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# BIOFUEL PRODUCTION, SUSTAINABILITY AND FOOD SECURITY IN INDIA

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## ABSTRACT

*Biofuels provide only around 2% of total transport fuel today, by 2050, 32 exajoules of biofuels will be used globally, accounting 27% of the world transport fuel. Some biofuels already perform well in economic terms, particularly sugarcane ethanol and other low cost agricultural biofuels. The biofuel program in India at niche stage though the policy has been rolled out well in advance. India has carefully designed the biofuel policy and blending ratio to reduce $CO_2$ emissions and import of the crude oil. The log linear demand function was used to estimate the crude oil, diesel and petrol demand. Based on the demand, the bioethanol and biodiesel requirements were estimated. The possible ways to meet out the biofuel demand and production frontier were elaborated. Proper policy making, domestic production support measures for sustainable biofuel production and infrastructure for anhydrous ethanol storage are the guidepost for successful biofuel program in India.*

***Keywords: sugarcane, demand, supply, biofuels, sustainability***

## 1. Introduction

Fossil energy resources are declining and the need to become less reliant on these energy resources is becoming much emphasized in the 21st century. Alternative energy sources are much needed. Biofuels are one possible replacement to fossil fuels. Although biofuels still cost more than fossil fuels, its share in terms of fuel use is increasing worldwide.

Worldwide expansion in the production of biofuels is currently one of the hot topics on the agenda of agriculture and food research. On the one hand the development is welcomed as an additional source of income, since markets for agro food products is relatively inelastic. The global production of biofuels is estimated to be about 90 billion litres of ethanol and 21 billion litres of biodiesel per year (Fig.1).

Biofuels can make a significant contribution in reducing the dependency on fossil fuel imports, especially in the transport sector. Another advantage of biofuels is contribution to climate protection. Biofuels are usually considered to be carbon–di-oxide ($CO_2$) neutral and helps to reduce greenhouse gas emissions. Fossil fuels, on the other hand, major source of $CO_2$ emissions. In Europe, for example transport is responsible for about 21 % of all greenhouse gas (GHG) emissions which lead to global warming. Biofuels are usually used for transport fuels, but they are also used for electricity and heat generation. In relation to reducing dependency on fossil fuel imports, the use of biofuels as transport fuels is particularly effective, the efficiency could be greater if biomass were also used for biofuel production.

Biofuels have taken centre stage in efforts to wean industrial nations from fossil fuel consumption. The current spectacular success of the ethanol industry in the United States, Brazil and other countries has built on the relatively simple bioconversion of feed stocks such as corn grain, sugarcane juice and molasses, but the availability of these feed stocks is unlikely to expand dramatically.

Now, there are growing concerns that biofuels and magnitude of the agricultural world prices. Increasing biofuel production either due to pure market forces or policy has significant impacts on agricultural markets, including the trade in agricultural raw materials. Linkages between food and energy production include not only competition for land, but also for other production inputs. For instance, the effect of an increasing supply of byproducts of biofuel production such as oil cake and gluten feed also affects animal production.

There is a wide range of appropriate biomass sources and a broad mixture for biofuel production. Input for biofuel supply often constitutes by products from agriculture but biomass can also be grown to specific purpose of biofuel production. Common liquid biofuels are the first generation common liquid biofuels are pure plant oil, biodiesel and ethanol based on sugar and starch crops (Fig.2). Among the second generation, synthetic biofuels as biomass-to-liquids (BtL) are currently the subject for wide ranging discussion. However, the promising qualities and potential of biofuels also bring an element of risk. The social and environmental dimension of cultivation has to be taken into account. A new and growing market for biofuels may provide incentives for over harvesting and the establishment of plantations, the intensity of agricultural land may rise and this would have major impacts on habitats, biodiversity, soils and food production.

This paper highlights the salient features of India’s biofuel policy, particularly pertaining to bioethanol & biodiesel and discusses how it influences the sustainability and commercialization of biofuel production in India. In India, molasses (a by-product of sugar production) is the main raw material for ethanol to meet the country’s mandated blending requirements. The other bio based blending source is biodiesel and its production and long term availability were also discussed.

The present paper maps out the issues namely (i) The overview of the biofuel production and policy orientation in India (ii) Methodology for demand estimation and supply projections (iii) Impact of the biofuel production on food security and (iii) long term strategy to meet out the green energy requirements.

### 1.1 Biofuel scenario in India

The current growth in transport activity is a significant environmental concern in India. The country’s carbon emissions are growing at an average of 3.2 percent per annum, making it one of the top five global contributors to carbon emissions. The Government of India (GOI) transport policy targets Euro-III and Euro IV norms for vehicles, which require clean quality fuel has necessitated the adoption of biofuels.

India is one of the world's leading producers of sugarcane and sugar. Sugar molasses, a byproduct of the sugar industry, is used for production of most of the rectified spirits (alcohol) produced in India, including bioethanol for fuel. Due to the cyclical nature of sugarcane and sugar production in India, sugarcane farmers and the sugar industry experience periodic market gluts of sugarcane, sugar and molasses production impacting prices and farm incomes. The Government of India (GOI) has been focusing to use bioethanol fuels to bring stability in farm incomes.

Biodiesel production efforts are focused on using nonedible oils from plants (*Jatropha curcas, Pongamia pinnata* and other tree borne oilseeds) and animal fats such as fish oil. The focus is to encourage the use of waste lands and other unproductive land for the cultivation of these relatively hardy new biofuel crops. The GOI does not want biofuel feedstock crop cultivation to compete with food crops for scarce agricultural land and water. An estimated 55.3 million hectares are considered waste land in India, which could be brought into productive use by raising biodiesel crops. Nevertheless, the biodiesel production was not in the large scale due to lack of infrastructures.

### 1.2 Biofuel policy

#### 1.2.1 Ethanol Policy

The commercial production and marketing of ethanol blended gasoline started in January 2003, the first phase of the ethanol blended petrol (EBP) programme that mandated blending of 5 % ethanol in gasoline in 9 states and 4 union territories.

In August 2005, the government completed an agreement between the sugar industry and petroleum companies to enable the purchase of ethanol and the ethanol programme was restarted in a limited number of designated states and union territories. With a strong resurgence in sugarcane/sugar production in 2006-07, the GOI announced the second phase of the EBP programme in September 2006 that mandated 5% blending of ethanol with petrol (gasoline) subject to commercial viability in 20 states and 8 union territories. Since 2013, the GOI have mandatory of 5 % blending of ethanol in the petrol for the fuel use in the country.

#### 1.2.3 Biodiesel Policy

In April 2003, the GOI launched a national mission on biodiesel that identified *Jatropha curcas* as the most suitable tree borne oilseed for the production of biodiesel and focused on promoting plantations of jatropha on wastelands. The GOI and Planning Commission targeted 13.5 million hectares to be planted in order to produce sufficient biodiesel to blend at 20 percent with biodiesel in 2016-17.

### 1.2.3 New Biofuel policy

The GOI has brought out comprehensive roadmap to biofuels production and use in the country in 2012. The Policy endeavours to facilitate optimal development and utilization of indigenous biomass feed stocks for production of biofuels. Biofuels provide a strategic advantage to promote sustainable development and to supplement conventional energy sources in meeting the rapidly increasing requirements for transportation fuels associated with high economic growth, as well as in meeting the energy needs of India's vast rural population. Biofuels can increasingly satisfy these energy needs in an environmentally benign and cost effective manner while reducing dependence on import of fossil fuels and thereby providing a higher degree of national energy security.

The Indian approach to biofuels is based solely on non food feed stocks to be raised on degraded or wastelands which are not suited to farming, thus avoiding a possible conflict of fuel vs. food security. Biodiesel production will be taken up from non edible oil seeds in waste /degraded / marginal lands. An indicative target of 20 % blending of biofuels, both for biodiesel and bioethanol by 2017 has been proposed. Minimum Support Price (MSP) for non-edible oil seeds would be announced with periodic revision to provide fair price to the growers. Minimum Purchase Price (MPP) for purchase of bioethanol and biodiesel would be announced with periodic revision. Major thrust will be given to research, development and demonstration with focus on plantations, processing and production of biofuels, including second generation biofuels. Financial incentives, including subsidies and grants will be provided for second generation biofuels.

Efforts to produce ethanol from other feed stocks like sweet sorghum, sugar beet, sweet potatoes, etc. are at an experimental stage in India. The government supports research for identifying sweet sorghum cultivars suitable for semi-arid waste land which could be used for bioethanol production. However, other than sugarcane, biofuel from other sources are very limited in India.

## 2. Methodology

The blending requirement of ethanol and biodiesel solely depend on the petrol and diesel demand of the country. The petrol and diesel are derivative of the crude oil. So, the estimation of the crude oil, petrol and diesel demand was necessary. The biodiesel and ethanol blending requirement was derived by simple equation by using petrol and diesel as a dependent variable. The estimation procedure and methodology was given below.

**2.1 Data Sources**

The study was based on yearly data for the 1980–2010 period. The data for India's crude oil, petrol (million litres) and diesel consumption (in million tonnes) was collected from the ministry of petroleum and natural gas, government of India (MoPNG). The annual average international crude oil prices per barrel in US$ was collected and then converted into constant rupee (or 'real') price of crude oil by converting the prices into current Indian rupees using the official exchange rate and then dividing by India's WPI (base year 2004–05). In the case of petrol and diesel, we used the data on their retail prices in Delhi collected from the MoPNG. It was converted the nominal price into real price by dividing it with the WPI (base year 2004–05). The real GDP at factor cost (in 2004–05 prices) was used as a proxy for real national income. The required data were collected from the hand book of statistics on Indian economy.

**2.2 Econometric methodology**

Most of the variables were found to be integrated of order one (denoted I(1)) testing for the stationary of the variables. Thus, a co-integration estimation procedure was needed. In this study, the demand for crude oil, petrol, and diesel in India was estimated by using the auto-regressive distributed lag (ARDL) co-integration procedure proposed by Pesaran et al. (1999), Parikh et al. (2007) and Agarwal (2012). The ARDL model is valid for non stationary variables as well as for a mixture of I(0) and I(1) variables. Further, a small sample size of about 30 annual observations which was not sufficient for a vector error correction procedure (Johansson and Juselius (1990). Thus, the ARDL estimation procedure was appropriate for determining the long run demand relation for crude oil, petrol and diesel.

The augmented ARDL model is written as follows:

**Equation**

$\alpha(L)Y_t = \mu_0 + \sum_{i=1}^{k} \beta_i (L) x_{it} + u_t \ldots$ ***(1)***

where $\alpha(L) = \alpha_0 + \alpha_1 L + \alpha_2 L^2 + \ldots + \alpha_t L^t$ **;**

$\beta(L) = \beta_0 + \beta_1 L + \beta_2 L^2 + \ldots. + \beta_t L^t$;

$\mu_0$ is a constant;

$y_t$ is the dependent variable;

L is the lag operator such that $L^i x_t = x_{i-t}$.

In the long run equilibrium $y_t = y_{t-1} = y_{t-2} = \ldots y_i$ and $x_{it} = x_{it-1} = x_{it-2} = \ldots x_{io.}$

Solving for y, we get the following long run relation:

$y = a + \Sigma\, b_i\, x_i + \gamma_t$ … ***(2)***

where

$a = \frac{\mu 0}{\alpha_0+\alpha_1+\cdots\alpha_t}$; $b = \frac{\beta i0+\beta i1+\beta i2+\cdots\beta it}{\beta_0+\beta\alpha_1+\cdots+\beta t}$ and $\gamma t = \frac{U_t}{\alpha_0+\alpha_1+\alpha_2+\cdots\alpha_n}$

In this procedure, the existence of the long run relationship is confirmed with the help of an F-test, which determines if the coefficients of all explanatory variables are jointly different from zero (Gerald 1999) and have provided upper and lower critical bound values for an F-test when all or some of the variables are I (1).

The error correction (EC) representation of the ARDL method can be written as follows:

$\Delta y_t = \Delta\hat{\alpha} - \sum_{i=1}^{k} \hat{\alpha} j\, \Delta y_{t-j} + \sum_{i=1}^{k} \beta_{io}\, \Delta x_{it} - \sum_{i=1}^{k}\sum_{i=0}^{n} \beta_{\ i,t-j}\, \Delta x_{i\ t-j} - \alpha(1,p)\, ECM_{\ t-1} + \mu_t$

where $ECM_t = y_t - \hat{\alpha} - \sum_{i=1}^{k} \beta_{io}\, \Delta x_{it}$;

$\Delta$ is the first difference operator;

$\alpha j$, t-j and $\beta_{ij,\ t-j}$ are the coefficients estimated from Eq. 3

; and

$\alpha(1,p)$ measures the speed of adjustment.

**2.2.1. Crude oil demand**

**Equation**

$LnDcrude_t = \alpha + \beta\ Ln\ Pcrude_t + \gamma\ LnY_t + u_t$ … ***(3)***

where

α, β, γ are the parameters to be estimated;

$u_t$ is the error term;

LnDcrudet is the log of demand for crude oil in year t;

$LnPcrude_t$ is the log of real price of crude oil obtained by converting the yearly average of the international crude oil price from US dollar to Indian rupee using the official exchange rate and then dividing by India's wholesale price index (WPI, base year 2004–05 = 100); and $LnY_t$ is the real national income proxies here by the real GDP at factor cost (base year 2004–05 = 100).

### 2.2.2. Demand function for Crude Oil

The demand for crude oil in India using equation (3) by employing the ARDL co-integration methodology. The results for the long run demand function of crude oil was given below:

**Equation**

$Ln\ Dcrude_t = -9.09\ C - 0.41\ Ln\ Pcrude_t + 1.00\ Ln\ Y_t$ ……. ***(4)***

(4.86)** (2.37)* (9.73)**

*F*-Test Statistics (for testing co-integration) = 3.92**

$R^2$= .97; *DW* = 2.34; Serial correlation *[χ2(1)]* = 1.61; Functional form *[χ2(1)]* = 2.12

Normality test *[χ2(2)]* = 1.00; Heteroskedasticity *[χ2(1)]* = 0.003

Note: Numbers in parentheses above equation (a) denote the t-statistics of the respective coefficients. Asterisks * and ** denote significance at the 5 % and 1 % significance levels.

The F-statistics confirm the co-integration relationship as its values are above the upper bound at the 1 % significance level. Further, diagnostic tests have shown that serial correlation in the error term is not significant, functional form is not rejected, normality of error term is not rejected and there is no heteroskedasticity in the model. These tests corroborate the validity of the estimated demand function for crude oil. The coefficient of crude oil price is negative and significant at the 5 % level, indicating that crude oil price in India does have a significant influence on crude oil demand. Further, the coefficient of income is positive as expected and statistically significant at 1 % level. The income elasticity is found to be highly elastic, with a value of one. This implies that a 1 % increase in real GDP would lead to an increase in the crude oil demand by about 1 % in the long run. This suggests that the crude oil demand would keep increasing rapidly due to rapid economic growth.

It is expected that an increase in price would reduce crude oil demand ($\beta<0$) whereas an increase in real GDP would imply greater industrial production and increased transportation of goods and people, leading to increasing crude oil demand ($\gamma>0$) (Chemin et al 2012). The magnitude of the income and price elasticity determines the changes in crude oil demand in response to changes in its price and the real GDP and thus, has major implications for projecting the future demand of crude oil in India. The demand function for petrol is estimated with the real price of petrol and real GDP as explanatory variables. We estimated the demand for petrol using a similar log linear demand function:

### 2.2.3. Estimation of Petrol demand

**Equation**

$LnDpetrol_t = \alpha + \lambda LnPpetrol_t + \gamma Y_t + v_t$ … ***(5)***

Where $\alpha$, $\lambda$, $\gamma$ are the parameters to be estimated;

$v_t$ is the error term;

$LnDpetrol_t$ is the demand for petrol in year t; and

$LnPpetrol_t$ is the log of real price of petrol, obtained by using the retail price of petrol and by dividing with the WPI (base year 2004–05).

### 2.2.4. Demand function for Petrol

The demand function for petrol with petrol price (P*) and real income (Y) as explanatory variables (see equation 5) and the results were as follows:

**Equation**

*LnDpetrol = -18.67 C - 0.85 LnPpetrolt + 1.39 LnYt* …… ***(6)***

(21.88)** (14.47)* (1.92)*

*F*-Test Statistics for testing for co-integration = 2.81**

$R^2$= .99, DW = 1.87; Serial Correlation [$\chi2(1)$] = 0.25; Functional Form [$\chi2(1)$] = 1.87

Normality test [χ2(2)] = 0.16; Heteroskedasticity [χ2(1)] = 0.16

**Note:** Numbers in parenthesis below equation (6) denote the t-statistics of the respective coefficients. Asterisks * and ** denote significance at the 5 % and 1 % significance levels.

As with petrol, it was used the petrol price in Delhi state as a proxy for petrol prices in India for our analysis. As before, $LnY_t$ is the log of real income as measured by real GDP at factor cost (base year 2004–05). An increase in the real price of petrol is expected to decrease petrol demand ($\lambda<0$), whereas an increase in the real national income should encourage more people to buy vehicles and lead to greater transportation of goods and services, thus increasing the demand for petrol ($\gamma>0$).

**2.2.5. Estimation of diesel demand**

**Equation**

$LnDdiesel_t = \alpha + \varphi \, Ln \, Pdiesel_t + \gamma Y_t + v_t$ … ***(7)***

Where, α, φ, γ are the parameters to be estimated;

$v_t$ is the error term;

$LnDdiesel_t$ is the demand for diesel in period *t;* and

$LnPdiesel_t$ is the log of real price of diesel, obtained by dividing the retail price of diesel by the WPI, (base year 2004–05=100).

**2.2.6. Demand function for Diesel**

The estimated diesel demand function to know the long run elasticity's and the results were given below:

**Equation**

$Ln\ Ddiesel = -11.89\ C - 0.56\ Ln\ Pdiesel + 1.02\ Ln\ Y$ ………… ***(8)***

(6.87)** (3.61)** (8.62)*

*F*-Test for Co-integration = 11.73**

$R^2$= .96, DW = 1.50, Serial Correlation [χ2(1)] = 2.16; Functional Form [χ2(1)] = 0.02

Normality test [χ2(2)] = 1.77; Heteroskedasticity [χ2(1)] = 0.313

**Note:** Numbers in parentheses below equation (8) denote the t-statistics of the respective coefficients. Asterisks * and ** denote significance at the 5 percent and 1 percent significance levels.

The F-test confirms the long run relationship between diesel price and real income on diesel consumption in India. Further, diagnostic tests show that serial correlation in the error term is not significant, functional form and normality of error term are not rejected and that there is no heteroskedasticity in the model (Ghosh 2010). These tests corroborate the validity of the estimated demand function for diesel.

The F-test for co-integration is significant at the 1 percent confidence level, which confirms the existence of a long term relation between the demand of petrol with its price and with real GDP (Goldar et al. 1990). Further, diagnostic tests have shown that serial correlation in the error term was not significant, functional form was not rejected, normality of error term was not rejected and the heteroskedasticity test is at an acceptable level. These tests corroborate the validity of the estimated demand function for diesel.

The diesel price in Delhi state as a proxy for diesel prices in India because while prices may vary somewhat between states due to differences in local taxes and transportation costs, they are highly correlated with each other. Also, data was not available for all states for the whole sample period. $LnY_t$ is the real income in terms of real GDP at factor cost (base year 2004–05). An increase in the real price of diesel would decrease demand for diesel so that $\phi$ is expected to be negative, whereas an increase in the real income would increase demand for diesel and so its coefficient, $\gamma$, is expected to have a positive sign.

### 2.2.7. Calculation of Ethanol demand

The demand for ethanol is a derivative of the petrol demand in the country. The demand for petrol is increasing trend due to increase in the number of the vehicles and rising per capita income. The ethanol demand was estimated by following simple equation.

**Equation**

Ed = 0.05 X Pd ………………………………………………………………… ***(9)***

Ed = 0.10 X Pd ………………………………………………………………… ***(10)***

Ed = 0.20 X Pd ………………………………………………………………… ***(11)***

Ed= Bioethanol demand; Pd- petrol demand.

0.05, 0.10 and 0.20 = Denotes 5 %, 10% and 20 % blending of the ethanol in petrol.

Pd = Petrol demand.

The ethanol demand for 5%, 10% and 20% blending with petrol was estimated with respective equation.

### 2.2.8. Calculation of Biodiesel demand

The demand for biodiesel is a derivative of the diesel demand in the country. The demand for diesel is increasing trend due to increase in the number of the vehicles and rising per capita income. The biodiesel demand is estimated by following simple equation.

**Equation**

Bd = 0.05 X Dd ………………………………………………………………… ***(12)***

Bd = 0.05 X Dd ………………………………………………………………… ***(13)***

Bd = 0.05 X Dd ………………………………………………………………… ***(14)***

Bd= Biodiesel demand

Dd - Diesel demand

0.05, 0.10 and 0.20 = Denotes 5 %, 10% and 20 % blending of the biodiesel in diesel.

The biodiesel demand for 5%, 10% and 20% blending with biodiesel was estimated with respective equation.

## 3. **Results and discussion**

### 3.1 Bioethanol demand

The has shown that the projected demand for petrol and the amount of ethanol required for 5, 10 and 20 % blending was estimated for different time period (table 1). The above demands were worked out based on lag linear demand function fitted for petrol.

The bioethanol requirement was estimated by fitting a simple function of petrol demand. The petrol demand was 31890, 40550 and 49210 million litres respectively in the year 2020, 2025 and 2030. The ethanol demand for 5%, 10% and 20% of the requirement would be 5000, 6400 and 10000 million litres in the year 2030, which would be more than 100 % of the year 2010 bioethanol blending requirement. Nevertheless, the country had already demonstrated potential alcohol production of 3200 Million litres in 2006-07 which was good enough to fulfil the 5 % blending requirement of the country. The projected ethanol production through by products utilisation will also be good enough to meet the requirement of the 5 % blending demand at the year 2030 (table.1) (Coop sugar 2012).

Nevertheless, blending requirement of more than 5 % need policy intervention to produce the required quantity of bioethanol to satisfy the blending demand. Diversion of excess sugarcane production towards bioethanol production (table.3) and juice to ethanol program during surplus sugar production (Brazilian system of sugar complex) will be the right direction to produce the required quantity of bioethanol to achieve the bioethanol blending program in the country.

### 3.2 Biodiesel demand

Diesel consumption in India is estimated at 66.9 million tonnes in 2010-2011. Given this figure, the biodiesel requirement for 20 % blending was 14.80 million tonnes. The diesel requirement in 2020 and 2030 would be about 99.5 and 160.3 million tonnes. The blending requirement for 5 %, 10 % and 20 % would be 14.8, 19.9 and 32 million tonnes respectively in the year 2030. The biodiesel requirement in the year 2030 would be more than 100% when compared to the year 2010-11(Table 2). The production of required quantity is quite a daunting task and involves about 14 million hectares of land under jatropha cultivation. India may have to import biodiesel or vegetable oil feedstock or even oilseeds.

### 3.3 Can India meet policy targets?

Sugar industry sources report that the Ethanol Blending Program (EBP) is not sustainable as the ethanol supply hinges on sugarcane and sugar production. Sugarcane and sugar production in India typically follows a six to eight year cycle, wherein three to four years of higher production are followed by two to three years of lower production. The Indian sugar industry crushes about 65-70 % of the sugarcane for sugar production, the remaining cane used for local sweeteners (khandsari and gur), seed, feed and sugarcane juice, chewing and ceremonial events. The molasses (byproduct) is used for production of rectified spirits and ethanol.

Since sugarcane and sugar production is cyclical, availability of sugar molasses and sugarcane juice for ethanol production varies depending on the sugarcane cycle. Lower sugar molasses availability and consequent higher molasses prices would increase the cost of production of ethanol, thereby causing disruptions in the supply of ethanol for the EBP programme at pre negotiated fixed ethanol prices.

But, it cannot be justified because sugarcane cycle mainly happened due to stagnated sugar price in the last 15 years. Most of the sugar factories could not make profit since legal restriction for production of juice to ethanol program, consequently the sugarcane farmers was paid less than proportionally to the ever raising cost of production. During the bumper production, the cane was harvested much beyond the maturity period, which forced farmers to change cropping pattern. The total sugarcane production, future sugar demand and surplus sugarcane production was estimated (table. 3). The table has illustrated that the country is producing surplus sugarcane to meet out centrifugal sugar as well as traditional sugar production. The future projections shows, there won't be any shortfall in total sugar requirement of the country (table. 3).

The country has already has shown the capability of producing ethanol for 10 % blending in 2010-11 through sugarcane alone (table. 4). The sugar production was also excess of 5-8 million tonnes since 2010-11 sugar year. Another peculiarity of ethanol production in India is by and large based on by products utilisation (molasses). The analysis has clearly shown that the excess sugarcane production (150 million tonnes) will be good enough to produce 5000 million litres of bioethanol if the excess sugarcane diverted towards juice to ethanol production. It needs only policy orientation by the government of India to allow the excess sugarcane production to ethanol blending program (EBP) without affecting the required sugar production of the country in the year 2030. In addition creation of infrastructure to store anhydrous ethanol during surplus production is utmost important to supply and continue the EBP without any hindrance.

India's commercial production of biodiesel in India is very small. The small quantities of jatropha and other non-edible oilseeds procured by traders are mostly crushed for oil, which was exported to the international markets.

The edible oils are in short supply and country has to import up to 40% of its requirements. Hence prices of edible oils are higher than that of petroleum and diesel. India is not in a position to use edible oils for biodiesel program.

Difficulties in procuring oilseeds and lack of developed infrastructure may obstruct substantial biodiesel production and importing biodiesel may become necessary, especially if the price of crude oil continues to rise. Europe and the United States are rapidly increasing production, but their biodiesel is mainly earmarked for domestic consumption. So, India's biodiesel imports would probably come from developing countries.

### 3.4. Second Generation Biofuels

The new technique was identified to liquidate the biomass to produce fermentable products which can acts as a source for ethanol production. By this method, second generation biofuels was derived from inedible plant material, including fast growing weeds, agricultural waste, sawdust, etc. and numerous scientific studies have shown them to be prime candidates for replacing gasoline to meet our transportation fuel needs.

Algae can be used as a second generation biofuel producer. It showed that algae are by far the highest producer of biofuels. Soybean producing between 40 and 50 gallons of biofuel per acre, rapeseed between 110 and 115 gallons per acre, mustard 140 gallons per acre, palm oil 650 gallons per acre and algae 10,000 gallons per acre.

However, before we can begin to roll down the highways on sustainable, carbon neutral gasoline, numerous barriers must be overcome starting with finding ways to break lignocelluloses biomass down into fermentable sugars. So, the second generation biofuel at research level and commercial production may not be possible in near future. Hence, the biofuel program fully depend on ethanol and vegetable oil in the country and world.

### 3.5. Impact of Biofuel Feedstock on Food/Price/Livelihood

The natural question arising from the diversion of arable land from food production to bioenergy crops is likely to have impact on food production and food security. Biofuel proponents and there is already a vocal 'biofuel lobby', argue that bioenergy crops would only be grown on degraded or wasteland, not fertile land. But, if the wasteland is capable of supporting jatropha cultivation, should it not be used for the cultivation of selected cereal or oil crops, or if not that, then fodder grasses? India and all of South Asia have large livestock populations, which serve as additional support for local food security. The region is deficient in fodder and all kinds of non-arable land should be diverted to fodder grasses, not crops to produce agro fuels. Critics fear that the growth of the agro fuel sector will be detrimental to food production. The requirement of waste land would be about 14 million hectare to meet out 20 % biodiesel blending demand which accounts one fourth of the waste land in India. It can be justified that the whole waste land will not be occupied by jatropha alone.

As the production of ethanol for fuel is basically from sugar molasses, it has not had a significant impact on the production, prices and trade of sugar for food and industrial use. Despite a decline in production of sugarcane/sugar and consequently sugar molasses, higher prices of alcohol vis-a-vis fixed ethanol prices had limited fuel ethanol production. If ethanol prices are allowed to be linked to sugar molasses prices, it impact the availability of sugar molasses for use in cattle feed and the use of alcohol for industrial and potable liquor. When Stage III of the EBP programme is implemented, it also impact availability of sugarcane juice and sugar molasses for alternative uses when the biofuel production is less than the demand. But it has not shown adverse impact on other crop production and livelihood of the farmers. Nevertheless the international sugar and molasses markets have surplus production for the past one decade. So the impact on availability and prices of sugar will be minimum and it would be helpful to ease out the present glut in the international sugar markets/trade.

India does not produce any ethanol from cereal grains (maize, etc.) thus, there has been no impact of the ethanol programme on the domestic market for food, feed and trade of cereal grains and byproducts. Similarly, as the biodiesel programme is based on the use of non-edible vegetable oil, biodiesel production should not have an impact on feed, food, trade of oilseeds, vegetable oils and other edible products.

## 4. Conclusion

Fortunately, India’s sugar demand increasing 1.5 % every year necessitated sugar production would be 32 million tonnes in 2025. So, sugarcane cultivation is inevitable and has to be increased substantially to satisfy domestic demand. Increase in cane cultivation is helpful for more ethanol production through by product (molasses). The only hitch is sugarcane pricing. Price should be increased substantially to sustain the sugarcane farmers in sugarcane cultivation. The sugar industry will not be lacking in meeting the requirement of fuel ethanol in the country.

The amount of land available for jatropha cultivation is estimated at 13.4 million hectares, which could potentially yield 16 Mt/year of jatropha oil which would be enough to meet out 10 % blending. New infrastructure for seed collection, oil extraction, transesterification, biodiesel storage, blending with diesel and marketing is needed. But more importantly, large scale cultivation of jatropha must be established before biodiesel production and meeting the blending requirement nationally.

The two biofuels discussed in this paper, bioethanol and biodiesel would play an extremely important role in meeting India's energy needs. The ethanol industry, though mature, can benefit from improved agricultural practices in sugarcane cultivation, more efficient production processes and the use of alternate feed stocks including cellulosic raw material. On the other hand, the biodiesel industry is at the incubation stage and large scale jatropha cultivation must be established to avoid diversion of food crops or vegetable oils towards biodiesel program. If government follows the new biofuel policy strictly, biofuel production will be complementary rather than competitive to food production in India.

Finally, food security, energy security and climate change mitigation are critical to social, economic and environmental sustainability, not only at the national level but also globally. A successful resolution of these challenging issues requires the goodwill and commitment of all nations to work together. The economic methodology and assessments presented in this study has provided the analytical means and science based knowledge to evaluate policy options towards making the right choices that recognize the pitfalls and make progress for sustainable biofuel production and use in the country.

## References

A.F. Gerard., Shachmurove., Yochanan., 2008. Modelling and forecasting energy consumption in China: Implications for Chinese energy demand and imports in 2020. Energy Economics, 30, 1263-1278.

Chemin., Elodie Sentenac., 2012. Is the price effect of fuel consumption symmetric? Some evidence from an empirical study. Energy Policy. 41, 59-65.

Ghosh, S., 2010. High speed diesel consumption and economic growth in India. Energy, 35, 1794-1798.

Goldar., Bishwanath., Mukhopadhyay., Hiranya., 1990. India's Petroleum Imports: An Econometric Analysis. Econ. Political Weekly, 25, 2373-2377.

International Energy Agency,2008, World Energy Statistics, France. http://www.iea.org/textbase/nppdf/free/2008/key_stats_2008.pdf (accessed on 22/06/2013).

Johansen,S., Juselius,K., 1990. Maximum Likelihood Estimation and Inference on cointegration - with Applications to the Demand for Money. Oxford Bulletin of Economics and Statistics.

Parikh, Jyoti., Purohit, Pallav., Maitra, Pallavi., 2007. Demand projections of petroleum products and natural gas in India. Energy, 32, 1827-1837.

Pesaran, M. H., Shin, Y., Smith, R. J. 1999. Bounds Testing Approaches to the Analysis of Long-run Relationships', Cambridge Working Papers in Economics, No. 9907, Faculty of Economics, University of Cambridge.

Pradeep Agrawal., 2012. India's Petroleum Demand: Empirical Estimations and Projections for the Future. IEG Working Paper No. 319.

www.iea.org/ textbase/nppdf/free/2008/key_statsdf.

www.mnre.gov.in.

www.earth-policy.org

http://petroleum.nic.in/petstat.pdf

http://www.mnre.gov.in/policy/biofuel-policy.pdf

## Tables and Figures

**Table: 1. Future petrol demand and ethanol requirement**

| Year | Petrol demand Million litres ( M.L) | Ethanol blending requirements Million litres ( M.L) | | |
|---|---|---|---|---|
| | | 5 % | 10 % | 20 % |
| 2010 | 20640 | 1032 | 2064 | 4128 |
| 2020 | 31890 | 1594 | 3189 | 6378 |
| 2025 | 40550 | 2027 | 4055 | 8110 |
| 2030 | 49210 | 2460 | 4921 | 9842 |

Source: Author's calculation.

**Table: 2. Projected future demand for diesel and biodiesel**

| Year | Diesel demand (Mt) | Biodiesel blending requirements (Mt) | | |
|---|---|---|---|---|
| | | 5 % blending | 10% blending | 20% blending |
| 2010 | 66.90 | 3.70 | 7.40 | 14.80 |
| 2020 | 99.45 | 4.97 | 9.95 | 19.89 |
| 2025 | 124.79 | 4.18 | 8.36 | 16.72 |
| 2030 | 160.31 | 8.02 | 16.03 | 32.06 |

Source: Author's calculation.

**Table no 3. Total cane production, sugar demand and surplus cane production in India**

| Year | Total Sugarcane Production (Mt) | Total sugar demand (Mt) | Sugarcane required to meet the demand* (Mt) | Surplus sugarcane availability (Mt) |
|---|---|---|---|---|
| 2010/11 | 342 | 22 | 220 | 142 |
| 2020 | 412 | 28 | 280 | 142 |
| 2025 | 480 | 32 | 320 | 160 |
| 2030 | 510 | 36 | 360 | 150 |

Source: Author's calculation.

*10 % sugar recovery estimated as per average sugar recovery in India

**Table.4. Molasses, ethanol production and availability in the future period (2010-2030)**

| Year | Projection of cane crushed in sugar factories (Million tonnes) | Molasses Production (Million tonnes) | Ethanol Production Million Litres | Ethanol requirement for 20 % blending (Million litres ) | short fall in production to meet out 20% blending (Million litres ) |
|---|---|---|---|---|---|
| 2010 | 239.8 | 12.46 | 2050 | 4128 | -2078 |
| 2020 | 330 | 14.85 | 3960 | 6378 | -2418 |
| 2025 | 384 | 17.28 | 4608 | 8110 | -3502 |
| 2030 | 408 | 19.36 | 5100 | 9842 | -4742 |

Source: Author's calculation.

**Figures**

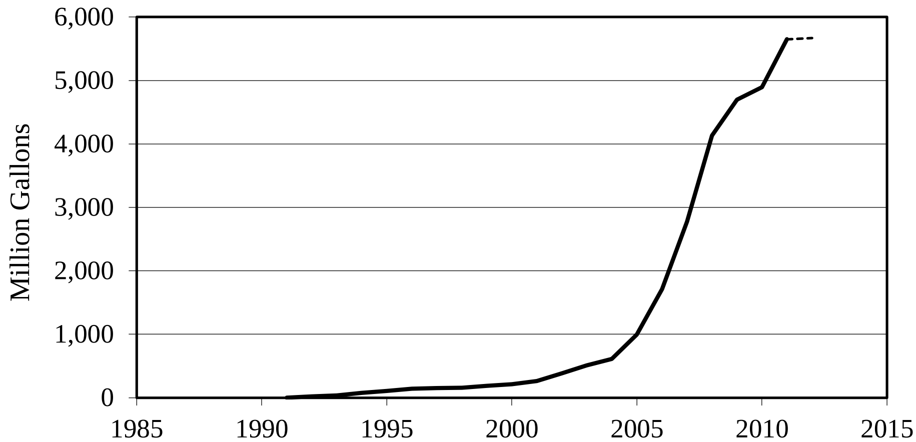


Fig.1. World Biodiesel Production, 1991-2012

*Source: F.O. Licht; World watch.*

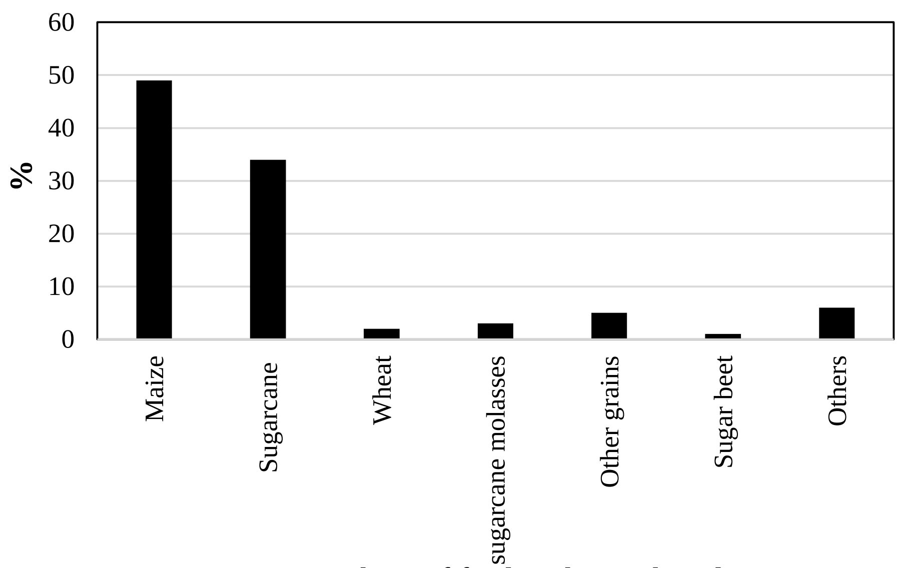


Fig. 2. Percentage share of feedstock in ethanol production in the world

Source: World Bank report on biofuels 2010.