CO, HC emissions.

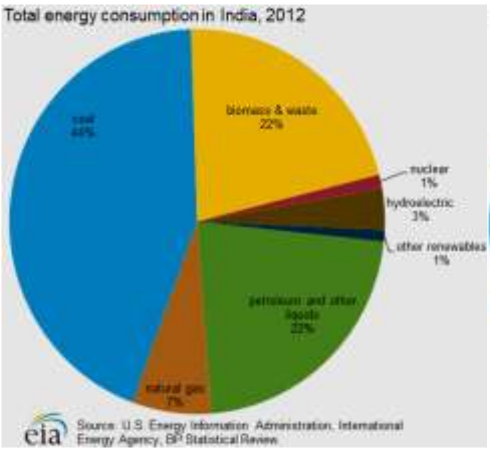
The experiments on twin cylinder four stroke, water cooled, diesel engine coupled with mechanical loading to investigate the effect of exhaust gas recirculation with sunflower methyl ester blends and diesel fuel and results indicates that 25% B20 SFME with 15% EGR rate produce 25% less NOx emissions equated to diesel fuel for the same level smoke emissions. Experimental investigation was done on diesel engine fuelled with biodiesel using canola oil ethyl ester with EGR and results suggests that use of bio-diesel decreases the thermal efficiency of engine. An experiment was made on Diesel engine with EGR using biodiesel to analysis the exhaust emissions and to understand cylinder pressure variations, heat release rates.

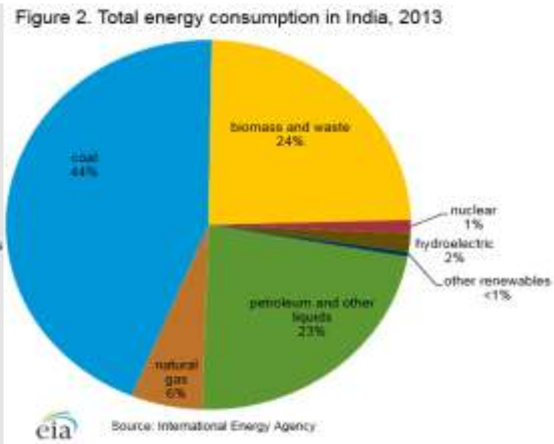
The objective of this research is to investigate the effect of exhaust gas recirculation with Jatropha methyl ester and diesel fuel on the reduction of NOx emissions and also to look into the performance and emission characteristics of a diesel engine with biodiesel as fuel with and without EGR at different percentages like 5%EGR, 10%EGR, under the same load conditions.

II. OVERVIEW OF ENERGY RESOURCES AND CONSUMPTION IN INDIA

India is third largest countries in Asia with a total area of 3,287,263 sq km, and it has a population of about 1.35 billion (growth rate of 1.11% per year). The total main energy consumption from crude oil (212.7 Mtoe; 29.38%), natural gas (45.1 Mtoe; 6.23%), coal (411.9 Mtoe; 56.90%), nuclear energy (8.6 Mtoe; 1.19%), hydro electricity (29.1 Mtoe; 4.01%) and renewable power (16.5 Mtoe; 2.28%) is 723.9 Mtoe (excluding conventional biomass use) in the calendar year 2016. Crude oil is the main source of fossil energy and its consumption has rapidly increased in recent years owing to the increase in the country's economic and population growth (Fig. 1). Biomass contribution has significantly dropped due to high growth in hydro and oil source. The main source of biomass is industry (49.70%) in the form of raw and processed wood (charcoal) which highly affects the green area and leads to deforestation in the country (Fig. 2). The transportation sector is the largest user of the refined fuel products, consuming about 22.50% from the total crude oil volume presently produced.

In south India many place Jatropha seed plantation take place but most of them export the seed to foreign countries. No one come forward for oil extraction. If rural people take action for extraction of Jatropha oil there will job for rural people and economic saving. We exchange of money between own country, hence Indian economy will increase. Based on crude oil price on market daily petrol and diesel prices getting rises for that purpose bio-diesel is very helpful. Petroleum product subsidies described for about 75% of tax revenues in 2011 and have been on the rise as an effect of this secession and the related arise in petroleum products in the international market.





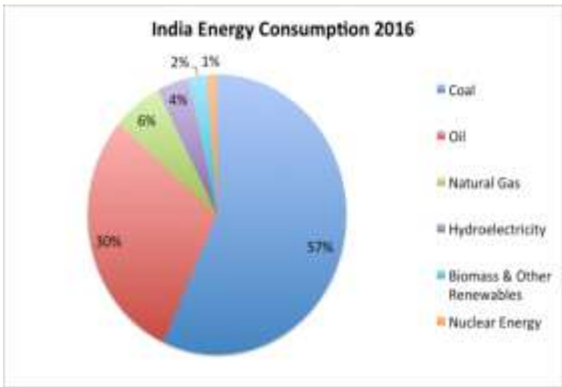


Fig.1. Energy consumption by source (2012 -2016), Source: Ministry of Petroleum.

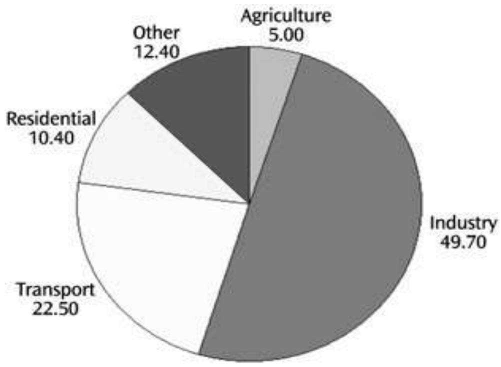


Fig.2. Biomass consumption by source, Source: Ministry of Petroleum

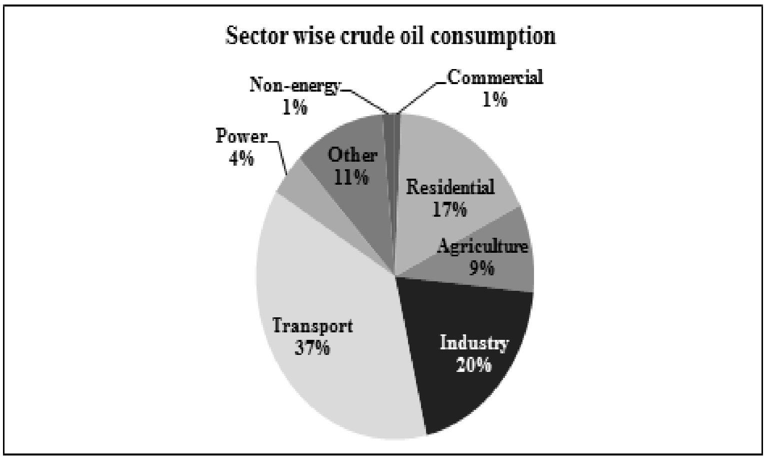


Fig.3. Oil Consumption by sector, Source: Ministry of petroleum

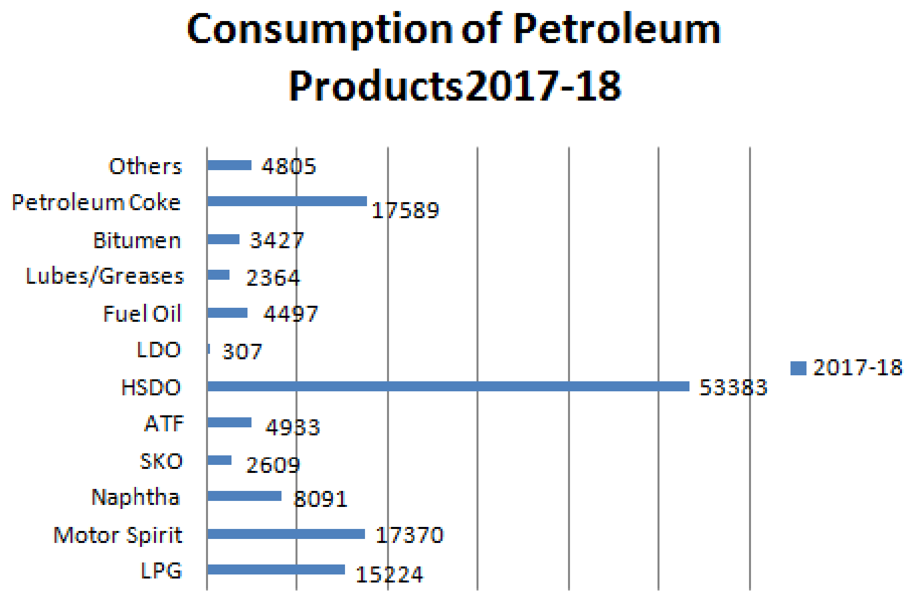


Fig.4. Petroleum Product Consumption in India (2017-18), (Thousands of metric tons), Source: Annual Reports of Ministry of Petroleum and Natural gas.

III. THE POTENTIAL AND GROWTH OF JATROPHA CURCAS AS A SOURCE OF ALTERNATIVE BIOFUELS FOR INDIA

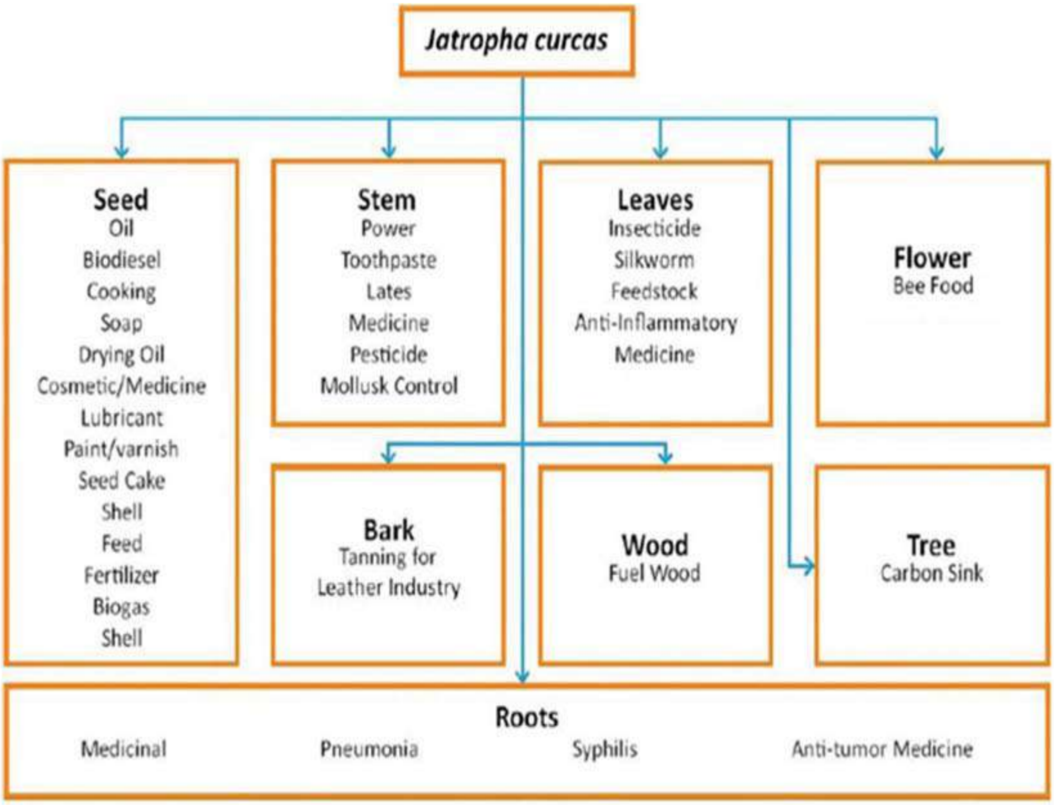


Figure 5: Uses of Jatropha curcas

Jatropha curcas is a perennial plant native to Central America and Mexico which yields multipurpose non-edible oil from its seeds. Jatropha curcas is multipurpose non edible oil yielding perennial shrub originated in tropical region. Jatropha belongs to the class Euphorbiaceous and has the tendency to develop latex and hence animals do not browse the plant. This is a sturdy and drought liberal crop which could be raised in marginal grounds with lesser input. The crop can be maintained for 30 years economically. There are around 476 species distributed throughout the world. Among them, 12 species are recorded in India. The species Jatropha is a predicting one with economical seed yield and oil recovery. The oil from Jatropha can be used as bio-fuel blend up to 20%. However, the refined oil is a qualified neat bio-fuel. Jatropha grows well under subtropical and tropical climates. It can tolerate extremes of temperature but not the frost. It is grown in wide range of soils. For economic returns, a soil with moderate fertility is preferred. Glycerin is a by-product of Jatropha seed processing and is an input in many consumer products such as personal care preparations, cosmetics, and pharmaceuticals.

Jatropha curcas grows as a small tree or large shrub, up to 5–7m height; with a soft wood and a life anticipation of up to 50 years. It can grow under a wide range of rainfall regimes from 250 to over 1200mm per annum. In plantations it can be planted at spacing of 2m×2m, 2.5m×2.5 m, or 3m×3m depending on rainfall or watering. Jatropha is now seen as having potential to produce the next highest yields (after the oil palm) at over 1.5 tons of oil per ha. The picking has to be done efficiently – as this process can constitute up to 80% of the variable costs. Overall, the pressed oil and seedcake must have a market value that well exceeds all the annual fixed and variable costs incurred (in addition to labour interest on investment in land acquisition, seedlings, site establishment, and depreciation of capital equipment).

A. Focus of Biodiesel Production

Jatropha oil is a triglyceride type of non-edible vegetable oil and in its pure form is a potential alternative to fossil diesel fuel. This is due to the fact that its methyl ester properties are similar to diesel fuel and also due to its plant origin its carbon content has been derived from the atmosphere, so it is considered a near-carbon-neutral fuel. However, direct burning of Jatropha oil in a diesel engine faces many problems related to viscosity. This is due to the oil's high molecular weight (as well as its chemical structure) which is around ten times higher than that for diesel. Therefore, the reduction in viscosity is very important to make Jatropha oil a suitable alternative fuel far from diesel and this can be achieved by the trans-esterification process.

The cost-effective large-scale production of biodiesel from non-edible oil feedstock such as Jatropha oil requires that free fatty acid (FFA) levels be below 1%, or if higher, that a highly effective system should be developed to deal with high FFA levels. In practice, the right way extracted Jatropha oil should normally have FFAs below 1%, it is not strange for levels to rise due to a number of persisting factors during the storage and transport stages. In parallel with India's Biofuel Roadmap, the process of production of biodiesel from Jatropha oil has been the subject of experimentation in the laboratory, and successful pre-treatment of high FFA percentages in Jatropha oil has been showed, reducing these to less than 1%. With this low level of FFA a high yield of biodiesel was obtained and validated as complying with the international biodiesel standards specification (ASTM D6751). Table 2 shows a comparison between fuel properties of Jatropha oil, Jatropha methyl esters (JME) and ASTM D6751/EN 14214 specification, while Table 3 shows the India-sourced Jatropha oil properties and the validation results of the laboratory experiments of the basic properties of the methyl ester of India-sourced Jatropha oil according to ASTM D6751.

TABLE I. COMPARISON BETWEEN FUEL PROPERTIES OF JATROPHA OIL, JATROPHA METHYL ESTERS AND ASTM D 6751/EN 14214 SPECIFICATION

Properties	Jatropha oil	JME	ASTM D 6751	EN 14214
Density at 15°C (kg/m^3)	917±1	879	875–900	860–900
Kinematic viscosity at 40°C (mm^2/s)	35.98±1.3	4.84	1.9–6.0	3.5–5.0
Acid value (mg KOH/g)	3.4-25.3	0.24	0.5 (Maximum)	0.5 (Maximum)
Flash point °C	229±4	191	130 (Maximum)	>101 (Minimum)
Cetane number	38	51	47 (Minimum)	51 (Maximum)
Sulfated ash	–	0.014 wt%	0.02 wt%	0.02 wt%
Water	5%	0.16mg/kg	0.05 mg/kg	0.05 mg/kg
Iodine number (g/100 g)	101.7	86.5	–	<120
Free glycerol	–	0.015 wt%	0.02 wt%	0.02 wt%
Total glycerol	–	0.088 wt%	0.25 wt%	0.24 wt%

It has been found that carbon dioxide emissions can be decreased by 65-80% by using jet fuel from renewable feedstock such as *Jatropha curcas*, compared to petroleum-derived aviation kerosene. The annual fuel consumption of the aviation industry worldwide is in the order of 1.5 to 1.7 billion barrels of traditional jet fuel, which contributes about 2% to the current global greenhouse gas (GHG) emissions. The International Air Transport Association (IATA) believes a 6% contribution of sustainable 2nd generation biofuels is achievable by 2020. On the other hand, The European Advanced Biofuels Flight Path Initiative plans to use 2 million tons of biofuels in the EU civil aviation sector by 2020, while Boeing supports an objective of 1% of global aviation fuels by 2015. The objective of the India Biofuel roadmap is to introduce a certified bio jet fuel by 2018, and for this aviation biofuel to have a contribution of the aviation fuel market by 2024.

Property	India CJO	India JME	ASTMD 6751
Acid value (mgKOH/g)	8.98	0.36	0.5 (Maximum)
Viscosity@40oC (mm2/s)	41	4.71	3.5–5.0
Density @ 20oC (g/cm3)	0.918	0.874	-
Iodine value (mg I2/g)	103.87	97.94	-
Calorific value (MJ/Kg)	-	38	-
Total glycerol wt %	8.27	0.100	0.25
Free glycerol wt%	-	0.01	0.02

TABLE II FUEL PROPERTIES OF INDIA JATROPHA OIL (CJO) AND INDIA JATROPHA METHYL ESTERS (JME)

B. Commercial Uses of Jatropha By-Products

Interest in producing Jatropha curcas for oil production is growing in many countries. Jatropha can both reduce imports of petroleum products and stimulate rural and regional economies, the plantings can be as a combination of industrial-scale plantings and small-holder plantings, and because there is potential for a number of different products from the oil and by-products. These include the seedcake and the glycerin by-product of the trans-esterification process used to convert the oil to biodiesel. Both these by-products will occur in large volume in industrial scale production and they each have multiple potential uses. The seed cake that elsewhere is just repaid to the plantation site as fertilizer, can be a raw material for biogas production at smaller or larger scale, or may be compressed into pellets or briquettes to be a fuel for use in industry like bakeries or brick kilns, or in more efficient household stoves, displacing charcoal or wood. The gross specific energy in each Jatropha biomass divide equated with that of other biomass and fossil fuel is illustrated in Table III. (According to the specification of ASTM D5865-02a).By-products of biodiesel production can also be used to generate electricity. It is estimated that if India is to produce enough biodiesel from Jatropha to replace even 5% of its diesel fuel (5% is about 150,000 tons) seedcake volumes will be very large. Product of 150,000 tone of biodiesel will demand up to 625,000 tons of Jatropha seed, and so up to 437,000 tons of seedcake will be gave rise as a residue. In this form it has an energy value of about 5 megawatt-hour (MWh)/tonne, and could be used as a fuel in smaller or larger energy plants, including in combined heat and power plants. In total the 437,000 tons of seedcake have an approximate energy value of 2,185 gigawatt-hours (GWh), and if used as a fuel in efficient combined heat and power plants could produce about 87 MW of electricity annually (assuming about 5000 ton to produce a MW-e). These CHP plants could be of any size from 5 MW-e outputs to 20 MW-e capacities or more.

TABLE III GROSS SPECIFIC ENERGY OF JATROPHA BIOMASS VS OTHER BIOMASS & FUEL (ASTM D5865-02A)

Biomass		Gross Specific Energy (Kcal/Kg)
Jatropha Biomass	Seedcake	4496
	Shell	3123
	Leaves	3624
Rice Husk		3000
Palm Shell		4200
Coal		5500

C. Rural Development and Empowerment

A Jatropha oil industry can help regional and rural communities become less reliant on imported fossil energy, gain better access to more reliable electricity supplies, develop small scale enterprises and reduce regional deforestation. As raw materials for these biofuels there are many tree species, bearing seeds available in India, which are rich in non-edible vegetable oil, like from Jatropha and Karanja seeds. But surprisingly these are not being used as per their potential. Therefore in India the feasibility of producing and using vegetable oils and their derivatives as biodiesel, as a diesel substitute can be considered along with the unutilization of the available potential of non-edible oil sources. There is a large junk of degraded forest land, unutilized public land, fallow lands of farmers and lands in the rural areas, which can be utilized for this purpose, ensuring overall economic growth of the country. So any overall project strategy needs to look at the way regional communities will fit into a national Jatropha oil production industry, so that the outcome will positively impacts on regional economies as well as on smallholder and family incomes and health.

D. The Function of Jatropha in deforestation and desertification

The climate of India is classified into three types. They are 'Kendrew- stamp', 'Kppen', 'Thornthwaite'. About 17% of India's land areas were regarded as Forest Area in the early 1990s. In 1987, however, actual forest cover was 640,000 square kilometers. Planting of Jatropha can play a part in this strategy, with the added benefit of offsetting the loss in forest area due to firewood removal and charcoal production, since Jatropha by-products serve as a very affordable and accessible alternative cooking fuel.

Fig.6 (a) Small jatropha oil extraction machinery being used in India (b) Crude-jatropha-oil filtering systems

Fig.7. MW Biomass based power plant at Sipcot Industrial complex, Pudukottai Dist., Tamilnadu.

IV. BIOFUEL ROADMAP FOR INDIA

In this roadmap, we have assumed that in order to achieve the blending objectives it will be necessity to go beyond first-generation solutions. For this argue, we examined the economic potential for second generation biofuels and these are the basis of mixing targets for the BAU scenario. Under the BAU scenario therefore, India will meet 5 percent, 10 percent, and 20 percent gasoline blending targets by 2020, 2025 and 2030, respectively. Similarly, as the economic possible for second-generation biodiesel is low, aim for biodiesel in BAU would be 1 percent, 5 percent and 10 percent by 2020, 2025 and 2030, respectively. In 2030–31, ethanol demand in India will be 8.6 billion litres which is less than 10 percent of the 2014 global ethanol afford of 94 billion litres (REN21, 2015). Same as, biodiesel require meeting the BAU objectives would demand three full-scale bio-plants with a capacity of 5006 million litres of ethanol/BTL per year by 2020. Daugaard et al. (2015) found that optimal bio-plant capabilities assess from 16 million gallons (61 million litres) per year for small scale installations, to 210 million gallons (795 million litres) per year for large-scale gasification installations. The NPB assumption that GoI will satisfy its 20 percent blending objective by 2020. Under this assumption, by 2020–21, the need for ethanol and biodiesel will be at 5.7 and 19.8 billion litres, respectively. This would necessitate 51 full-scale bio-refineries with a capacity of 500 million litres of ethanol/BTL per year by 2020. The above discussions clearly show what needs to be done; next we will explore how to translate this need into action.

A. Government Initiatives: National Policy on BIO-FUELS

With the general assumption of renewable energy resources for growing countries, we can now seek to guess some economics of the more significant renewable energies, with peculiar address to the global position, as well as that in the Third-World countries. Authentic data is not available in majority of the cases, and its projections even to the year 2020 A.D. are taken with numerous uncertainties. However, it is not hard to see that at least four types of Renewable Energies, namely biomass, direct solar energy, and wind, hydro-electricity, deserve immediate attention. From 1980 onwards, there are various sources of techno-economic data on renewable energy, owning a fair degree of reliability, which are:

1. Renewable Energy Conference at Rio de Janeiro in 1992.
2. World Renewable energy Conference VI, 2000
3. Kyoto Protocol, 2001
4. World Summit on Sustainable Development (WSSD), Johannesburg 2002.
5. World Energy Assessment - 2001 UNDP.

Bio-fuels supply a strategically reward to promote sustainable development and to accessory conventional energy origins in satisfying the quick increasing requirements for transportation fuels connected with high economical development, as well as in satisfying the energy needs of India's huge rural population.

Bio-fuels can more and more satisfy these energy needs in an environmentally benignant and cost-effective manner while diluting dependence on significance of fossil fuels and thereby supplying a higher degree of National Energy Security. The India close to bio-fuels is grounded exclusively on non-food feedstock's to be aroused on debauched or barrens that are not suited to agriculture, thus avoiding a potential struggle of fuel vs. food security. With this viewpoint the National Policy on Bio-fuels and its implementation has been approved by the Union Cabinet on December 24, 2009. The Policy attempts to help and bring about optimum growth and usage of indigenous biomass feed stocks for product of bio-fuels. The salient features of the National Policy on Bio-fuels are:-

1–Bio-diesel production will be taken up from non- edible oil seeds in waste/degraded/marginal lands.

2–An indicative target of 20% blending of bio-fuels, both for bio-diesel and bio-ethanol, by 2017 has been proposed.

3–Minimum Support Price (MSP) for on-edible oil seeds would be announced with periodic revision to provide fair price to the growers.

4 – Minimum Purchase Price (MPP) for buy of bio-ethanol and bio-diesel would be declared with periodical revision.

5 – Major force will be given to explore, growth and demonstration with focus on plantations, treating and product of bio-fuels, including Second Generation Bio-fuels.

6 – Financial bonuses, including subsidies and grants, may be viewed for second generation bio-fuels. If it turns essential, a National Bio-fuel Fund could be considered.

7 – A National Biofuel Coordination commission, guided by the Prime Minister, will be set up to furnish policy guidance and coordination.

8 – A Biofuel guiding commission, chaired by Cabinet Secretary, will be set up to supervise implementation of the Policy.

The Ministry of New & Renewable Energy has been intended as the coordinative Ministry for biofuel development and usage while particular characters have been allotted to other related Ministries. MNRE has taken several steps on various views of biofuel development. A usage has been started with scientific agencies – CSIR, DRDO, ICAR, NOVOD, DBT Board on collection, testing and recognition of elite germplasms of jatropha and on suing and end use technologies. The target is to give and make available elite establishing materials for plantations. The technological authorities and the individual sphere have named 25 master genotypes/additions of jatropha for promote multiplication for presentation at various sites in potential States. Another exert has been taken up on naturalistic costing of biodiesel which will provide guidance on review and revision of the buy price for biodiesel. A study has been attempted to measure the status of Jatropha plantations in nine States. Major force is being given to development of second generation biofuels. An US -Indo MoU has been subscribed up on biofuels with focus on joint R&D, especially on second generation biofuels such as, algae biodiesel and cellulose ethanol. Another initiative with research institutes and industry is on for development of high efficiency engines for use of SVO for stable applications.

B. Supply chain for biomass

India has competent labour and significant financial resources, which can be carried into storming up the accumulation of feedstock from crop remainders; demonstrating accumulation infrastructure, and shipping and dealing of large quantities of biomass. These are essential paces towards promoting biofuel use in India and will aid the country to get into second-generation biofuel production.

C. Transport and Distribution Infrastructure and End Use

Biodiesel and Ethanol are not fully simpatico with conventional petroleum substructure; hence, the conveyance of these biofuels expects a distinguish infrastructure. Long-distance transport of current biofuel products at scale requires infrastructure that is either determined in capacity (e.g., rail) or inaccessible at enough scale (e.g., dedicated pipelines). Foster, to avoid constrictions caused by inconsistency with spread biofuels, it is requirement to take care to dispersion infrastructure and end utilize technology consequences. The ethanol "blending wall" (the setting of ethanol in gasoline to 10–15 percent) due to vehicle characteristic restraints (OECD/IEA, 2011 is one example of potential infrastructure chokepoints that need to be covered. As has been successfully established in Brazil and Sweden, the introduction of flex-fuel vehicles (FFV) and high-level ethanol fuses are good ways of quashing ethanol infrastructure inconsistency issues. Policy evaluates may be needed, such as responsibilities for retailers to allow for high level biofuel fluxes (e.g. E85) or tax incentives for FFVs.

V. EXPERIMENTAL INVESTIGATION

A. Experimental Setup**:**

The engine used for this study was a single cylinder, four stroke, air cooled, and direct injection diesel engine coupled to eddy current dynamometer with a control system. This dynamometer is provided to test the engine at different loading conditions to measure the load on the engine. Exhaust gas analyzer was used to find the emission characteristics of the engine and AVL smoke meter was used to measure the smoke content in the engine exhaust. Table 4 and 5 gives the engine specifications and various instruments used in performing this work. Table 6 gives properties of diesel and bio-diesel used. Fig.8 shows the experimental setup made during experimental investigation.

Engine parameters	Basic data
Model and type	Fujikawa 295D, diesel four stroke
Number of valve	4
Air charge system	Naturally aspirated
Cylinder / type	2 / Vertical
Volume (cc)	1630 cc
Diameter x stroke	95 x 115 mm
Compression ratio	19 : 1
Maximum torque	96.9 Nm at 1500 rpm
Maximum power	13.5 kW at 1500 rpm
Fuel system	Direct Injection 195 bar
Inner valve seat diameters intake	38.3 mm
Inner valve seat diameters Exhaust	32.5 mm

TABLE 4 Engine Specifications

Instrument	**Purpose**
Exhaust Gas Analyser	Measurement of HC,CO,CO2 and NOx emissions
Smoke Meter	Measurement of smoke emission
EGT Indicator (K type thermocouple)	Measurement of exhaust gas temperature(EGT)

TABLE 5 List of measuring instruments

Sr. No.	Parameters	Diesel	Jatropha Oil
1	Calorific Value. MJ/kg	42.6 - 45.0	39.6 - 41.8
2	Density kg/m'	830	910 - 930
3	Kinematic Viscosity (26°C). mm2/s	4.2	55
4	Flash point (0C)	80	180
5	Ignition point (0C)	257	340
6	Cetane value	45-55	40-45
7	Sulphur (%) by Wt	1.0 - 1.2	0.13

TABLE 6 Properties of Diesel and Jatropha methyl ester

B. Exhaust Gas Recirculation:

The purpose of the EGR system is to precisely recirculation the exhaust gas under different operating conditions and to override flow under conditions, which would compromise good engine performance. The exact amount of exhaust gas, which must be measured into the intake manifold, changes significantly as engine load varies. In EGR system the percent of recirculated gas is controlled by gate valve. This results in EGR system functioning on a fine line between good NOx control and engine operation.

EGR is a utile technique for cutting NOx formation in the combustion chamber. Exhaust comprises of N2;C02;and water vapors mainly. When a function of this exhaust gas is re-circulated to the cylinder, it acts as thinners to the combusting variety. This also reduces the 02 concentration in the combustion chamber. The heat energy of the EGR is much more prominent than fresh air; hence EGR gains the heat capacity (specific heat) of the intake point, thus decreasing the temperature rise for the same heat relinquish in the combustion chamber.

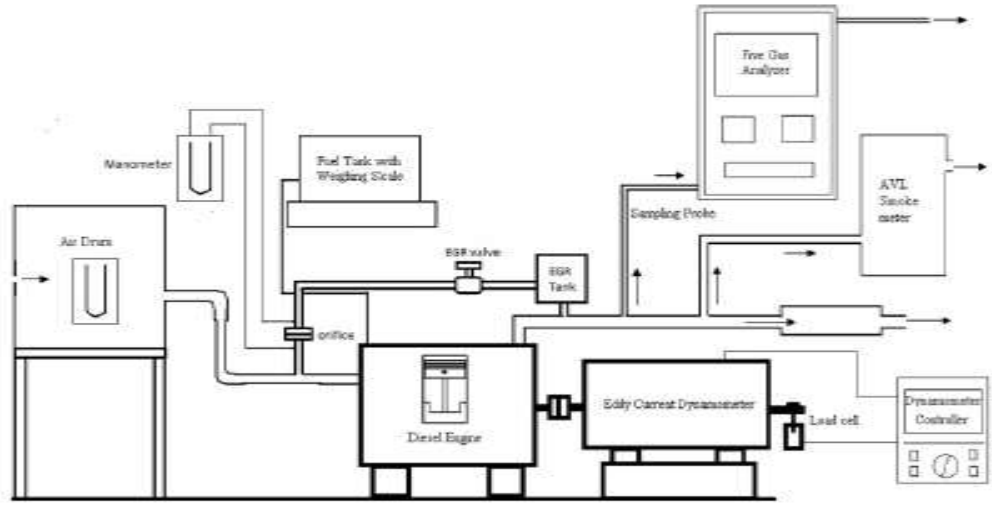


Fig8. Experimental Setup

VI.RESULTS AND DISCUSSIONS

A. Brake Thermal Efficiency:

i. Brake Power:

$$B.P = \frac{2\pi N \times R_{eff} \times W}{4500} \quad (kW)$$

Where
BP = Brake power in kW.
N = Speed of the engine in rpm.
W = Load in N.
R_{eff} = Effective radius of Brake drum in m

ii. Total Fuel Consumption:

$$TFC = \frac{V_{CC} \times \text{specific gravity of diesel} \times 3600}{t \times 1000} \text{ (kg/hr)}$$

Where
V_{CC} = Volume of fuel consumption (10cc)
S = Specific gravity of fuel (0.833)
t = Time for 10cc of fuel consumption (s)

iii Brake Thermal Efficiency (η_{bte})

$$\eta_{bte} = \frac{BP \times 4500 \times 60 \times 4.2}{C_v \times TFC \times 427} \quad (\%)$$

Where
BP = Brake power in kW
C_v = Calorific value of fuel (43,300 kJ/kg)
TFC = Total fuel consumption in kg/s

The mutation of brake thermal efficiency of the engine with several JBD fuses and jatropha curcas vegetable oil is shown in Fig. 4.2 and compared with the brake thermal efficiency obtained with diesel. From the test results it was observed that initially with increasing load the brake thermal efficiencies of the jatropha biodiesel blends and the diesel were increased and the maximum thermal efficiencies were obtained and then tended to decrease with further increase in load. But the brake thermal efficiencies of the fuses and the jatropha curcas oil were let down than that with diesel fuel throughout the total rate. The maximum values of thermal efficiencies for 20% Blend jatropha biodiesel diesel at 60% load.

B. Specific Fuel Consumption:

The specific fuel consumption of diesel and various blends of jatropha and diesel oil at varying load in the range 0% - 100%. It was observed that the specific fuel consumptions of the oil as well as the blends were decreased with increasing load. The fuel consumptions were also found to increase with a higher proportion of jatropha biodiesel in the blend. It is observed that the specific fuel consumption decreases with the increase in the flow rate of EGR into the inlet manifold of the engine. The lowest specific fuel consumption is obtained at the compression ratio of 17: I. Lowest values for specific fuel consumption are experienced at the load of 6 kg in the optimum compression ratio and EGR flow rate. The specific fuel consumption decreases with the increase in supply of EGR as the amount of fuel required to produce 1 kW power reduces with the increase in the supply of EGR in to the combustion chamber.

C. Smoke Emission

Fig. 11 gives smoke emission values at different load for diesel and bio-diesel with EGR and without EGR. The trend shows that smoke intensity increasing with load variation using diesel and bio-diesel with and without EGR. Higher values of smoke intensity using EGR are due to lack of sufficient oxygen in the combustion chamber, which results in incomplete combustion.

D. Carbon Monoxide Emission (CO)

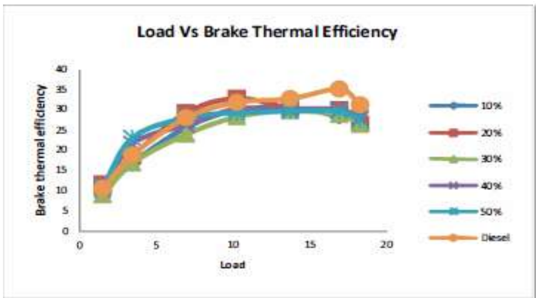
Carbon Monoxide emissions occur due to the incomplete combustion of fuel. The variation of CO with load is shown in Fig.12. The emissions of carbon monoxide are toxic. CO is well- known to deprive the brain, heart and other vital organs of the body, which can lead to death. This effect forces the measurement of CO in the evaluation of biodiesel with and without EGR. It is observed that CO emissions of B20 are lower than diesel at all loads. This is due to oxygen content in biodiesel that results in complete combustion of fuel and supply the necessary oxygen for to convert CO into CO2. It is also noted that CO emissions of B20 with 10% EGR is higher compared to B20 fuel.

E. Unburnt Hydrocarbon (HC)

The variations of HC emissions using diesel and bio-diesel blend with and without EGR at different loads is shown in Fig.13. Unburnt hydrocarbon emissions are the results of incomplete combustions. The pattern of the hydrocarbon emissions is closely related to many design and operating variables. It is observed that HC emission increases with increase in load due to lack of available oxygen for combustion. Adding bio-diesel to diesel, increases the availability of oxygen due presence of molecular oxygen in bio-diesel, and therefore HC emissions are lower with EGR when compared with neat diesel. Also with increase in EGR rate, oxygen availability decreases and thus HC emissions are higher.

F. NOx EMISSION

The variation of NOx emission with load for various compression ratios. The determined emission of the engine decreases with the increase in the flow rate of the partly cold EGR into the inlet manifold of the engine. Lowest NOx emissions are experienced at a compression ratio of 17: l. The lowest NOx emission is obtained in the compression ratio 17: 1 and the flow rate of 6 liters per minute because of the high supply of partly cold EGR which enables better combustion. Lowest values for emissions are experienced at the load of 6 kg in the optimum compression ratio and EGR flow rate.



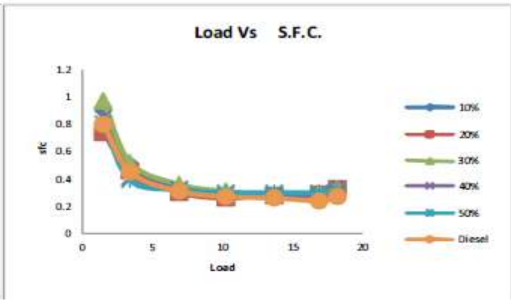
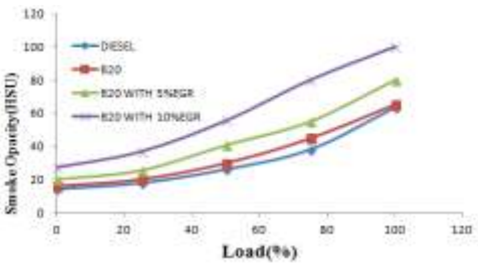


Fig. 9 Load vs Brake Thermal Efficiency Fig. 10 Load vs S.F.C



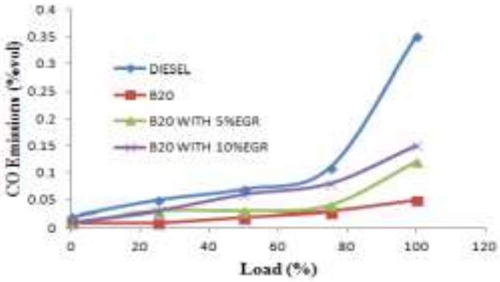
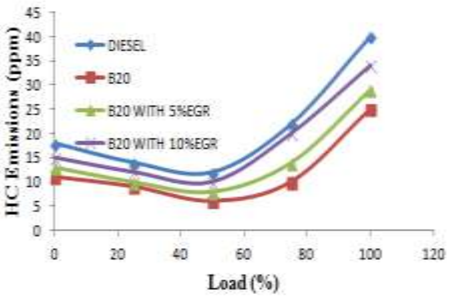


Fig.11. Variation of Smoke Opacity with Load

Fig.12. Variation of Carbon Monoxide (CO) with load



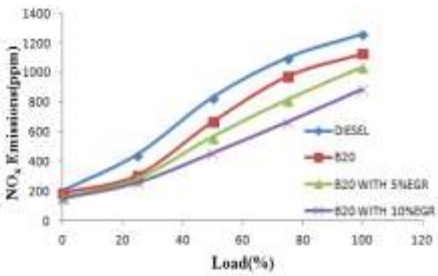


Fig13 HC Emissions vs. Load. Fig.14 NOx Emissions variations with load

VII. CONCLUSIONS

In this study, India has a steadily increasing requirement for fossil diesel for both transport and generation of electricity in regional areas beyond the national electricity grid. There is a growing awareness that biodiesel produced in India could be blended with the available fossil diesel, resulting in many positive economic, social and environmental benefits. While in India biodiesel is presently only being produced in small trial amounts, one strong reason to look at increasing this is to help reduce deforestation, by the substitution of very significant volumes of biodiesel production byproducts for wood and charcoal. This is mostly as wood and charcoal, used mainly for cooking and providing industrial heat (bakeries, brickworks, etc), and chiefly sourced from forest clearance (so causing extensive deforestation) and as agricultural residues. The Roadmap addressed the potential of Jatropha oil for biodiesel production for transportation sector, jet fuel for aviation sector and better utilization of available forms of biodiesel byproducts for regional energy production. A central function of this is the utilize of the very large possible volumes of jatropha by-products (mainly jatropha seedcake) as a source of energy to replace the use of wood and charcoal in households and industry, or as a feedstock for biogas production at smaller or larger scale. The glycerin by-product of the transesterification process used to convert the oil to biodiesel will occur in large volume in industrial scale production and have multiple potential uses.

Based on the results obtained from the present investigation using diesel and biodiesel with and without EGR, following conclusions may be drawn:

i) NOx emissions are reduced by 30% at 10% EGR compared to that of neat diesel due to lower flame temperatures and reduced oxygen availability.

ii) Brake thermal efficiency increases at lower loads using EGR due to re-burning of recirculated gases and then decreases, at higher loads. 10% EGR is optimum for better brake thermal efficiency values.

iii) HC and CO emissions are decreased using EGR while smoke capacity emissions are increased.

iv) Specific fuel consumption is higher using biodiesel with and without EGR because of its lower calorific value and higher viscosity.

Thus, usage of 20% by volume of biodiesel in diesel does not affect any of the measured performance or emission to a greater extent except for NOx emissions. Therefore, EGR must employ with bio-diesel to reduce NOx emissions.

REFERENCES

[1] IEA (International Energy Agency) (2011), *Biofuels for Transport Technology Roadmap*, OECD/IEA, Paris, Retrieved October 19, 2012 from the IEA Web Page:
http://www.iea.org/publications/freepublications/publication/biofuels_roadmap.pdf

[2] Divakara BN, Upadhyaya HD, Wani SP, Gowda CLL. Biology and genetic improvement of Jatropha curcas L.: a review. Applied Energy 2010; 87(3):732–42.

[3] Meher, L.C., D. Vidya Sagar, and S.N. Naik, Technical aspects of biodiesel production by transesterification—a review. Renewable and Sustainable Energy Reviews, 2006. 10(3): p. 248-268.

[4] A.S. Silitonga, A.E. Atabani, Irfan Anjum Badruddin, T.M.I. Mahlia, H.H. Masjuki, A S. Mekhilef. Review on prospect of Jatropha curcas for biodiesel in Indonesia; Renewable and Sustainable Energy Reviews 2011.15: p. 3733–3756.

[5] Andrew Lang, Hazir Farouk. (2013*). Jatropha oil production for biodiesel and other products – a study of issues involved in production at large scale*. Aeronautical Research Center-Sudan, World Bioenergy Association, Stockholm, Sweden.

[6] Biopellet Production from Jatropha Seedcake –Emission Reduction, windililiana, Dwi setyaningsihIrzaman. Presented On: International Sustainable Development Research Conference30may –1 June 2010, Hong Kong.

[7] K.Rajan, K.R.Senthilkumar, "Effect of Exhaust Gas Recirculation (EGR) on the Performance and Emission Characteristics of Diesel Engine with Sunflower Oil Methyl Ester", Jordan Journal of Mechanical and Industrial Engineering, Volume 3, 2009, pp: 306 – 311.

[8] Nanthagopal K, Rayapati Subbarao, "Experimental investigation and performance evaluation of DI diesel engine fueled by waste oil- diesel mixture in emulsion with water", Thermal Science,2009, 13(3): pp.83-89.

[9] Zafer Utlu, Mevlut Sureyya Kocak, " The effect of biodiesel fuel obtained from waste frying oil on direct injection diesel engine performance and exhaust emissions", Renewable Energy, Volume 33, 2008, pp: 1936-1941.

[10] Murari Mohon Roy *, S. M. Najmul Hoque, Md. Ariful Islam and Md. Mustafizur Rahman., "Use of exhaust gas recirculation (EGR) and cyclonic separator for simultaneous NOx and PM reduction in DI diesel engines". Journal of Petroleum and Gas Engineering Vol. 2(3), pp. 54-63, March 20 1 1.

[11] Ming Zheng a, *, Graham T. Reader b, J. Gary Hawley c., "Diesel engine exhaust gas recirculation-a review on advanced and novel Liisa A. Tremere (2011),"Noradrenergic Modulation of Light-Driven Egr- l Expression in the Adult Visual Cortex". Journal of Experimental Neuroscience 20 1 1: 5 13 -19

[12] K. Pramanik, 'Properties and Use of Jatropha Curcas Oil and Diesel Fuel Blends In Compression Ignition Engine', Renewable Energy, 2003, Vol. 28, Issue No. 2, 239-248.

[13] K. Sivaramakrishnan and P. Ravikumar, 'Determination of Cetane Number of Biodiesel and It's Influence on Physical Properties', AR PN Journal of Engineering and Applied Sciences, 2012, Vol. 7, Issue No. 2.

[14] Ackom, E.K., Alemagi, D., Ackom, N.B. Minang, P.A., Tchoundjeu, Z. 2013. "Modern Bioenergy from Agricultural and Forestry Residues in Cameroon: potential, Challenges and the Way Forward," Energy Policy, 63: 101–113.

[15]Ackom, E.K., Mabee, W.E., Saddler, J.N. 2010 (a). "Backgrounder: Major Environmental Criteria of Biofuel Sustainability," A Report to the IEA Bioenergy Task 39 (See: http://task39.org/files/2013/05/ Backgrounder-Major-environmental-criteria-of-biofuel-sustainability-IEA-Bioenergy-Task-39-1.pdf Accessed on 15th October 2015).