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# India: Study on Cross-Sectoral Implications of Biofuel Production and Use

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Prepared by Mr. Herath Gunatilake

For
Department of Economic Affairs
Delhi, India



Asian Development Bank

# Cross-Sectoral Implications of Biofuel Production and Use in India

**Final Report of TA 7250-IND**
**Submitted to the**
**Department of Economic Affairs**
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# Executive Summary

Indian biofuel sector policies evolved over a decade and the adoption of the National Biofuel Policy in December 2009 is a milestone for the development of the sector. ADB granted TA-7250 (IND): *Cross-Sectoral Implications of Biofuel Production and Use* with the objective of generating scientific information on biofuels to help enhance the implementation of the biofuel policy. The broad objective of the TA was to undertake a comprehensive analysis of the socio-economic and environmental impacts of large-scale production and use of biofuels. The TA appointed a Steering Committee to ensure a transparent and consultative process in undertaking its work and conducted an inception workshop in December 2009 to discuss and agree on the type of research and corresponding methodologies to be used in analyzing the cross-sectoral implications of biofuels. It also appointed an Oversight Committee consisting of eminent economists and scientists to ensure high quality outputs. The Oversight Committee provided review comments for the draft final report and endorsed the findings and recommendations of the revised report in a meeting held in September 26, 2010, in Delhi.

The analyses undertaken in this report were mainly based on secondary data, supplemented by field visits, unstructured interviews and focus group discussions. Chapter 2 of the report presents a review of the biofuel policy in India and an assessment of the adequacy of natural resources to support the national policy targets without compromising the food production in India. Chapter 3 examines the supply chain for ethanol and biodiesel to identify various constraints in each segment of the chain. Chapter 4 examines the major natural resource, environmental and social implications of large-scale biofuel production and use in India. Chapter 5 presents an assessment of the financial feasibility of biofuels, whereas Chapter 6 undertakes a cost-benefit analysis to examine the national welfare impacts of biofuel production and use. Chapter 7 further analyzes economy-wide impacts such as economic growth, inflation, fiscal impacts, wage and income changes, and climate change mitigation due to large-scale biofuel production in India using general equilibrium approaches. Chapter 8 synthesizes all the findings to present conclusions and recommendations.

The analysis mainly focuses on first generation biofuels and their use as transport fuels. Sugarcane was considered as the main ethanol crop while tropical sugar beets (TSB) and sweet sorghum (SS) were also considered as potential ethanol crops. Jatropha and pongamia were the main biodiesel crops considered in the analyses.

## Main Findings

**Biofuel Policy:** India's biofuel policy is comprehensive and gives a broad outline to all the major areas that need attention. These guidelines have to be translated into a biofuel program and a series of projects to reap the potential benefits. Given the vast differences in the economic performances and cross-sectoral implications of ethanol and biodiesel, the biofuel policy can serve better if these two sectors are dealt with separately.

**Potential for Producing Biofuels:** Simple natural resource accounting shows that 20% blending of ethanol with petrol can be achieved by 2017, only if sugar cane juice is converted to ethanol to supplement molasses ethanol. Sweet sorghum (SS) and tropical sugar beets (TSB) are still at the initial stage of development and face major technological and financial constraints. About 32 million hectares of wasteland are required for biodiesel production together with yield improvements to meet a 20% blending target with petroleum diesel. However, it is unlikely that India can achieve the 20% blending target by 2017 given the current infant stage of the biodiesel industry in the country.

**Food Security:** At the current level of productivity, a 20% blending of sugar cane based ethanol cannot be achieved without affecting the food sector. SS and TSB will also compete with the food sector for land and water. However, molasses based ethanol blending does not have any impact on the food sector. If confined to wastelands and using only limited irrigation during the establishment phase of the crops, biodiesel production will not have any adverse impact on the food sector.

**Technological Constraints:** The sugarcane sector is well organized and there are no major technological or other constraints, which prevent meeting the blending targets. The SS and TSB supply chains are yet to be fully developed and they face a major bottleneck at the juice extraction segment of the supply chain making juice extracting units financially unattractive. In contrast to sugarcane, the biodiesel supply chain is in its infancy and understanding the agronomy of the crops and development of nurseries and plantations with high yielding varieties are major constraints, which need to be removed for the sector to take off.

**Impact on Water:** Sugarcane is a water intensive crop but if confined to existing sugarcane lands or to molasses based ethanol, ethanol production will not add to the irrigation water demand. Biodiesel crops most likely will not add to the water problems if confined to limited irrigation in the early stage of the crop establishment.

**Environmental Impacts:** Both ethanol and biodiesel crops have limited negative environmental impacts which can be easily mitigated using available technologies and regulatory measures. Compared to ethanol, biodiesel crops have a number of positive environmental effects and their carbon benefit potential is also large. There are no foreseeable negative social impacts of biodiesel.

**Financial Feasibility - Ethanol:** Ethanol production is not profitable under the administratively determined price of Rs21.5/liter. The recent price revision may provide adequate profits to producers.

**Financial Feasibility - Biodiesel:** Biodiesel production is also not financially feasible under the current pricing mechanism. The current administratively determined price of Rs26.5/liter needs to be revised to provide financial incentives along the supply chain.

**Economic Feasibility – Ethanol:** Molasses based ethanol is economically feasible at the current price of oil and increases of oil prices make molasses based ethanol economically more attractive. The diversion of ethanol from current uses in industry and as potable alcohol is not economically viable. The cost of sugarcane juice based ethanol exceeds the social benefits, hence, sugar cane juice ethanol is not economically justifiable. Higher oil prices do not make sugarcane juice based ethanol economically attractive. Therefore, sugarcane based ethanol will not be economically viable even in the future. Alternative feed stocks such as TSB and SS are not economically feasible at current oil prices. Therefore the ethanol sector should revise its national targets to an economically beneficial target - up to 5% blending only using molasses ethanol.

**Economic Feasibility – Biodiesel:** Both jatropha and pongamia provide acceptable economic returns at current oil prices, and an increase in the price of diesel makes biodiesel economically more attractive. Employment generation and CDM benefits are also significant in the case of biodiesel. Therefore, the expansion of biodiesel production is socially desirable and the results of this report support an aggressive program for biodiesel in India.

**Economy Wide Impact of Biodiesel:** The Indian general equilibrium model, with only biodiesel interventions, shows that biodiesel could provide India with an opportunity to enhance economic growth and the well-being of rural populations. The national biofuel program has the potential to create a significant number of jobs with substantial real wage increases; hence, it is a potential avenue for poverty reduction within an inclusive growth policy framework. The negative effect of the program, i.e. higher fiscal deficits, seems not to dampen the growth effect. In contrast, the 20% ethanol blending does not add much value to the economy.

**Other Policy Options:** There is convincing evidence that oil prices may trend higher over the next two decades and this would have a substantial negative macroeconomic impact for India. A 50% increase in oil prices between 2010-2030 would significantly reduce economic growth, real consumption and household income. Expansion of biodiesel is one policy response India can use to counteract the economic impacts of oil price hikes. Biodiesel intervention can significantly counteract these negative impacts whereas ethanol intervention has a minimum offsetting impact. Combining supply-side energy solutions, like biodiesel development, together with modest energy efficiency improvements and productivity improvements in agriculture will provide impressive results.

## Recommendations

- **Separate Policies for Ethanol and Biodiesel:** Separate policies for ethanol and biodiesel would serve the two sectors better given the difference in economic performance and other issues.

- **Focus on Molasses based Ethanol:** Ethanol production should be limited to molasses based ethanol.

- **Research on Second Generation Biofuel:** There is limited scope for first generation ethanol in India. However, there seem to be a large potential for second generation ethanol. Therefore, research efforts on second generation ethanol should continue.

- **Public Sector Support for biodiesel:** The main focus of public support should be on biodiesel. Following are the specific areas that require immediate attention:

  a) Land use mapping and land allocation study and for formulating a strategy for the necessary legal, institutional, and other provisions to make wasteland available for biodiesel production.

  b) Revision of biodiesel and oil seed prices and provision of a stable policy environment for the biodiesel sector to develop.

  c) Accelerated research program on agronomy, selection and breeding, pest and diseases control, other management practices, and the propagation of high yielding planting materials for plantation development.

  d) Incentive packages for the private sector to mobilize private investment resources for the development of the biodiesel sector.

e) Further studies to examine the potential synergy between India's rural development programs and biodiesel sector development particularly focusing on the long gestation period of biodiesel crops.

f) Establishment of a national agency with branches in relevant states to design and implement the above stated public support program, oversee and monitor the biodiesel industry, periodically review the cost of production and prices, and design and recommend subsidies and taxes based on changes in oil prices.

**CHAPTER 1**

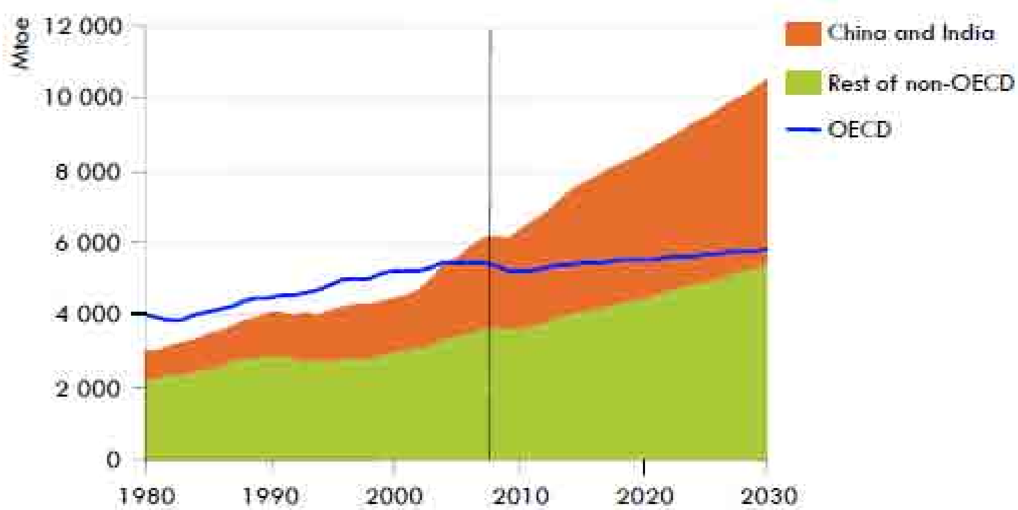
# Introduction

## 1. Global Energy Issues

Energy security has been an important global policy issue for more than four decades. Global energy markets have relied heavily on fossil fuels like oil, natural gas, and coal, which provide almost 80% of the world's supply of primary energy[1] needs. Being non-renewables, however, they have brought with them global destabilizing price shocks. The extensive worldwide use of fossil fuels has not only threatened energy security but has resulted in serious environmental concerns – particularly climate change. One of the key challenges facing the developing world is how to meet its growing energy needs and sustain economic growth without contributing to climate change. Cleaner renewable sources of energy are the ultimate solution to the global energy crisis and biofuels are renewable energy sources, which have been receiving increased attention in recent years.

Global primary energy demand is likely to increase by as much as 40% by 2030[2] with oil, coal and gas continuing to dominate the energy mix for the next quarter of a century.[3] Most of the demand for energy will be driven by non-OECD countries, which are likely to account for over 90% of this increase (Figure 1.1). China and India are expected to take up roughly 53% of this incremental demand. As both countries have limited indigenous energy resources, they will increasingly compete for a larger share of the globe's energy supplies.

**Figure 1.1: World Primary Energy Demand**




*Source: IEA*

[1] World Energy Outlook (WEO) 2007
[2] Reference Scenario of WEO 2009
[3] World Energy Outlook 2009

The situation with crude oil is even grimmer. Global oil supplies are likely to take a hit due to the attainment of "Peak Oil" in the early part of the 21st century. This will result in a gradual decline in production with no new major fields being discovered on land and new reserves found in deep water or in remote areas having high costs of production. With the attainment of "Peak Oil" and the increased concentration of global crude reserves in just a few countries, energy security is likely to remain a major concern. Prices are likely to rise dramatically once again adversely affecting the energy security of vulnerable nations. Although the global financial crisis led to a dramatic drop in crude oil prices[4], it was only a temporary phenomenon and energy prices, particularly oil, have already risen from a low of under $40/bbl in December 2008 to more than $80/bbl in April 2010. Further rises in energy prices will adversely affect economic growth and poverty reduction efforts in developing countries forcing them to search for alternative sources of energy to sustain economic growth. This report focuses on the feasibility of using biofuels as alternatives to fossil fuel energy in India. While biofuels can be used for various purposes, this report primarily focuses on the use of biofuels for transportation.

## 2. India – Energy Outlook and Challenges

India is an energy deficit nation having one of the lowest levels of per capita consumption of energy globally. According to the Integrated Energy Policy of India, its per capita energy consumption was 439 KGOE in 2003, which was much lower than in developed countries but also than the global average of 1,688 KGOE.[5] The country's proven oil reserves are estimated to be about 775 million tons[6] while consumption is about 150 million tons/year (Table 1.1). With limited reserves, India's indigenous production was around 33.51 million tons in 2008-09 and consumption was around 161.7 million tons.[7] India does not have the ability to meet the country's growing demand for energy from indigenous sources even in the short term. As a result, the country is increasingly becoming dependent on imported crude oil. Figure 1.2 shows the future global energy import scenario predicted by International Energy Authority (IEA).

**Table 1.1: Proven Reserves, Present Production and Present Levels of Imports of Coal, Oil and Gas**

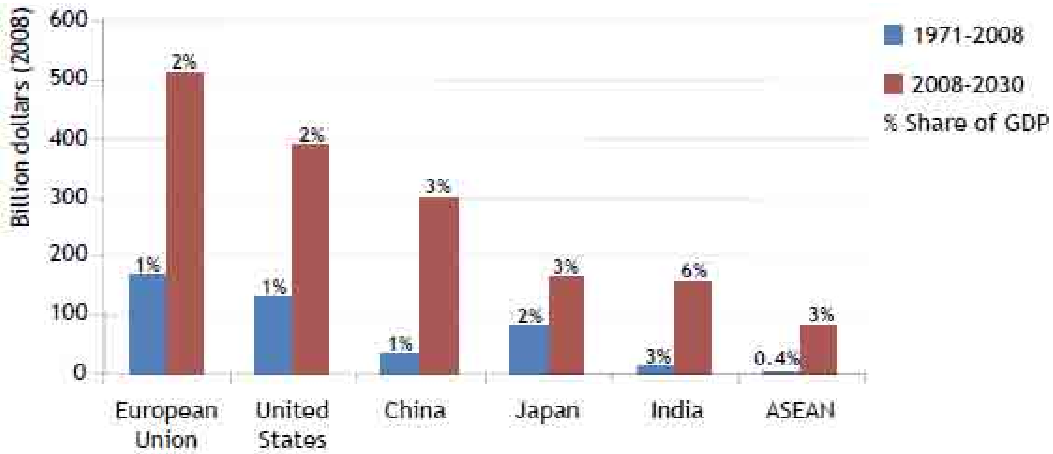
| Head # | Proven Reserves | Present Production | Present Imports |
|---|---|---|---|
| Oil (MMT) | 775 | 33.5 | 128.2 |
| Gas (BCM) | 1,074 | 32.85 | 8.06* |
| Coal (Billion Tons) | 267.2 | 0.525 | 0.035 |

** Million Tons of LNG, Data for 2008-10*

*Source: Economic Survey 2009-10; Ministry of Petroleum and Natural Gas and Ministry of Coal*

[4] BP Statistical Review 2009
[5] Source: Integrated Energy Policy, Planning Commission, Government of India
[6] Basic Statistics on Indian petroleum and natural gas 2008-09, Ministry of Petroleum and Natural Gas
[7] Basic Statistics on Petroleum and Natural Gas, 2008-09, Ministry of Petroleum and Natural Gas

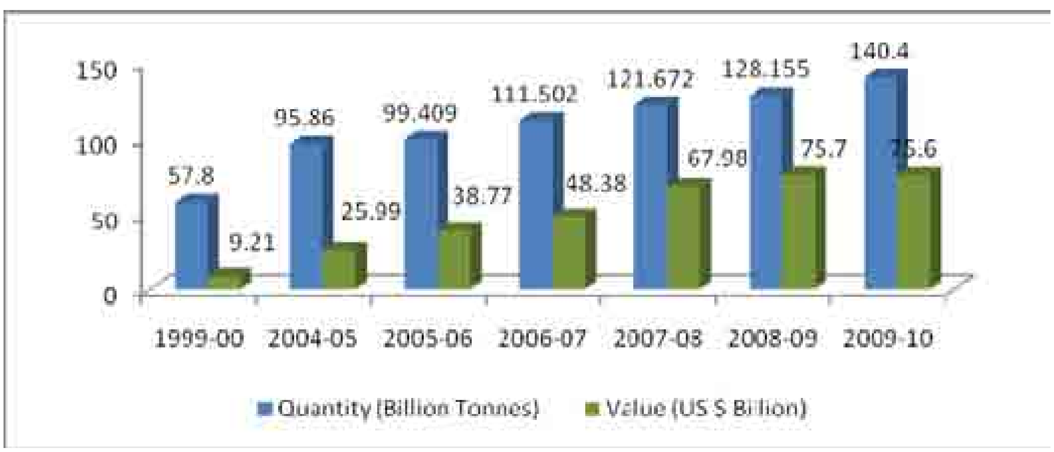
**Figure 1.2: Average Annual Net Imports of Oil and Gas**




*Source: Ministry of Petroleum and Natural Gas*

India has been a net importer of liquid fuels and the volume and value of these imports have risen in the past few years as highlighted by Figure 1.3. The import of crude oil has risen from 57.8 million tons ($9.21 billion) in 1999-2000 to approximately 140.4 million tons ($75.6 billion) in 2009-10, accounting for about 81% of total oil consumption in the country. With the country entering a more energy intensive phase of its development, demand for transportation and consequently liquid fuels will dramatically rise in the future.

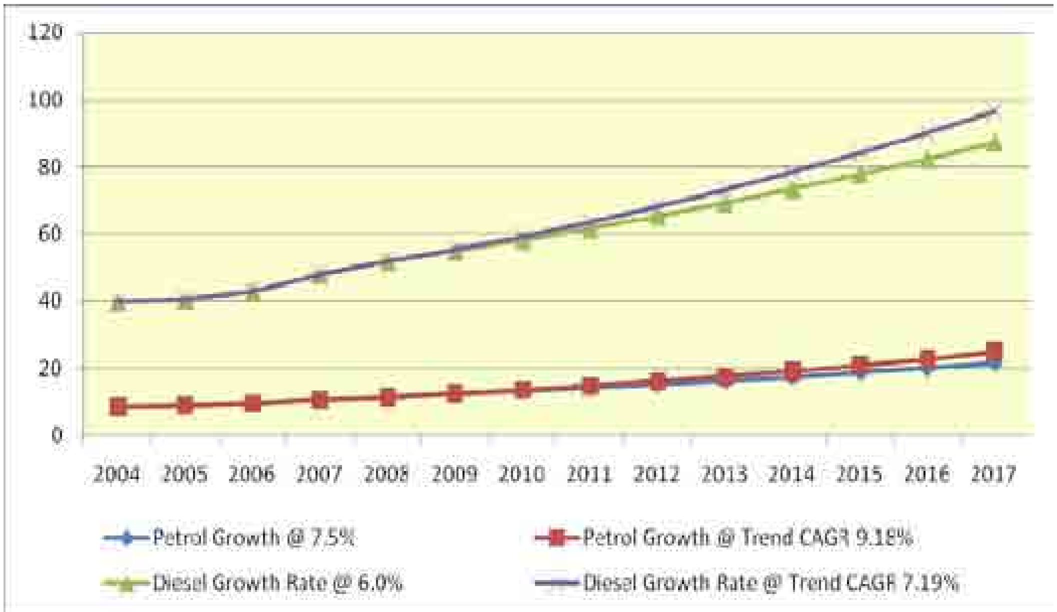
**Figure 1.3: Volume and Value of Imports of Crude Oil by India - 1999-2009**




*Source: Ministry of Petroleum and Natural Gas*

Petrol and diesel consumption have been rising rapidly over the past few years. For example, diesel consumption grew at a cumulative average growth rate (CAGR) of 7.19% between 2004-05 and 2009-10, while it grew at 6% over the past decade. Petrol consumption grew at a CAGR of 9.18 % in the last five years and 7.5% in the last decade. Conservative estimates based on growth in the last decade indicate petrol consumption is likely to rise to 21.59 million tons and diesel to 87.3 million tons by 2017-18 (Figure 1.4).

**Figure 1.4: Actual and Projected Growth in Petrol and Diesel Consumption**




*Source: Ministry of Petroleum and Natural Gas*

With global demand and global energy prices likely to increase in the medium to the long term, higher oil imports could adversely affect the country's balance of payments and future development. This outlook for energy in India forces it to intensify its efforts to search for alternate fuel options. In this context, biofuels may offer an attractive option for meeting part of India's energy needs. India has been taking various initiatives to introduce biofuels. Five percent ethanol blending was made mandatory seven years ago. However, this period has been a part of the learning curve, as the mandatory program was started without fully understanding the implications and without any comprehensive policy in place. It was met with partial success in 2007-09 because only about 2% ethanol blending was achieved. Although the industrial capacity for producing ethanol and biodiesel has increased in the country, the biofuel program faced a temporary set back owing to a number of reasons including the decline in oil prices in 2008-09.

## 3. Biofuels – A Global Overview

Biofuel investments in 2008 accounted for almost 13% of the total global renewable energy investment ($16.2 billion) and were lower than wind (42% or $50.4 billion) and solar (32% or $38.4 billion)[8]. Geographically the major thrust for biofuels came from North America, Europe and South America[9] with major capacity addition in the United States, Brazil and Argentina. In the United States, 31 new ethanol refineries started operation in 2008 taking the total capacity up to 40 billion liters per year; while another 8 billion liters per annum were still under construction. Brazil had over 400 ethanol plants and 60 biodiesel plants in operation by the end of 2008 and was exporting almost 15% of its production (see Appendix 1 for details).

[8] REN 21 2009 Update
[9] REN 21 2009 Update

- **Ethanol**: Ethanol production in 2008 increased by 34% over 2007 to touch 67 billion liters[10] and has more than doubled between 2004 (30 billion liters) and 2008. The major impetus came from the United States and Brazil. Brazil dramatically ramped up production in 2008 to touch 27 billion liters, up from 18 billion liters in 2006. This was also seen in the consumption of automobile fuel in Brazil, where more than 50% of the total fuel consumption in the non-diesel vehicle fuel segment came from ethanol. The United States remained the global leader in ethanol production with 34 billion liters in 2008, up from 2.1 billion liters in 2002. Many other countries like China, Thailand, Germany, France, Spain and Sweden are also implementing major national programs for biofuels.

- **Biodiesel**: Biodiesel saw an even more dramatic rise than ethanol[11]. Global biodiesel production increased six fold between 2004 and 2008, from 2 billion liters to more than 12 billion liters. The European Union (EU) contributed more than two-thirds of this production. In the EU, the top producers were Germany, France, Italy and Spain. Besides the EU, the main biodiesel producers were the United States, Argentina, Brazil and Thailand.[12] Brazil, introduced mandatory biodiesel blending of 2% in January 2008 and set a target of 5% in 2013, started blending 3% in July 2008 and increased it to 4% in July 2009 and 5% in January 2010.

## 4. Global Lessons from Biofuel Promoting Policies

Although a number of countries and regions have started promoting the development of biofuel industries, three main markets have stood out as examples of success stories of biofuel development.

**Brazil's National Alcohol Program:** This program, commonly known as *ProAlcool*, was launched during Brazil's economic crisis in the 1970s and is one of the most innovative and successful biofuel programs in the world. Since its launch the program has progressed from a 5% blending mandate to 20-25% and an increased use of neat ethanol in the highly popular flex fuel vehicles (FFVs). The biggest benefits of the program have been the foreign exchange savings (projected to be over $100 billion), reduction in emissions (almost 574 million tons between 1975 and 2005), and large-scale rural employment created by the ethanol sector. The salient features of the Brazilian incentive measures include: i) a guaranteed procurement price for ethanol; ii) a 5% tax subsidy on FFVs (equating the price of flex fuel vehicles with that of gasoline vehicles); iii) capital subsidies; iv) cost reduction and management programs for the sugar processing sector; and v) compulsory sale of ethanol at all fuel pumps and government control over ethanol stocks to guarantee supply.

**The United States ethanol program:** The rationale for the promotion of ethanol in the United States of America has been based on the economic benefits to rural communities, energy security and greenhouse gas (GHG) emission reductions. The incentives provided in the

[10] World Resources Institute
[11] Tyner, 2007
[12] Renewable Fuel Association

United States include: a federal blending subsidy; volumetric ethanol excise tax credits; and ethanol small producer credits. Penalties are also imposed on distributors for violating blending requirements. It was estimated that ethanol helped support nearly 400,000 jobs and added $53.3 billion to gross domestic product (GDP).

**The EU biofuels policy and mandate:** The European Union has been a pioneer in the promotion of biodiesel. The main drivers of biofuel adoption in the EU have been the targets set by European Commission Directives; 2% and 5.75% blends of biofuels in petrol and diesel by 2005 and 2010 for member states. Tax relief is one of the main incentives used by member states to promote biofuel use in the EU. Mandatory blending requirements along with tax relief have been used in conjunction with partial but increasing levels of taxation on fossil fuels to promote the use of biofuels. Some countries are also using quota mechanisms and tendering. Although the program started slowly, biofuel production picked up momentum in 2006 and 2007 with the share of biofuel touching 2.6% of road transport fuel in 2007. About 75% of the increase in biofuel use came from biodiesel.

The successes of biofuels in Brazil, US and EU[13] should encourage the development of biofuel sectors in energy deficit countries like India. Biofuel feedstock cultivation has the potential to act as a development agent by enhancing livelihood opportunities for rural communities while reducing the fuel import bill of the country. However, large-scale unplanned adoption of biofuels may also result in negative side effects such as an impact on food security, large-scale deforestation, degradation of the ecosystems, environmental pollution and the displacement of rural populations. Thus, scaling-up biofuel production requires proper understanding of the social benefits of biofuels as well as the cross-sectoral implications to avoid adverse impacts.

## 5. Objectives of the Study

ADB initiated the TA-7250 (IND) study on the *Cross-Sectoral Implications of Biofuel Production and Use* with the objective of generating scientific information on biofuel production and its use to facilitate implementation of the biofuel policy by the Government of India. The broad objective of the ADB assignment is to identify the policy options available for biofuels and undertake a comprehensive analysis of the socioeconomic and environmental consequences of these options. This assignment collates scientific information and undertakes analysis on the impact of biofuel production on the economy and on various related sectors. The focus and emphasis of the report is mainly on first generation biofuels. The study will only touch upon second generation biofuels in terms of their future potential in India.

The report is organized as follows:

Chapter 2 undertakes a review of the biofuel policy in India and assesses whether natural resources in India are adequate to support the national policy targets.

[13] Pakistan is also a large producer of molasses based alcohol. In 2007 it operated twenty-one distillery units, with an annual production capacity of 400,000 tons alcohol. In 2006, Pakistan produced and exported 36,500 tons of fuel grade ethanol, mostly to United States.

Chapter 3 develops and examines the supply chain for ethanol and biodiesel to identify various technological and other physical constraints in each segment of the chain.

Chapter 4 examines the major natural resource, environmental and social implications of large-scale biofuel production and use in India.

Chapter 5 examines the financial feasibility of each segment identified in the supply chain to assess financial incentives for private entities to undertake farming, oil extraction, processing/distilling and retailing of biofuels.

Chapter 6 extends the financial analysis to an economic analysis by aggregating the financial models to examine the welfare impacts of biofuel production and use from the society's perspective.

Chapter 7 further analyzes the economy-wide impacts such as economic growth, inflation, fiscal impacts, wage and income changes, and climate change mitigation due to large-scale biofuel production in India using a general equilibrium approach.

Chapter 8 synthesizes the findings to develop a policy framework for biofuel production and use in India, and provides specific recommendations.

**CHAPTER 2**

# Biofuel Policy and the Potential for Biofuel Production in India

India's biofuel policy has evolved over a decade and the National Policy on Biofuels has set an ambitious indicative target of 20% blending with both ethanol and biodiesel by the year 2017. The objective of this chapter is to review India's biofuel policy and examine the potential for biofuel production in terms of the availability of land and water. The potential is assessed using a simple resource accounting approach. Major technological constraints faced by the various types of biofuels are briefly assessed in the latter part of the chapter. A short review of the current status of second generation biofuels is also given at the end of the chapter.

## 1. Biofuel Policy Initiatives in India

India initiated biofuel production nearly a decade ago to reduce its dependence on foreign oil and improve energy security. The country began a 5% ethanol blending (E5) pilot program in 2001 and formulated a National Mission on Biodiesel in 2003 to achieve 20% biodiesel blends by 2011-2012[1]. Similar to the experiences found in many countries around the world, India's biofuel program has seen set backs due to supply shortages, sharp fluctuations in oil prices, and global concerns over food security. To remedy this India adopted a National Policy on Biofuels in December 2009. The program proposes a non-mandatory 20% blending target for both biodiesel and ethanol by 2017[2]. The following section briefly reviews the history and summarizes the National Policy on Biofuels.

### 1.1. Ethanol Program: 2001-2008

In light of rising oil prices and increased dependence on imported oil, India established an ethanol pilot program in 2001. The program consisted of three E5 blending pilots in Maharashtra and Uttar Pradesh and research and development (R&D) studies investigating the technical feasibility of ethanol use[3]. The pilot projects were successful and in September 2002, the Ministry of Petroleum and Natural Gas mandated an E5 blending target for nine states and four Union Territories, effective January 1, 2003[4]. The nine states participating in the program were: Andhra Pradesh, Goa, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu, and Uttar Pradesh. The four Union Territories were: Chandigarh, Damman and Diu, Dadra and Nagar Haveli, and Pondicherry.

The 5% target was established after consultations with key stakeholders at the state and central government levels, including the Society for Indian Automobile Manufacturers and major sugar manufacturers[5]. It was found that there were adequate surplus supplies of

[1] Government of India(GoI) 2002; GOI 2003, This National mission was however not launched.
[2] GoI 2009
[3] Gopinathan and Sudhakaran 2009
[4] GoI 2002
[5] Gopinathan and Sudhakaran 2009.

molasses and alcohol in the country to meet the initial 5% target as well as possibly scaling up the target up to 10% nationwide[6]. Under the program, India's oil marketing companies (OMCs) were responsible for purchasing and blending ethanol. In April 2003, India further strengthened its ethanol program when the Planning Commission released a report on biofuels[7]. The report analyzed various blending targets, price and feedstock availability scenarios and issued the following recommendations to advance India's ethanol program:

- The country must move toward the use of ethanol as a substitute for gasoline.
- Production of molasses and distillery capacity can be expanded to meet 5-10% blends of ethanol.
- Ethanol may be manufactured using molasses as the primary feedstock supplemented by sugarcane juice when there is an excess supply of sugarcane.
- Restrictions on the movement of molasses and establishing ethanol manufacturing plants may be removed.
- Imported ethanol should be subjected to suitable duties.
- Buyback arrangements with oil marketing companies will be arranged.
- Financial incentives should be provided to establish new, state-of-the-art distilleries.
- R&D programs should be established to research alternative feedstock including sugar beet, corn, potatoes, grain and straw

At the time the initial policy was established, India was endowed with surplus sugar supplies. However, severe droughts in 2003 and 2004 reduced supplies by over 60% from historic averages and molasses supplies by over 53%. Further, ethanol was subject to various central and state alcohol taxes and levies, which created challenges for moving ethanol around the country[8]. This diminished ethanol supplies and, as a result, India had to import 447 million liters (ml) of ethanol from Brazil in 2004 to meet the E5 blending target. In October 2004, India amended the E5 mandate requiring E5 blends only when adequate ethanol supplies were available and when the domestic price of ethanol was comparable to the import parity price of petrol[9].

India continued importing ethanol to meet its blending targets and became the largest importer of Brazilian ethanol in 2005 importing 411 ml from Brazil, which accounted for approximately 9% of the global ethanol trade. However, transporting ethanol across states remained difficult. As a result, the majority of the imported ethanol was used for chemical manufacturing rather than for fuel blending[10]. Therefore, the government recommended a

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[6] Gopinathan and Sudhakaran 2009
[7] GoI 2003.
[8] Gopinathan and Sudhakaran 2009.
[9] Gopinathan and Sudhakaran 2009, referencing Ministry of Petroleum and Natural Gas Basic Statistics, 2004.
[10] GoI 2006.

further scale-back in the ethanol program outlined in its Integrated Energy Policy (IEP) in August 2006. The IEP contained the following recommendations for the ethanol program[11]:

- Set the import tariff on ethanol, independent of use, at a level no greater than the price of petroleum products.
- Require, not mandate, OMCs to blend 5% ethanol.
- Price ethanol at its economic cost in relation to petrol but not higher than its import parity price.
- Allow for 5-7 year forward contract purchases at the parity price of petrol.
- Consider waiving all or part of the excise and levies charged on blended petrol.
- Provide incentives for research on cellulosic ethanol.

Despite the IEP recommendations the Ministry of Petroleum and Natural Gas strengthened and expanded its Ethanol Blending Program (EBP) in September 2006. The EBP mandated E5 blends, effective November 1, 2006, in 20 states and four Union Territories, subject to commercial viability[12]. India experienced a surplus in sugar production during the 2005-2006 season, which most likely facilitated the new policy decision. As result of the policy, 10 states had enacted the EBP by 2007.

The 11th Five-Year Plan (2007-2012) recommended increasing ethanol blending mandates to 10% once E5 blends were put in place across the country[13]. The Planning Commission recommended this increase to occur around 2010. In September 2007, the Cabinet Committee on Economic Affairs (CCEA) implemented E5 blends across the country[14] and recommended E10 blends where feasible, effective October 2007. The indicative E10 blending target will be scaled up to 20% blends (E20) by 2017, as proposed by the country's recently enacted National Policy on Biofuels.

### 1.2. Biodiesel Program: 2003-2008

India commenced its biodiesel program in 2003 with the formulation of the National Mission on Biodiesel. The program called for mandating a 20% biodiesel blending target by 2011-2012 using *jatropha curcas* as the primary feedstock. Jatropha is a small shrub that grows on degraded land producing non-edible oilseeds, which can be used to manufacture biodiesel. Although 400 non-edible oilseeds can be found in India, jatropha was selected for the program because of its high oil content (40% by weight) and low gestation period (2-3 years) compared with other oilseeds[15].

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[11] GoI 2006
[12] Ministry of Petroleum and Natural Gas 2007.
[13] GoI 2007
[14] The policy excludes the areas of Jammu and Kashmir, the Northeastern States and Island Territories.
[15] GoI 2003.

To meet the 20% blending target, the recommendation was to cultivate jatropha on 11.2 million hectares (ha) of under-utilized and degraded lands. This was to be implemented in two phases: a research and demonstration phase from 2003-2007 (Phase I) and an implementation phase from 2007-2012 (Phase II). The main goals of Phase I were to cultivate 400,000 ha of land, establish a research network of 42 public universities, and to enact a 5% blending target (B5). The program would be expanded under Phase II to achieve a 20% blending target (B20) by 2011-2012. To support the program, the Ministry of Petroleum and Natural Gas enacted a National Biodiesel Purchase Policy and set a price of Rs25 per liter, subject to periodic review, effective November 1, 2006[16]. The Ministry designated 20 OMCs in 12 states as purchase centers. The buyback program remains in effect but the price was raised to Rs26.50 per liter in October 2008[17].

Although the biodiesel blending targets were not codified, interest in jatropha rapidly accelerated after the introduction of the National Mission on Biodiesel. According to a global jatropha market survey, India was the world's leading jatropha cultivator in 2009, controlling approximately 0.93 million ha of plantations. Further, it is anticipated India would remain a leading cultivator and projected nearly two million ha would be under cultivation by 2015.

Despite India's initial progress in promoting jatropha, the industry has experienced set backs because of declining international oil prices and the continued variability in the agronomic performance of the crop. To date, there remains considerable uncertainty surrounding seed yields, input and maintenance requirements for the crop[18], all of which have inhibited market development. Additional concerns surrounding land tenure and rural livelihood benefits have further stymied the industry[19]. As a result, India's Integrated Energy Policy, released in 2006, recommended significant increases in research funding for jatropha and pongamia, another tree born oilseed. Further, the 11th Five-Year Plan recommended a blending target of 5% biodiesel by the end of 2012, a significant reduction from the 20% target proposed under the National Mission on Biodiesel.

In September 2008, the Ministry of New and Renewable Energy (MNRE) resumed discussions on biodiesel and issued a draft National Biofuels Policy[20]. The draft policy appeared to have backed off the country's exclusive promotion of jatropha and instead called for the use of any non-edible oilseeds grown on marginal, degraded or wastelands. The draft policy also recommended establishing 20% blending targets by 2017 for both ethanol and biodiesel.

### 1.3 National Policy on Biofuels

On December 24, 2009, the government adopted the National Policy on Biofuels[21]. It established a 20% blending target by 2017 for both ethanol and biodiesel. Both targets will be phased in over time and until a phase-in schedule is finalized, the current E10 indicative

[16] GoI 2005.
[17] Cabinet Committee on Economic Affairs 2007.
[18] Achten, Verchot et al. 2008
[19] FOE 2009
[20] GoI 2008
[21] GoI 2009

blending target will remain in effect. There is no mandatory nationwide blending target for biodiesel at present. Blending targets will be periodically reviewed and adjusted as needed. The policy proposes establishing a National Registry of feedstock availability to help monitor production potential and set blending targets.

The MNRE is tasked with coordinating the policy. Two new committees, the National Biofuel Coordination Committee (NBCC) and the Biofuel Steering Committee headed by the Prime Minister and Cabinet Secretary, respectively, was established on May 2010 to coordinate and implement the policy. As with previous biofuel policies, OMCs will be responsible for purchasing, storing, distributing and marketing biofuels.

**Feedstocks**: The new policy is not feedstock specific, as was the case with previous biofuel policies. Instead, the policy calls for using non-food feedstocks grown on degraded wastelands in order to avoid conflicts with food security. This provision will distinguish India's program from other international biofuel programs. This stipulation is aimed at biodiesel feedstocks as the policy promotes the use of non-edible oilseeds cultivated on degraded land for biodiesel. The policy states that the government will assess the potential of over 400 tree born non-edible oilseeds currently available in India. The policy does not list preferred ethanol feedstocks but mentions molasses, which has historically been the primary feedstock used in India.

**Mode of Production:** In order to avoid conflicts with food production, the policy promotes establishing plantations on government or community-owned wasteland and on degraded or fallow land. Both forest and non-forest land will also be considered. Contract farming schemes will also be established in order to raise feedstock on privately owned wasteland and seed buyback programs will be implemented to encourage contract farming. The policy specifically states plantations on agricultural lands will be discouraged. However, the policy does not provide any guidance as to how these provisions will be enforced.

**Policy Mechanisms**: The policy identifies several mechanisms that will be considered to promote biofuel production. The policy document contains few details on the specifics of each mechanism because, presumably, these items are still under development. Many of the proposed mechanisms resemble those recommended in the 2003 Planning Commission report on biofuels[22]. The policy outlines mechanisms in the following areas: subsidies; preferential financing; fiscal incentives; research, development and demonstration (RD&D); and international collaboration.

**Subsidies:** The primary government subsidies under consideration are price supports, land concessions, and labor subsidies. In terms of price supports the policy proposes establishing minimum support prices (MSP) for oilseed procurement, which will be paid by the OMCs. Additionally, the government will examine setting up a statutory minimum price (SMP) program for oilseed procurement at biodiesel processing centers. The policy recommends modeling an oilseed SMP program after the existing program for sugarcane procurement. If implemented, this could greatly expand the number of buyback locations operating in the

[22] GoI 2003

country. Currently, restricting buybacks to the 20 designated OMC locations has frequently been criticized[23]. Additionally, the government may also establish a minimum support price (MSP) for oil seeds.

Oilseed plantations that qualify will be eligible to receive a subsidy for labor costs under the government's Mahatma Gandhi National Rural Employment Guarantee Act[24]. The law guarantees 100 days of labor per year for Rs60/day for adult members of rural households, living below the poverty line. The law typically applies to unskilled labor on publicly funded projects, such as construction.

**Preferential Financing:** Recognizing the need to create the necessary infrastructure to facilitate biofuel production, the policy calls for national finance institutions to develop preferential financing schemes for biofuel projects. The National Bank of Agriculture and Rural Development (NABARD) will provide loans to farmers to help with plantation costs. Additionally, the Indian Renewable Energy Development Agency (IREDA), the Small Industries Development Bank of India (SIDBI) and various commercial banks will be encouraged to provide financing for all activities to develop biofuel value chains.

The government of India will also seek financing from multilateral and bilateral lending institutions for investments in the sector as well as assistance for carbon financing opportunities. Finally, the government will also permit 100% foreign direct investment (FDI) in biofuel projects in order to attract international investment and joint ventures. However, FDI will not be allowed for plantation projects or for projects exporting biofuels. Therefore, FDI will likely be sought for processing and refining activities.

**Fiscal Incentives**: Additional subsidies and grants may also be considered to promote new and second generation biofuel production. The policy does not state the specific feedstock being considered under this category. If necessary, the government will create a National Biofuel Fund to provide financing for these efforts. The plan also calls for incorporating biofuels into other pre-existing central and state government financing schemes promoting renewable energy. However, the plan does not refer to specific policy schemes where biofuels should be integrated. The government will also reduce or eliminate taxes and duties on biofuels. The policy will maintain the current concessional excise duties on ethanol and biodiesel. Presently, the excise duty for ethanol is 16% while biodiesel is exempt from taxes. No further central government taxes or duties will be implemented for ethanol or biodiesel. The government will also reduce customs and excise duties for plant and engine technologies but the precise reduction rates are not detailed in the policy.

**Research and Development:** The government will undertake research and development and demonstration to establish competitive domestic biofuel industries. Research and development (R&D) will primarily focus on establishing plantations, biofuel processing and production technologies, improving the efficiency of end-use applications and by-product utilization. Demonstration projects will be set up for both ethanol and biodiesel projects, which

[23] GoI 2006
[24] Ministry of Rural Development 2010

will focus on production and conversion technologies. The government will engage in public private partnerships (PPP) to support these initiatives.

The government will fund research initiatives at academic, government, non-profit and corporate research institutions to support the R&D programs. Multi-institutional research programs with clearly defined objectives and timelines will also be established. The government will establish a research and development subcommittee under the Biofuel Steering Committee to oversee this. The sub-committee will be led by the Department of Bio-Technology and include members from the Ministry of Agriculture, Ministry of New and Renewable Energy and the Ministry of Rural Development. The Ministry of New and Renewable Energy will coordinate the subcommittee as this Ministry is responsible for implementing the overall biofuel policy.

**International Cooperation:** India will also pursue strategic international partnerships to carry out its biofuel policy and promote domestic biofuels industries. Priority areas for such collaboration will include technology transfer, joint research and technology development, field studies, pilot scale plants and demonstration projects. In February 2009, before the official announcement of its biofuel policy, India entered into a memorandum of understanding (MOU) with the US Department of Energy to promote biofuel cooperation[25]. The goal of the MOU is to support the production, conversion, utilization, distribution and marketing of biofuels in a sustainable and environmentally friendly manner in accordance with each country's respective strategies and goals. The MOU outlines cooperation in eight specific areas, subject to revision and expansion.

## 2. Natural Resources Availability Assessment

This section assesses the natural resource availability to meet the blending requirements stipulated in the national biofuel policy.

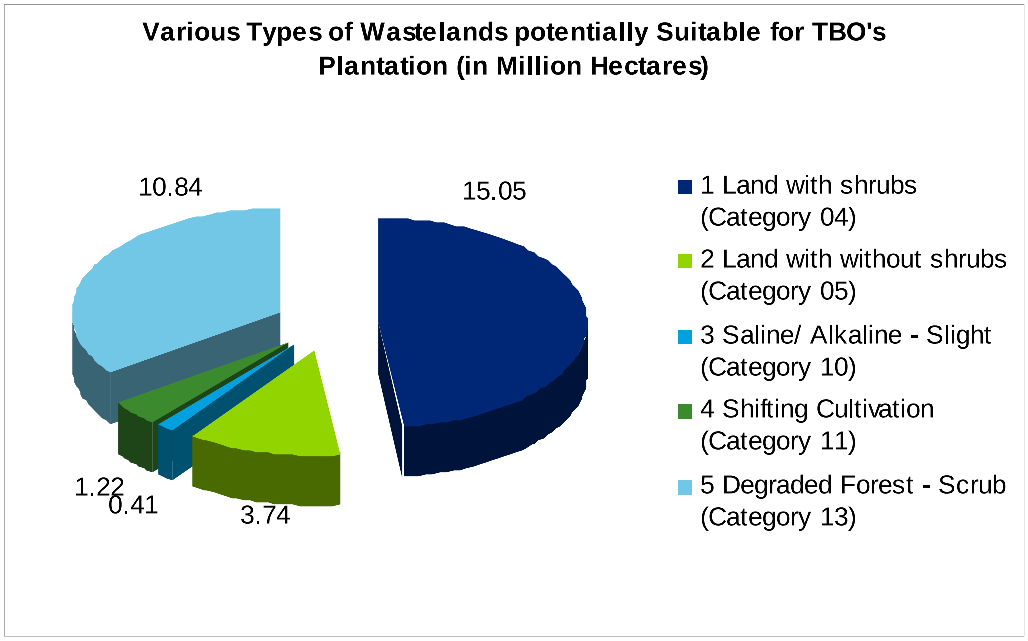
### 2.1. Assessment of Land Availability

#### 2.1.1. Land Requirement for Biodiesel

The Government's policy is to allow only unused degraded land for growing non-edible oilseed bearing tree plantations such as *jatropha curcas* or *pongamia pinnata* for producing biodiesel. The *Wasteland Atlas of India* 2005[26] has estimated that of the total land area of India (328.7 million ha) about 55.37 million ha of lands are wastelands excluding those in the state of Jammu and Kashmir. Here the information from the Atlas is used as the basis for assessing the land requirement for biodiesel production.

[25] GoI 2009
[26] Wasteland Atlas of India 2005, Ministry of Rural Development

**Figure 2.1: Various Categories of Lands Suitable for Biodiesel Plantations**




The Atlas classified wasteland under 13 main categories. The Department of Land Resources under the Ministry of Rural Development[27] has suggested setting out criteria (see Box 2.1) for the selection of suitable land for oilseed plantations. Based on these criteria six categories of wasteland were recommended for oilseed plantations. According to this assessment, the total potential area available was estimated to be 32.3 million ha, and the distribution is shown in Figure 2.1[28]. The availability refers only to the physical availability, but access of land for biofuel plantations depends on a number of factors including climatic and soil conditions, access to infrastructure such as roads and electricity, as well as the ownership of the land. The available information about wasteland suitability for oilseed plantations is sketchy and a proper wasteland mapping exercise should precede any major biodiesel development program in India.

Box 2.1. Wasteland Selection Criteria for Oil Seed Plantations

- Annual rainfall should exceed 600 mm.
- The pH of the soil should be less than 9.
- The temperatures should not fall below 0°C and frost conditions should not prevail.
- The slope of land should not exceed 30°.
- The land should not be water logged.
- The land should not be barren rocky/stony.

Among the available estimates, the Integrated Energy Policy 2006 has projected a potential of 20 million tons of oil equivalent (MTOe) or 25.71 million kilo liters (KL) of biodiesel

[27] Integrated Analysis of diesel substitutes for oil seeds in India-PetroFed,

[28] In another estimate however, it was assumed that only one third of the waste lands maybe available for planting of non-edible oil bearing trees. Criteria used for the one third suitability assumption is not clear.

produced from plantations on 20 million ha of wasteland and 10 MTOe or 19.65 million KL of ethanol produced through the intensive cultivation of over 1.2 million ha. The requirement for biodiesel to meet 20% blending in 2017 will depend on the consumption of diesel and the trend in the growth of diesel consumption. At a cumulative average rate of growth (CAGR) of 6%, the trend of the past decade[29], it is expected that diesel consumption will be around 87.30 million tons (mt) by 2017. To achieve the 20% blending target. biodiesel requirement will be 20.54 million KL per year. The Planning Commission has estimated a biodiesel requirement of 13.38 mt or 15.20 million KL by 2012 based on a blend of 20%. Bharat Petroleum has estimated a biodiesel requirement of 20.97 million KL of crude substitution by biodiesel by 2020[30]. While these figures vary from estimate to estimate, as the target year is different in each case, we use 21.35 million KL/year by 2017 as the most suitable estimate for land requirement assessment.

Total land requirements depend on the productivity of the plantation, which varies depending on climate, quality of planting material and other plantation management practices such as the application of irrigation water and fertilizer. According to conservative estimates, a relatively low yield of one ton of oilseed can be obtained per hectare on less fertile wasteland, in rainfall deficient areas[31]. Another factor that determines the biodiesel yield is the oil content of the seeds. With conservative yields of 1 ton/ha and oil content of 30%, the biodiesel yield can be as low as 0.32 KL/ha. Under the most pessimistic scenario, about 64 million ha of land are required to meet the 20% blending requirement of biodiesel (Table 2.1). Under the most optimistic scenario, the land requirement by 2017 will be about 21 million ha. According to current understanding of the yield potentials, it is reasonable to assume about 32 million ha would be required to meet the 20% blending target. This analysis shows that high yielding varieties (for both higher seed yield as well as oil content) and better agronomic practices such as limited irrigation are required to meet the biodiesel target with the available wastelands.

**Table 2.1: Assessment of the Land Requirement for 20% Blending by 2017**

| Assumption | | | Required amount of land for 20% blending, (million ha) |
|---|---|---|---|
| Yield Tons/ha | Oil Content in Seed (%) | Biodiesel Yield (KL/ha) | |
| 1.0 | 30 | 0.32 | 63.78 |
| 1.5 | 40 | 0.64 | 31.89 |
| 2.0 | 30 | 0.64 | 31.89 |
| 2.0 | 40 | 0.86 | 23.92 |
| 3.0 | 30 | 0.97 | 21.26 |

[29] Petroleum Statistics, Ministry of Petroleum and Natural Gas Website
[30] Bansal, 2007
[31] FAO-IFAD, 2010

In addition to the wastelands identified, some other unused land categories are also available for biofuel production. For example, the National Biofuel Mission[32] identifies categories of land suitable for biofuel production such as agricultural border fences (3 million ha); agro-forestry[33] (2 million ha); public land along roads, railways, and canals (I million ha); and integrated watershed development program land (2 million ha). Once all of these are used together with the productivity increases that can be achieved by selection and breeding, the land requirement can be met to produce the 20% blending requirement for biodiesel.

### 2.1.2. Land Requirement for Ethanol

Currently ethanol is being produced from molasses, which is a by-product of the manufacture of sugar. Cane juice can also be used for producing ethanol without going through the sugar production process. Besides sugarcane, other grains or tuber crops can also be used as alternate crops to produce ethanol. However, food crops are not encouraged for ethanol production in India. This analysis considers two non-food crops for ethanol production, sweet sorghum (SS) and tropical sugar beet (TSB).

As in the case with biodiesel, the resource requirements for ethanol would depend on the current consumption of petrol and the trend in growth. Petrol consumption has been experiencing rapid growth, especially in the last few years, with a trend of CAGR of 7.5% in the past decade[34]. Based on this trend, it is expected that petrol consumption would be around 21.6 million tons (mt) by 2017. To achieve the target of a 20% blend of ethanol with petrol, the ethanol requirement will be 5.76 million KL per year.

The Integrated Energy Policy 2006 estimates that 10 tons of energy equivalent (MTOe) or 19.65 million KL from ethanol produced from 1.2 million ha of fertile and irrigated land could be produced through intensive cultivation. By far the dominant feedstock for the production of ethanol has been molasses, the production of which has been fluctuating due to the cyclical nature of the sugar industry. On a decade-based average, India produces about 8.4mt of molasses per year. However, this is expected to increase to 17.6 mt by 2017 and will support 11.64 % of blending with petrol, if fully used as transport fuel. The use of the total quantity of molasses for ethanol is unlikely because of its more lucrative alternate uses such as potable alcohol and industrial alcohol. Thus, molasses alone does not provide a viable option for achieving the target of 20% blending.

Since the price of molasses rises dramatically in lean years, while the oil marketing companies (OMCs) have fixed prices for three years, the ethanol blending program (EBP) ceases to function as the prices offered or contracted by OMCs are un-remunerative to the ethanol producers. Sugarcane juice is an alternative choice as a feedstock because it is a well established crop. The use of sugarcane juice in surplus years is recommended in the biofuel policy. The average Indian yields have fluctuated between 65 t/ha and 71 t/ha. The area under sugarcane planting has also varied, from 4.22 million ha in 1999-00 to 5.15 million ha in 2006-

[32] GoI 2003; CIA 2009
[33] Biofuel crops can be grown as hedge rows in agro-forestry systems.
[34] Based on data of MOPNG website data.

07, falling back to 4.4 million ha in 2008-09. Sugar consumption was estimated at 16.2mt in 2000-01 and has been increasing at a CAGR of about 4% in the past decade to about 23mt by 2008-09. At this rate, it is expected to increase to 34.2mt by 2017. Production has increased from 18.52mt in 2000-01 to 26.36mt in 2007-08 with the exception of 2006-07, which had the all time highest production of 28.3mt. Looking across these fluctuations, sugar production has been growing at a CAGR of about 4.5% over the past decade due to the increase in area farmed.

For the purpose of assessing land resource requirements, we consider the following scenarios. In these scenarios we use the average Indian yield of sugarcane at about 70 tons/ha, which should give an average yield of about 4.9 KL/ ha of ethanol.

**Scenario 1:** This scenario assumes that all molasses is used for ethanol production and the balance is obtained from sugarcane. If the average molasses production remains at 8.4 mt (the average between 2000-2009), ethanol production would be 1.89 million KL. To meet the required balance for ethanol, 0.79 million ha of sugarcane would be required. However, if sugar production continues to grow at a CAGR of 4.5%, molasses production is expected to increase to 17.6 mt by 2017 and this will support 11.64% of blending with petrol, if fully used as transport fuel. The balance area of sugarcane required would be 0.35 million ha to meet the 20% blending requirement. This scenario is unlikely because the use of all available molasses for ethanol for transport is not feasible, given the alternative demands for molasses.

**Scenario 2:** This scenario assumes the use of sugar juice to produce the total requirement of ethanol for 20% blending. In such a scenario, the area of land required to produce 5.76 million KL of ethanol would be 1.18 million ha by the year 2017. Here the land requirement is assessed assuming no productivity growth in sugarcane farming. Under such circumstances the use of sugarcane from 1.18 million ha for production of ethanol will result in a reduction of sugar production of 8.23mt/year. Assuming this amount of raw sugar were to be imported at $350/t it would cost about Rs126.6 billion ($2.88 billion) /year.

**Scenario 3:** This scenario assumes sugarcane productivity growth. Here, it is assumed a CAGR of 4% in sugarcane yield increases. With this assumed growth, the ethanol yield should be 6.97 KL/ ha by 2017. The area of land required to produce 5.76 million KL of ethanol would be 0.83 million ha by 2017, if only cane juice is used to produce the total quantity of ethanol required.

From the above it can be observed that the requirement for irrigable land will not exceed 1 million ha, out of the total irrigated potential of nearly 102.8 million ha. This amount of land can be readily made available for production of ethanol, provided the ethanol price is high enough. Moreover, the sugar industry is well developed in India and under suitable circumstances the industry can easily meet the 20% blending requirement. However, the major problem is that India does not have additional irrigable arable land to use for sugar farming. In one of the scenarios, sugar production has to be displaced and an equivalent quantity of sugar imported. In another scenario, irrigable crop lands such as wheat or rice have to be converted to sugar to meet the 20% requirement. In both cases ethanol production cannot be increased without reducing some food crop production.

With the Government of India's stand that energy crops should be developed without affecting food crop production, ethanol blending at 20% will require a significant increase in agricultural productivity, in particular sugarcane. Such a productivity increase may release some arable land to produce sugarcane for ethanol production without reducing food. However, the situation is more complex with a growing population and increasing rural incomes. Population increases as well as rural income increases lead to higher food consumption. Given the fixed arable land resources, which are already in production, any allocation of arable land to energy crop production will adversely affect the production of food in India. Therefore, it may be wise for the country to confine itself to molasses based ethanol production for transportation needs.

The Indian sugar industry is cyclical by nature. Production was 18.5mt in 2000-01, 28.3mt in 2006-07 and estimated at 14.6mt in 2008-09. For 2009-2010 it is forecast to be 18.5mt. The cyclical nature of the sugar industry is well known and is due to huge excess or glut of sugar in some years followed by some years of shortage accompanied by wide price fluctuations. The excess sugar in surplus years can be used for ethanol production without affecting the food sector. For example, India produced 28.3mt in 2006-07 against a domestic requirement of 21mt.

If the ethanol industry is linked to cyclical production and limited to molasses and excess sugar, it may not be feasible to meet the 20% target but it would avoid impacting on the food sector. This approach will also have the advantage of stabilizing sugar prices. However, the main problem here is that excess ethanol processing capacity has to be created that may not be fully utilized (sugarcane is available for only about five to seven months in a year in any case). If other feedstocks such as TSB or SS can be produced in a planned manner to use the excess capacity of ethanol production in lean months, the sugar-based ethanol industry may be able to avoid excess capacity issues. In this combined model of ethanol production, the use of sugarcane may not have a substantial impact on the food sector.

#### 2.1.3. Land Required for Alternate Crops

Other feedstock crops such as TSB and SS can be successfully cultivated in India. If the rainfall is sufficient[35] SS can be grown without irrigation particularly during the monsoon season (kharif). It can also be grown as a crop in the second harvest (rabi) season with lower irrigation needs than that of sugarcane. However, experience has shown that the combined average yield of SS for two crops is lower (about 40 tons/ha/yr) than for sugarcane, even with the additional yield of three tons of sorghum grain. The expected yield of alcohol is low, at about 55 liters/ton. Therefore, the land requirement would be higher than that of sugarcane for any equivalent production of ethanol. If 50% of the ethanol is coming from molasses and the rest is from SS the land requirement would be about 1.3 million ha. The SS will be grown on

[35] Sweet Sorghum requires about 4,000 cubic meters ($m^3$) of water per ha per season.

arable land and there will be some displacement of food crops and consequently some adverse impact on the food sector.

TSB is a six-month crop and normally one crop can be taken per year with a yield of 65 tons/ha and an ethanol yield of 70 l/t. Under the equivalent scenario of molasses with TSB ethanol production to meet the 20% blending requirement, about 0.63 million ha of arable land is required. The land requirements for both SS and TSB are larger than if we are only using sugarcane but land would be available for six months each year for other crops. TSB and SS are not commercially established like sugarcane and their cost competitiveness, in comparison to sugarcane based ethanol, is not fully understood. Therefore, it is expected that SS and TSB can only play a supplementary role in the ethanol industry until adequate yields can be achieved in the field to prove their readiness for commercial production.

## 2.2 Assessment of Water Requirements

The discussion in this section provides a preliminary sketch of the water resource needs for meeting transport blending requirements for ethanol and biodiesel. Parallel to the analysis above for land requirements, it focuses on the resources needs for the feedstock. In Chapter 4, this discussion will be amplified to include the needs for processing and the broader implications of creating a large biofuels industry on water resources, including the possible impacts on water pollution.

### 2.2.1 Water Requirements for Ethanol Feedstock

Water consumption in sugarcane cultivation is high. It is estimated that the total water required for sugarcane varies from 1,400-1,600 millimeters per hectare per year (mm/ha/yr) for subtropical regions while in tropical areas it could be 1,700-3,000 mm/ha/yr. The rainfall in the sugarcane growing subtropical areas is 550--600mm, while in the tropical areas it is 550--700 mm. As a result, the irrigation water requirement for tropical areas is much higher, about 1,150 to 2,100 mm, than in the subtropical regions[36,37]. Because of the current common and inefficient practice of flood irrigation, only about 35-40% of irrigation water is utilized by the plants while the rest is wasted. This waste provides opportunities for on-farm water use efficiency improvements. The yield and water consumption of various alternate crops for ethanol production is given in Table 2.2.

[36] Is Sugarcane a Water Guzzler –I &II, Dr Narendra Singh Indian Sugar, September 2007 and April 2008

[37] Water Requirement & Irrigation Management in Sugarcane Crop, Dr JP Singh, All India Seminar on Water Management in Sugarcane Development, March 2008

**Table 2.2: Water Use by Different Ethanol Crops**

| Crop | Sugarcane | Sweet Sorghum | Tropical Sugar Beet |
|---|---|---|---|
| Water Requirement ($m^3$/ha) (average) | 14,000 to 30,000 (20,000) | 4,000 x 2 seasons | 10,000 to 14,000 (12,000) |
| Crop Duration (months) x number crops per year | 12-16 x 1 | 4 x 2 | 5-6 x 1 |
| Yield range (t/ha/yr) (average) | 60-150 (70) | 15-40 (40) | 60 – 80 (65) |
| Approximate Yield of Ethanol (l/ha) | 4,900 | 2,200 | 4,550 |
| Irrigations (Number of cycles) | 10 to 25 | 2 to 3 x 2 | 8 to 10 |
| Water Requirement per liter of ethanol ($m^3$/ha) | 4.1 | 1.8 | 2.7 |

This simple assessment shows sugarcane uses a higher quantity of water compared to the other crops. However, in the case of ethanol production using sugarcane, there would not be an incremental increase in water use if existing sugarcane lands are diverted to ethanol production. There would be additional water requirements only if other croplands that use less water are converted to produce sugarcane. Which crops would be displaced cannot be determined a priori and therefore the additional water use requirements cannot be estimated with any degree of accuracy. Moreover, this simple assessment considers only the existing technology. If second generation ethanol technology becomes commercially viable and sugarcane bagasse (fiber waste remaining after cane is crushed to extract juice) is used for production of cellulose based ethanol, water consumption per liter of ethanol production would halve.

### 2.2.2. Water Requirements of Biodiesel Feedstocks

Oil seed plantations do not require much irrigation as they can be grown on dry wastelands. The Ministry of Rural Development (MoRD) and other agencies of the Government of India have stated that TBOs such as jatropha should be grown in areas that have a minimum rainfall of 600mm. Many experts are of the opinion that in drier areas some limited irrigation may be required to establish biodiesel crops. Water is required at the nursery for growing seedlings and saplings. If the saplings are grown for four to six months they do not require additional irrigation if they are planted in the monsoon season in areas with reasonable rainfall (600mm and above). In case there is drought or the area is deficient in rainfall, some limited irrigation may be required in the first two years. Pongamia has the advantage that since the roots go deep into the ground it can survive with lower rainfall once it is established. However, the gestation time is longer and the tree reaches maturity much later. Given the variability of climate and soil conditions and lack of field level research findings, it is hard to estimate what the additional water requirements would be for biodiesel production. The very general assertion one may make based on the nature of trees and the environment in which they usually grow is that biodiesel crops may not exert additional significant pressure on irrigation water consumption in India. Development of low water using cropping patterns and making them popular among farmers as an integral part of a biodiesel promotion package can ensure this.

## 3. Technological Constraints

### 3.1. Planting Materials and Agronomic Constraints

The availability and quality of planting material are important aspects for a successful biofuel development program. In the case of sugarcane based ethanol the feedstock cultivation is well established. However, there is a need for improvement of yields for all crops including sugarcane, TSB, and SS. Sugarcane is a well established crop but the average yield is low and therefore there is a need to develop high yielding varieties that are drought tolerant and efficient with respect to various inputs including water. A few varieties have been introduced recently that have shown some promise both in the north and the south. SS and TSB were recently introduced and they require a much bigger effort for making appropriate genomes available for scaling up their production.

The feedstock development for biodiesel in India is at an infant stage and there is a need for aggressive R&D if the sector is to meet the targets set out in the biofuel policy. Both jatropha and pongamia have been domesticated very recently and high yielding varieties have not been identified. Being a wild plant there is great variability of yield and oil content and the information for reliable yield is lacking. Current jatropha plantations comprise, at best, marginally improved wild plants[38]. There are a number of constraints in both jatropha and pongamia feedstock collections. The seed weight is low and oil content is variable while many plants show high vegetative growth but low seed yield. The high staminate (male) to pistillate (female) ratio also adversely affects the yield. There is no synchronicity of flowering and fruit/seed maturity, which leads to increased labor intensity and harvesting costs. Coordinated and accelerated R&D programs are required to overcome these constraints. Since the time required to develop a high yielding feed stock can be long, immediate action on the matter is required. Although the current situation with respect to yields is not promising, the diversity observed in yields and untapped potentials provide great opportunity to apply available green

[38] Jatropha: A Smallholder Bioenergy Crop, Food and Agriculture Organization of the United Nations, Rome, 2010.

revolution technologies to achieve higher yields. Better yielding trees can be selected and vegetative propagation/tissue culture can be used to multiply those naturally occurring high yielding trees. Selection and multiplication itself can initially provide a significant jump in yields. Cross breeding and various genetic engineering and other high-tech approaches can then be applied to further increase the yields.

Compared to ethanol crops such as sugarcane, biodiesel crops require extensive research such as spacing and fertilizer trials, on pest and disease control methods, and on agronomic practices, in addition to selection and breeding for yield improvements. One of the biggest problems is that many such activities will not be undertaken by the private sector especially at the initial stages of the biofuel industry. The public sector has to undertake most of the research and development activities to ensure that initial basic requirements are met for the industry to take off with private sector participation.

### 3.2. Technological Constraints

The world-wide impetus for promoting biofuels has led to an increased focus on technology development and R&D. Biofuels have been classified as "first-generation" and "second-generation" on the basis of the nature of the feedstock used. First generation biofuels are usually derived from sugars, grains, or seeds; often the edible portion of the plant. Although global biofuel production using first generation technologies has increased rapidly over the last decade, key concerns are being raised about their long term sustainability mainly due to their likely impact on food security. This has led to the development of second generation biofuel technologies. Second generation biofuels are produced from the non-edible lingo-cellulose biomass, i.e. non-edible residues of forests and agriculture, energy crops and organic municipal solid waste. The use of these feedstock would significantly increase the availability of biofuels and are projected to make them cheaper as the technology matures. These biofuels would not affect food security and have a smaller carbon footprint than current first generation fuels. However these biofuels are still in the development stage and are rarely being produced on a large-scale globally.

#### 3.2.1. Ethanol Technology

India is among the top five ethanol producers in the world. Until now almost all of India's capacity for ethanol has been from molasses. Recently, a few Indian companies have taken the first tentative steps to produce ethanol using alternate feedstock like sugarcane juice, sweet sorghum and tropical sugar beet. India started its ethanol blending program in January 2003 and adequate capacity (1.7 billion l/yr) has been installed for meeting the requirements of E10 (blending up to 10%). The technology for the production of ethanol from molasses is well established, as there are almost 350 distilleries in India. The technology for ethanol production in India is becoming increasingly sophisticated as companies located in India are now providing technology and supplying energy efficient plants all over the world.

(a) **Molasses**: The key technological constraint for production of ethanol from molasses has been the effluent, which has a high organic content. It can be used as a fertilizer together with irrigation, but the effluent cannot be used throughout the year. Another

(b) **Tropical Sugar Beet (TSB):** TSB has been introduced recently in India and the TSB technology is still maturing. The main technological constraints include: poor sugar extraction; long crop cycle (six months) that allows only one crop each year; and the perishability of the crop and the need to extract sugar within a short period after harvesting. Seasonal harvests come to the processing mills within a short period of time and these mills can be operated only for a few months each year. Without using other supplementary feedstocks to operate the plant for a longer period, this may make processing units financially unattractive.

(c) **Sweet Sorghum (SS):** Sweet Sorghum is a sugar-rich stalk similar to sugarcane and is touted as a "smart biofuel crop". It is supposed to have wide adaptability, rapid growth, high sugar accumulation and biomass production potential. In addition, SS is believed to be water and fertilizer efficient, has a short crop cycle of four months and has the additional availability of co-products such as grain. There have been some technological problems related to the extraction of juice from the stalk in existing sugar mills. The main constraints are the low SS yield, the requirement to extract juice and ferment within a short period of time and the financial non-viability of juice extraction plants.

### 3.2.2. Biodiesel Technology

Various non-edible oil seed plants are available in the forest and in scattered plantations in many states across the country. However, since these species have not been domesticated for harvesting, the yield and oil content have large variations. Although the indigenous feedstock for biodiesel production are available in limited quantities, a number of plants using continuous process technology have been established with a capacity of about a million tons per year. Many of these plants are based on imported crude palm oil and palm oil products. Some plants are also using fish oil and recycled oil. Most of the plants are either set up in special economic zones (SEZs) or as 100% export oriented units and are located in Andhra Pradesh and West Bengal. The main issue in the commercial development of biodiesel in India is the availability and yield of the feedstock, which was discussed earlier in this chapter.

## 4. Second-Generation Biofuels

It is believed that most of the constraints of first generation biofuels can be resolved by second generation biofuels. Large-scale RD&D projects are being set up in many countries with generous government assistance to develop second generation biofuels. The cost effectiveness and commercial viability of these fuels will be known in the coming decade. The various second-generation biofuels currently receiving serious attention include:

**Cellulosic ethanol:** The feedstock is non-food forestry products or farm wastes, including twigs, sawdust, and grass;

**Syngas:** Produced from a variety of feedstock, including agricultural waste, but historically from coal; syngas is an intermediary product composed of carbon monoxide and hydrogen that can be converted into ethanol using Fischer Tropsch processes;

**Bio-oil:** Produced from a variety of biomass feedstock, by fast pyrolysis (decomposing the feedstock at high temperature), bio-oil can be used in other processes to provide liquid fuels for transport;

**Renewable diesel:** Processing of vegetable oils, including waste products from the commercial food industry, to produce transport fuels;

**Algae-based biofuels:** A revolutionary technology that propagates and uses microbes to convert carbon dioxide to liquid fuel products. There are a large number of possible processes and products that could involve algae in biofuel production. The research is, however, only in the initial stages. Experiments have been carried out in small (up to 3,000 liters) processes; however, the field is not yet mature enough for commercial use;

The concept of producing biofuels along with value-added products such as bio-composts, biogas, electricity, chemicals (from by-products such as glycerine), nutraceuticals, and bio-polymers are becoming more important to ensure financial sustainability of both first and second generation biofuels. The large Indian biofuel producers are already working in this direction. Sugar plants are becoming highly integrated with cogeneration, and ethanol and bio-compost are being produced.

India has initiated various steps to promote R&D in second generation biofuels of all types. The MNRE Department of Bio-technology (DBT) and Ministry of Science and Technology have extensively promoted research and a large number of research organizations are working in this area. An example of India's efforts to develop second generation biofuel technology is the R&D promoted by DBT at the DBT-ICT Centre for Energy Bioscience. Here these fuels are being developed in collaboration or partnership with a number of research organizations. Cellulosic ethanol technology developed at this institution will be used to set up a 10 tons/day biomass-based pilot plant at Indian Glycol, which is expected to produce about 3,000 l/day of ethanol. The trials at this plant are expected to prove the technology developed and determine the cost competitiveness of cellulosic ethanol.

As stated earlier, the yield of ethanol from bagasse based ethanol has been estimated to be 0.3 KL/ton of biomass. A survey of the latest developments of next generation Renewable Diesel (ReDs) such as 'sun' diesel from biomass gasification or 'green' diesel from the pyrolysis of biomass and the subsequent conversion to 'green' diesel; shows that the conversion is about 0.2-0.3 ton of fuel per ton of dry biomass. In the case of FT-based 'green' diesel, power generation is possible and provides a source of additional income. The calorific value of pyrolysis oil is about two-thirds that of diesel. With a yield of 8 to 10 t/ha/yr of biomass, it may be possible to obtain 1.6 to 2 tons of green or sun diesel per year.

If the cellulose to ethanol technology progresses, it would be possible to use bagasse for the production of ethanol, which may nearly double the quantity of ethanol available from sugarcane juice. Large quantities of other feedstocks such as biomass from various sources including forests and urban biomass wastes are also available for producing biofuels. For example, India produces about 60 million tons of bagasse and trash, which can be used to produce 18 million KL of cellulosic ethanol. If 30% of this can be made available, the ethanol production would be 5.4 million KL, which is close to the 20% blending requirement for 2017. In addition, large quantities of biomass are available as residue from agriculture sector such as straw, stalk and husks from various crops. It has been estimated that of the total crop residue biomass of 415.4 million tons about 102 million tons may be surplus[39]. If this surplus is used it can produce more than 20 million KL of cellulosic ethanol.

Second generation biofuels have technical barriers that manifest in the high cost of production. In the case of cellulosic ethanol the cost of enzymes has been a problem. However, significant reductions in cost have been achieved due to concerted efforts and considerable funding in some developed countries. It is believed this technology may soon start competing with corn-based ethanol provided biomass is available at attractive prices. Pyrolysis is a technology that has experienced considerable research. However, with high acidity and high oxygen content, the resulting bio-oils are unsuitable as transport fuel without further processing and can only be used as heating or furnace oil. This second generation 'green or sun' diesel technology is still being tested. The price competitiveness of the final product of biomass to liquid (BTL) has to be still ascertained. Major gaps in algae technology include strain improvement; growth and hydrocarbon production; automated downstream processing; utilization of spent biomass; and the evaluation of closed and open cultivation systems. Overall, the second generation biofuel technologies are yet to prove their commercial viability.

## 5. Concluding Remarks

This chapter first presented a review of the biofuel policy in India and then undertook a simple natural resource accounting to examine the feasibility of meeting targets set in the policy. The Government of India's biofuel policy is comprehensive and it provides the broad guidelines required for the development of the sector. However, its implementation may require more detailed programs and projects.

Available secondary information was used to examine the feasibility of meeting the 20% blending of ethanol and biodiesel from the perspective of natural resource availability. An assessment of land availability shows that the 20% blending of ethanol can be achieved by 2017, if about 1.2 million ha of arable, irrigable land is allocated for ethanol cane juice based production. The land requirement will be about half that if molasses based ethanol production is combined with cane juice based production. The land requirement can be further reduced if sugarcane productivity can be increased. The sugarcane sector is well organized and there is no major technological constraint that prevents meeting the ethanol blending target provided the ethanol pricing issues are sorted out to the satisfaction of the relevant stakeholders. The basic

[39] Biomass Resource Atlas of India -2004-05

problem of sugarcane based ethanol is that it will reduce food production unless the productivity of the crop sector is raised significantly.

The land requirement for biodiesel based on non-edible oilseed plantations was assessed assuming only wasteland is used for biodiesel production. A preliminary assessment shows that about 32 million ha of wasteland is available for biodiesel production but some yield improvements will be needed to meet the 20% blending target by 2017. The use of all the available land for biodiesel can be constrained by many factors and a proper land use study is required before launching a biodiesel development program. The lack of good quality planting materials and low yields are the major constraints faced by the biodiesel sector, and quick and aggressive research and development programs for selection, breeding and large scale propagation of good planting material are imperative for the biodiesel sector to take off. The public sector has to play a key role in this endeavor at the initial stage.

India's outlook on water shows the country is already water stressed. If existing sugarcane land were used for ethanol production, there would not be additional water use. An estimation of any additional water requirements is not easy because it is hard to predict what crops may be displaced by increased sugarcane cultivation. Biodiesel crops use only limited irrigation during the early stages of the establishment and during prolonged periods of drought. Given that data is not available on water use by biodiesel crops, it is hard to make an assessment about their water requirements. Nevertheless, the information that is available suggests that a 20% blending target for biodiesel may not add significant stress to the irrigation water demand of India.

Other ethanol crops such as SS and TSB are still at the initial stages of development and they face a major technological constraint – the requirement of extracting the juice within a short period. The financial sustainability of milling units which operate for only a few months a year is problematic and this would limit the use of these crops unless other feedstocks can be processed during the off-season. Moreover, these alternative crops will also compete for land and water used by food crops. Second generation biofuels may overcome the competition between food and energy crops for natural resources such as land and water in India, but the large-scale commercial use of second generation technology will only come about in the medium to long-term.

## CHAPTER 3

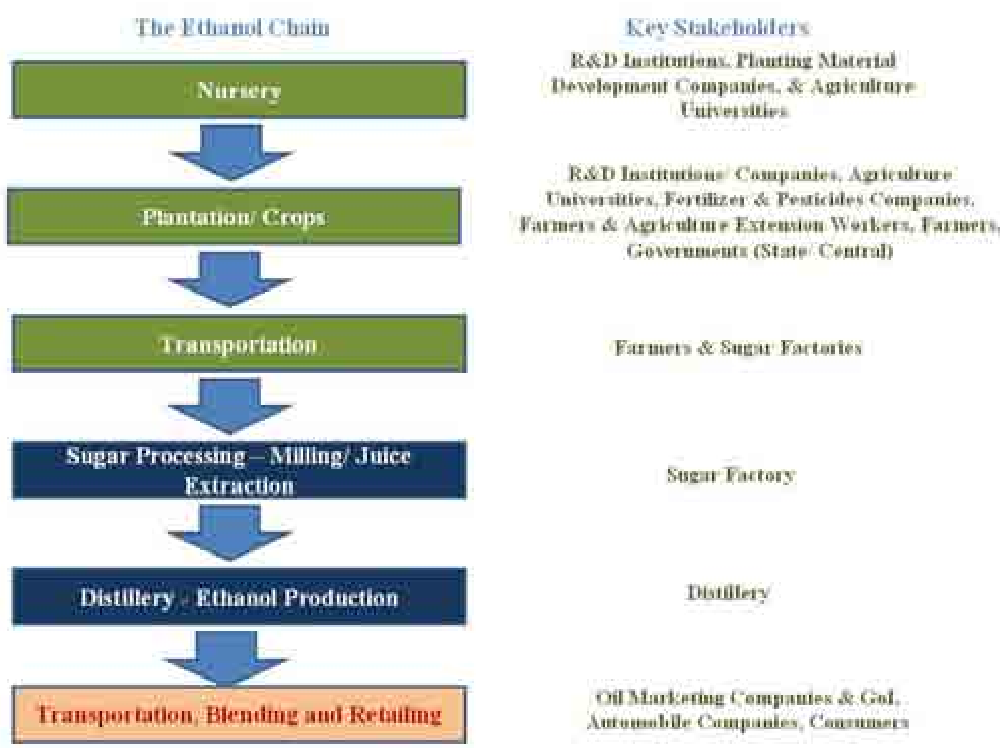
# Biofuel Supply Chains in India

This chapter briefly describes the supply chains for ethanol and biodiesel in India, and identifies the major bottlenecks hindering the development of the sector along the chains. It also provides the foundation for the financial analysis of biofuel activities along the supply chain, in addition to identifying the major constraints.

### 1. Ethanol Supply Chain

The ethanol and the biodiesel supply chains share a number of similarities as well as some rather stark differences. Some of these have been highlighted in Chapter 2 where the technological constraints were discussed. The main activities of the ethanol supply chain consist of research and development for the cultivation of feedstock, plantations and their management, harvesting, storage and transportation of feedstock, processing, storage, transportation, blending, and retailing of ethanol. The ethanol supply chain is illustrated in Figure 3.1, which showcases the main links of the ethanol value chain and the key stakeholders in each link of the chain.

**Figure 3.1: The Ethanol Supply Chain and Key Stakeholders**



The critical bottlenecks impacting on the development of the ethanol value chain to meet the national goal of 20% blending in petrol by 2017 are shown in Table 3.1.

**Table 3.1: Supply Chain Bottlenecks for Ethanol**

| Supply Chain Segments | Major Bottlenecks | | |
|---|---|---|---|
| | Sugarcane | Tropical Sugar Beet | Sweet Sorghum |
| **Nursery** | • Lack of appropriate high-yielding varieties suitable for different regions | | |
| **Plantation or Crops** | • Cyclical production due to variation in yields and area under cultivation<br>• Low prices<br>• Poor commercial practices by sugar mills<br>• Lack of investment and mechanization | • Lack of commercialization | |
| **Transportation** | • High cost of transport from producer to markets | | |
| **Milling/Juice Extraction** | • No significant issues | • Commercialization yet to be achieved<br>• Milling units not financially sustainable, especially due to limited operating periods (1-2 months annually) | |
| **Processing or Distilling** | • No significant issues | | |
| **Blending or Retailing** | • Long-term, inflexible price contracts by oil marketing companies (OMCs)<br>• Non-remunerative prices for ethanol<br>• Resistance to direct retailing by OMCs<br>• Inappropriate regulations<br>• Lack of support by automobile companies for higher ethanol fuel blends | | |

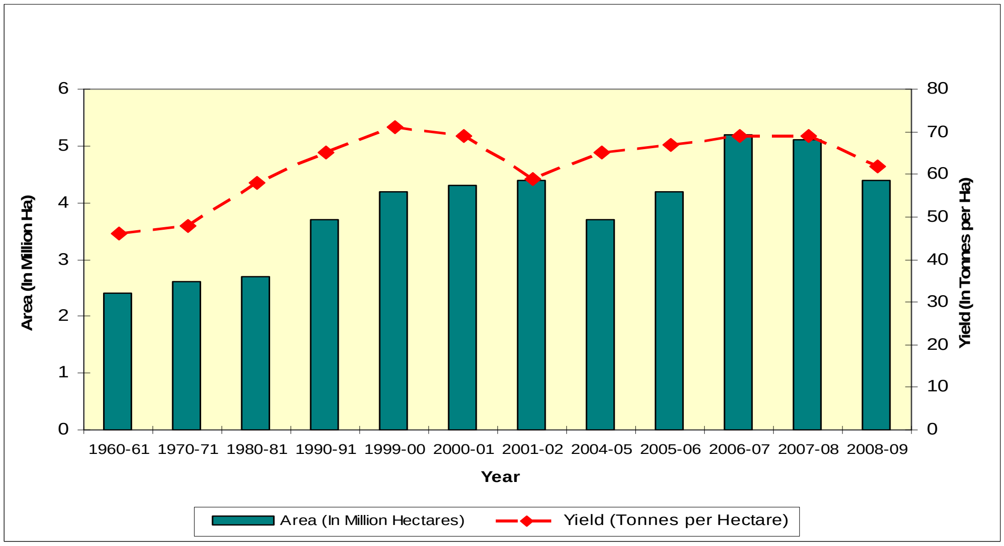
### 1.1. Plantation Phase

This section highlights the constraints and issues in detail at the plantation stage:

**High Yielding Varieties:** One of the main bottlenecks affecting the ethanol supply chain is the non-availability of high yielding planting materials. Over the last decade India has witnessed a plateau in sugarcane yields (Figure 3.2) due to the absence of new, high yielding varieties. The production cost of sugarcane has increased in recent years, which has had a domino effect on the cost of downstream products. India's R&D in this sector has not been able to introduce new high yielding varieties in sugarcane growing regions. In recent years the yield of sugarcane has actually gone down (Figure 3.2) due to drought, insufficient investments in fertilizers and crop protection, and diseases. In addition there is a long lag time in the roll out of new high yielding varieties.

**Cyclical supply shortages and supply gluts:** Regular cycles of supply shortages and gluts in the sugarcane industry have meant that there is a significant variation in the area under sugarcane plantation in the country, which means a high variation in the price of sugar and sugar by-products (Figure 3.2). Rising prices and consequently increases in the minimum support price of food grains has also meant that farmers have found better returns from food grains and have switched to these more remunerative crops. The cyclical nature of the industry has led to financial difficulties for mills resulting in farmers not receiving payments on time. This has also turned farmers away from sugarcane.

**Figure 3.2: Sugarcane Yield and Area under Cultivation**




*Source: Economic Survey of India*

**High labor costs:** Sugarcane planting and harvesting are labor intensive and wage increases result in higher costs of production. Seasonal labor shortages can affect harvesting, reducing the yield of ethanol and increasing costs.

**Lack of knowledge and experience in alternate feedstocks:** There is little or no experience in India in developing large-scale commercial cultivations of alternate feedstocks like SS and TSB. This along with a developing technology package has meant that the cost of production of bioethanol from alternate feedstocks has also been high, limiting large-scale replication.

### 1.2. Processing and Blending Phase

Although the main bottlenecks in the supply chain are found in the plantation phase, a number of constraints affect the other components of the chain like the high demand for molasses and low procurement pricing of ethanol. The major ones are highlighted below:

**Alternative uses of molasses:** Molasses is a by-product of manufacturing sugar and its availability depends on quantity of sugar produced. Therefore, molasses availability varies with the production of sugar, which is cyclical in nature. Molasses based ethanol has its use as potable liquor and for making a variety of different commercial chemicals. The transport ethanol has to compete with these sectors and often the alternative uses provide a better price. According to the available estimates, potable alcohol use will increase from 1.45 million kiloliters in 2010/11 to 1.9 million kiloliters in 2014/2015 at a 7% growth per year. Similarly industrial alcohol use will increase from 1.05 million kiloliters to 1.28 million kiloliters at a 5%

growth rate. This estimate by the Indian Chemical Council[1] predicts a significant deficit in molasses based ethanol even if 5% blending is the target for transport.

**Low procurement prices:** OMCs, until recently, were offering a procurement price of Rs21/ liter for a three-year contract with ethanol producers. Molasses production fluctuates annually and prices are volatile even on a monthly basis and therefore it may be impractical for ethanol producers to enter into a three-year fixed price contract with the OMCs. Moreover, the price is arrived at during a tender process where the lowest bid is accepted and all other bidders forced to match the price. When the price of molasses went up significantly, producers did not find the ethanol price remunerative and stopped supplying the OMCs. Very recently the ethanol price was increased to Rs27 per liter.

**Low economies of scale:** The average plant capacity of ethanol producers is significantly lower than in countries like Brazil and the United States, which leads to a higher cost of production.

## 2. The Biodiesel Supply Chain

The biodiesel supply chain shares a number of similarities with the ethanol supply chain including the plantation component. However, the processing components in biodiesel consist of extraction of straight vegetable oils and the chemical transformation of these oils (transesterification), which do not occur in the ethanol chain. The various linkages of the biodiesel supply chain have been illustrated in Figure 3.3.

Biodiesel feedstocks like jatropha and pongamia are still in their development phase. Both of these plants are relatively new when it comes to the mapping of their characteristics and genetics by scientists. Of the global extent under Jatropha cultivation, 85% is located in Asia, mainly India, Myanmar, China and Indonesia. The critical bottlenecks impacting the development of the biodiesel supply chain are shown Table 3.2.

[1] This data were obtained from Indian Chemical Council presentation to the Expert Committee on Ethanol Pricing for Fuel Blending

**Figure 3.3: The Biodiesel Supply Chain and Key Stakeholders in India**

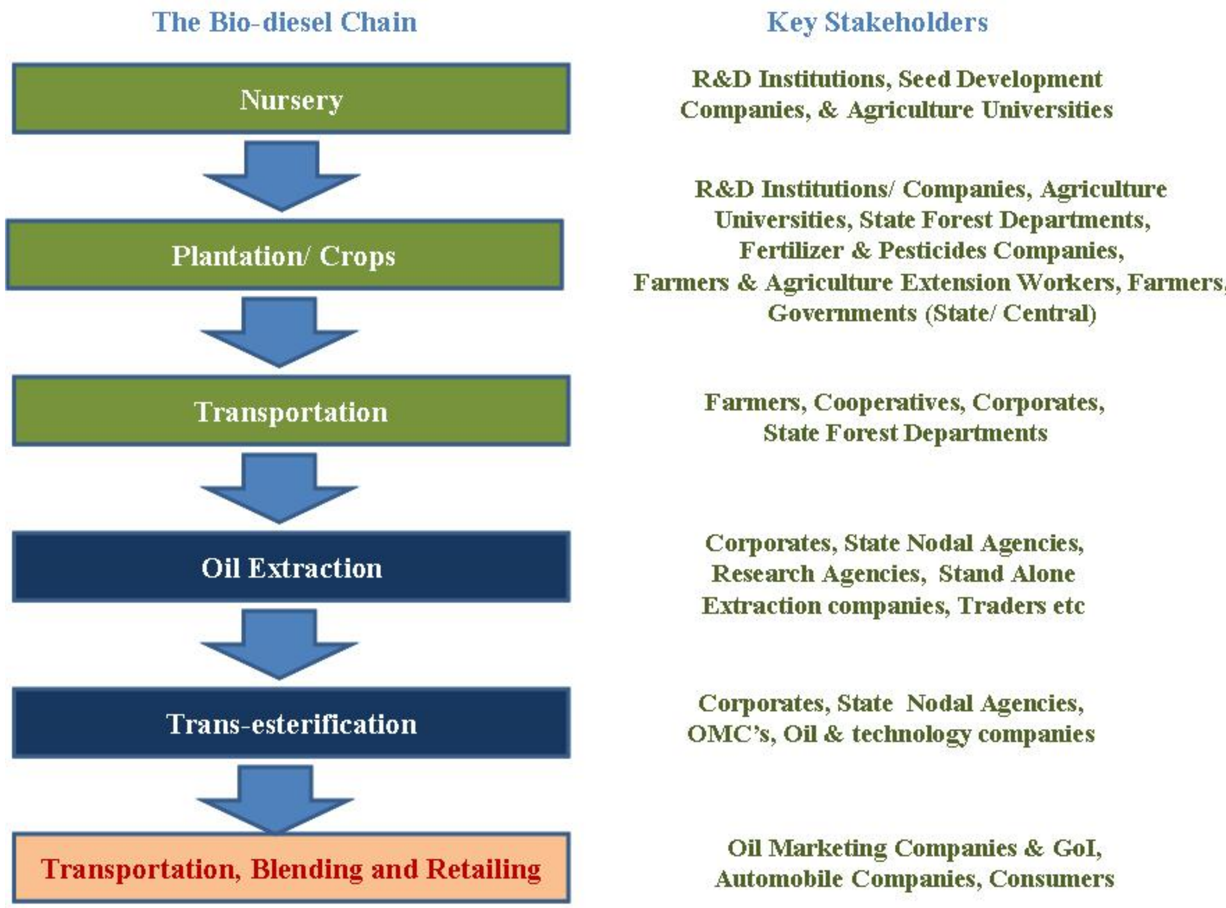


**Table 3.2: Critical Bottlenecks Across the Biodiesel Supply Chain**

| Supply Chain Segments | Major Critical Bottlenecks<br>Jatropha and Pongamia |
|---|---|
| Nursery | • Lack of high yielding varieties, quality planting material and high variation in yields |
| Plantations/Crops | • Land availability and allocation<br>• Agronomic and management practices not fully developed<br>• Absence or announcement of low minimum procurement price of seed<br>• Long gestation period, no revenue in first few years<br>• High labor cost of harvesting<br>• Uncertainty about the future of the industry |
| Transportation | • High transportation costs especially if plantations are spread over a large area |
| Oil Extraction | • Higher cost of extraction due to low capacity utilization<br>• Lack of adequate supply of seeds<br>• Dispersed feedstock production limit the scale economy |
| Transesterification | • Higher cost of transesterification due to low capacity utilization<br>• Shortage of feedstocks<br>• Dispersed feedstock production limit the scale economy<br>• Uncertainty of the biodiesel industry |
| Blending/Retailing | • Non-remunerative prices set by OMCs which are not revised regularly<br>• Opposition of OMCs to direct retailing of biodiesel by others |

### 2.1. Plantation Phase:

The main bottlenecks afflicting the plantation phase of the biodiesel supply chain are described below:

**Non-availability of high yielding varieties:** The availability of high yielding varieties of seed for both these tree born oilseeds (TBOs) is one of the biggest constraints in the development of a biodiesel value chain. The main reason for this is that although both of these TBOs have been around in the wild for a long time, systematic investigation and analysis has only recently been started on these two species. Most of the genome being used today is from the wild, which displays relatively low yields and high variability in those yields from location to location. The scientific recording of yields for both jatropha and pongamia was initiated only recently and limited data is available for seed yields. According to an FAO[2] document, potential yields for jatropha in semi-arid conditions in Andhra Pradesh, have been forecast at around 1.0 ton/ha. At this level of yield and the prevailing oil prices, large-scale commercial cultivation of jatropha and pongamia may not be viable. Therefore the key intervention required in the sector is the development of consistently high yielding jatropha and pongamia species.

**Lack of quality planting material:** Nurseries have to be developed using high yielding varieties and to make the seedling or saplings readily available. Even though some state governments such as Andhra Pradesh, Chhattisgarh, Uttarakhand are providing seedlings free of charge or at a nominal cost, the inaccessibility of the high yield seedlings remains the key impediment in the development of biofuel crop cultivation. In addition, there is a need for the development of a set of agronomic and plantation management practices for jatropha and pongamia on a commercial scale.

**Relatively low minimum support price for jatropha seed**: The low minimum support price for seeds being offered by most states is not high enough for seed collectors to earn enough to meet the minimum wage requirements for most states. Growers also find that the administratively set price is not adequate to make a profit. No seeds are being picked up in a large number of plantations across Chhattisgarh because of this. At the same time the network for seed procurement is not organized and needs to be strengthened.

**Lack of experience in plantation development and management :** As both jatropha and pongamia are relatively new TBOs to be brought under commercial cultivation, no data or records exist of mature plantations. Therefore, the agronomy, pest and diseases, fertilizer responsiveness, and irrigation water requirements at the field levels are not known.

**Availability of suitable land sites and their allocation:** In India, cultivation of biofuel crops is to be taken up on fallow or wasteland. The government will have to play a significant role in allocating this land as ownership lies with State Governments. However the identification and allocation of land is a long-drawn-out process as land in India is one of the most disputed and litigated of all commodities.

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[2] FAO, 2010

**Need for financing:** Jatropha and pongamia both have long gestation periods and have limited or no returns in early years of plantation. It is almost impossible for poor small-scale farmers to take up the planting of these TBOs without adequate support in the first few years. However, the variability of the yield along with the limited to almost no knowledge of the agronomy of the plantation, means that financing is a big risk for farmers as well as for banks. Inter-cropping has been practiced at some locations to partially overcome this bottleneck.

### 2.2. Processing and Blending

A number of bottlenecks affect this phase in addition to low capacity utilization because of poor availability of feedstock for processing and low procurement pricing. These are highlighted below:

**Dispersed feedstock production:** This limits economies of scale for setting up facilities for extraction and transesterification. Other issues of technology selection have a direct bearing on the cost of production such as whether to use solvent or mechanical extraction or batch or continuous processing. The early mismatch between production and capacity and the staggered build-up of plant capacities leading to attaining economies of scale are also issues that would need to be discussed while evaluating the viability of business models.

**Low prices for biodiesel:** OMCs were initially offering a procurement price of Rs25.00/ liter for biodiesel. When no supplier was forthcoming, this price was increased to Rs26.50/liter. However, even this price was too low as the market price of seeds was significantly higher and as a result, until the present time, no biodiesel has been supplied to OMCs.

**Controlled markets:** The OMCs are reluctant to allow biodiesel producers the freedom to directly retail biodiesel to consumers. The OMCs state that all petroleum products come under the Ministry of Petroleum and Natural Gas (MoPNG) and can be retailed only by the OMCs.

The two biofuel supply chains will interact with the petroleum products (petrol and diesel) supply chains. These products are produced to technical specification at the refinery and transported to the various warehouses, also called oil depots, by means of tanker trucks or by railways or product pipelines. At the depot, the volume of product is measured and unloaded into large tanks. When the unblended diesel or petrol is to be supplied, the product is filled in measured quantities in tanker trucks and then transported to retail establishments where it is unloaded into underground tanks. The diesel or petrol is finally supplied through a dispenser to a consumer's vehicle.

For petrol and diesel blended with biofuels, certain additional steps are required. The biofuel is dispatched from the biofuel producing plant to the depot in tankers. The quality is checked and the quantity measured and unloaded into the biofuel tanks. From these tanks it can be blended with petroleum. During the blending stage, additives such as corrosion inhibitors or pour point depressants, which improve the properties of the blend, can be mixed in. The process of dispatching it to the retail petrol pump is the same as the one described for unblended petrol. But, in the case of blended products special precautions are taken to clean the tanks and remove water. The facility costs for adding biofuels to the petroleum plants include additional storage tanks for the biofuels and the metering systems. In addition special precaution has to be taken, especially in case of ethanol and its blends, that water does not enter the system: in order to avoid moisture from the air being picked up by the ethanol, special moisture traps need to be installed.

In case of vehicles using ethanol blends, some types of rubber fittings and gaskets may have to be changed as they deteriorate faster in contact with blended fuel than with traditional petroleum products. In addition the control unit or the carburetor in the car has to be adjusted so that the air-fuel ratio can be maintained for good vehicle efficiency and efficient operation. Ethanol blending beyond 10% requires changes in the vehicle fleet. This is one of the constraints to expanding ethanol use for transport.

India has been blending ethanol with petrol since 2003 and the fuel supply chain has been well established starting from the dispatch by ethanol producers to the blending by oil marketing companies and the dispensing at the gas stations or petrol pumps. The costs for establishing this infrastructure have been borne by the oil marketing companies. The blending of ethanol in India is well established and there is little need for enhanced integration with the fossil fuel supply chain. The investments in developing the fuel supply chain from the depot onwards are in common with fossil fuels and have been already undertaken by the oil marketing companies.

A final issue is that of the pricing of blended gasoline. Ethanol has a lower amount of energy content per liter compared to that of petrol. The calorific value of ethanol is 30 megajoules per kilogram (MJ/Kg) or 7,170 thousand calories per kilogram (Kcal/kg), whereas the equivalent value of petrol is 44.8 – 46.9MJ/Kg or 10,707-11,209 Kcal/kg. Blended petrol should provide lesser mileage per liter compared to petrol. Therefore, blended petrol should be priced lower than pure petrol. At a lower percentage of blending, the price difference may be small. However at higher levels of blending, lower prices should be offered to consumers. This has been the practice in both the United States and Brazil. This type of differential pricing system requires additional adjustments in petroleum retailing outlets.

### 3. Concluding Remarks

As can be seen from the analysis presented above, biofuel supply chains show a high degree of complexity due to the fact that they are dependent on a wide variety of inputs from multiple stakeholders. The ethanol and biodiesel supply chains show some similarities but the major constraints faced by the two are quite different. In the case of ethanol the supply chain is fully developed for sugarcane. One of the bottlenecks is the inappropriate and some times inflexible pricing mechanism. If this issue can be resolved, the supply chain would function smoothly and have the ability to deliver the targeted blending by 2017.

In comparison to sugarcane, the SS and TSB supply chains are yet to be fully developed and matured. The agronomy of these crops has been studied but adaptation at the farm level and commercial success is yet to be established. Price supports or any other assistance by the government, except for exemption from excise tax of the central government, is not yet in place. The major bottleneck along the supply chain occurs at the juice extraction level. The seasonal yield comes to mills in a short period of time and the juice extraction should be undertaken within this period. Therefore mills can only operate for one to two months a year and this problem may break the entire supply chain. The petroleum supply chain is fully in place for blending biofuels. However at higher levels of blending, the product should be priced differently and that may need further adjustments in the petroleum supply chains.

In contrast to the ethanol supply chain, biodiesel is at an infant stage. Nursery and plantation stages need immediate attention because without high yielding varieties and proper understanding of suitable agronomic practices the industry cannot take off as a commercially successful, national-scale venture. Processing and other downstream segments will quickly develop if the upstream issues and pricing issues are resolved.

In both ethanol and biodiesel, retailing could be a potential problem. The mandatory requirements of blending may force OMCs to blend ethanol. However, the real incentives of biofuels blending, profits for OMCs, need to be adequate to make OMCs whole-heartedly support the biofuel industry. This aspect, however, will require further analysis.

**CHAPTER 4**

# Cross-sectoral Impacts of Biofuels

## 1. Background

While there is growing interest in the development of biofuels it has also created a body of concern especially in the areas of food security, possible socioeconomic impacts, the environment, and climate change. In this chapter we will examine the cross-sectoral implications of both ethanol and biodiesel from the value chain perspective starting from cultivation to consumption. Ideally, a large number of scientific studies at the micro-level, analyzing land use, cropping patterns, and water and energy inputs and outputs for each of the crops in different geographic conditions and seasonal variations are required to give a complete picture of the impact of biofuel production and use. The limited availability of research on these aspects makes it difficult to accurately predict this. The discussion on the plausible impacts is based on the assumption that existing cropping patterns and technology will continue to be used by the industry in the future. Major changes in cropping patterns, energy crop varieties and related technologies may change these impacts drastically.

## 2. Impact on Water Resources

Average annual rainfall in India is nearly 4,000 cubic kilometers ($km^3$) and the average flow in the river system is estimated[1] at 1,869 $km^3$. Because rain is concentrated in the three monsoon months, the usable surface water is about 690 $km^3$ per annum. Similarly about 399 $km^3$/year of ground water is available for use. Very approximately, the total utilizable water resources of the country have been assessed as 1,123 $km^3$. As stated in Chapter 2 the current consumption levels of surface and ground water are between 630 to 645 $km^3$. The per capita fresh water availability in 2008 was 1,591 cubic meters ($m^3$), although this value varies from 360 $m^3$ in the Sabarmati basin to 16,589 $m^3$ in the Brahmaputra and Barak basins. This poor distribution of water availability does qualify India to be viewed as a water stressed nation. However, when considered as a whole, India is not a water scarce country and ranks among the top ten water rich countries in the world according to data from World Resources Institute[2]. While at the national level water availability is not a problem, there are vast regions across the country experiencing localized water stress. It needs to be kept in mind that there is considerable ecological diversity in India, which is reflected in the diversity in availability, usage and experiences of stresses with regard to water resources.

In terms of water consumption, 83% of India's utilizable water is devoted to the agricultural sector, mostly in the form of irrigation. Groundwater alone accounts for 39% of the water used in agriculture. Water use in agriculture often comes at the expense of other sectors such as industry and households. With the demand from other sectors rising at a faster pace, the availability of water for irrigation will fall. Water consumption by the industrial sector was

[1] Central Water Commission, 2008
[2] World Resources Institute 2000.

estimated to be around 3% of the total national consumption in 1990 but it has been rising due to rapid growth in the industrial and services sector. It is projected that this sector will continue to enhance its water consumption at a rate of 4.2% per year. According to the World Bank, the demand of water for industry, energy production and other uses will rise from 67 billion $m^3$ to 228 billion $m^3$ by 2025. Demand from the domestic sector has remained low and accounts for only 5% of the annual freshwater withdrawals in India. Demand from the domestic sector over the next 20 years will increase from 25 billion $m^3$ to 52 billion $m^3$. However, trends indicate that this increase in demand from the domestic sector will not be as much as that of other sectors. Table 4.1 provides the predicted water demand by different sectors in India

**Table 4.1: Water Demand in Across Sectors**

| Sector | Water Demand (billion cubic meters) | | | |
|---|---|---|---|---|
| | 2000 | 2010 | 2025 | 2050 |
| Irrigation | 541 | 688 | 910 | 1,072 |
| Drinking Water | 42 | 56 | 73 | 102 |
| Industry | 8 | 12 | 23 | 63 |
| Energy | 2 | 5 | 15 | 130 |
| Others | 41 | 52 | 72 | 80 |
| **Total** | **634** | **813** | **1,093** | **1,447** |

*Source: Central Water Commission, 2008*

Water pollution is one of the critical concerns in India according to the Planning Commission. About 80% of water pollution is caused by the domestic sector due to the discharge of untreated and partially treated wastewater into rivers, streams and lakes and the rest mainly comes from the industrial sector and marginally from the agricultural sector. There are no estimates for non-point source pollution with regard to the domestic and agriculture sectors in rural areas[3]. Excessive levels of chemical nutrients lead to *eutrophication* problems (harmful growth of algae in water bodies) in some regions. Chemical nutrient pollution may become a serious problem in India, considering that fertilizer consumption is projected to double by 2020. Although there is no verifiable data, water pollution is gradually increasing in India and this will lead to a decline in unpolluted water in the face of increasing demand. The impact of the expansion of biofuel production should be seen with this outlook of water in mind.

[3] Augustin, 2003

In the context of biofuel promotion in India a clear distinction should be made between ethanol and biodiesel. Increasing demand for biofuels has an impact on water quantity and quality but these are more pertinent to ethanol than biodiesel. Ethanol crops require large quantities of water and add to water pollution through agricultural drainage, which contains fertilizers, pesticides and sediments. Water requirements for biofuel production depend on the type of feedstock and geographic and climatic variables. Such factors must be considered to determine the water requirements needed and identify critical scenarios and mitigation strategies to arrest water pollution. Feedstock cultivation, usually row-crop agriculture, is the most water-intensive phase of biofuel production. There is spatial variability, as well as temporal variability in rainfall, which makes it difficult to predict how increased irrigation requirements will exacerbate the competition for water and create local water shortages. Nevertheless, some general inferences can be made at a national level.

It is important to recognize that some crops yield more biofuel energy with lower requirements for agricultural land, fertilizer, and water, and that consumptive water (*evapotranspiration*) requirements tend to increase with land requirement. Thus, from a water supply perspective, the ideal fuel crops would be drought tolerant, high yielding plants grown with little irrigation water. Biodiesel crops such as jatropha and pongamia fall under this category whereas ethanol crops require irrigation water in India.

### 2.1. Ethanol

Currently sugarcane molasses is the major source of producing ethanol in India. However, as discussed in Chapter 2, the total quantity of molasses is not adequate to produce ethanol to meet the 20% blending requirement. Sugarcane is considered an efficient converter of biomass from water but it needs about 200-300 $m^3$/ton and along with rice and cotton it is a high water consuming crop. Approximately 25,000 liters (l) of water are needed to produce 10 kilograms (kg) of sugarcane[4]. The evapotranspiration of sugarcane is estimated at 8.0-12.0 mm/t and the total rainfall required by sugarcane is estimated at 1,500-2,500 millimeters per year (mm/yr), which should be uniformly spread across the growing cycle[5]. Rainfall data from the Indian meteorological department shows there are very few areas with such high levels of rainfall and more importantly there is no sugarcane cultivation in regions such as Kerala, West Bengal and the North Eastern States which experience such rainfall. Instead it is cultivated in states such as Uttar Pradesh, Bihar, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu where rainfall is less than 1,500 mm/yr and irrigation has to be provided to grow sugarcane in these states. Compared to the water use by the crop, its processing requires much less water (See Table 4.2).

[4] WWF, 2009

[5] Macedo, 2005.

**Table 4.2: Water Consumption in the Ethanol Manufacturing Process**

| Value Chain | Process | Mean use (total $m^3$/sugarcane t) |
|---|---|---|
| Feeding | Sugarcane washing | 5.33 |
| Extraction (grinding) | Inhibition | 0.25 |
| | Bearing cooling | 0.15 |
| Juice Treatment | Preparation of lime mixture | 0.01 |
| Juice concentration | Cooling and soaking in a sulphite salt solution (1) | 0.05 |
| | Filter inhibition | 0.04 |
| | Filter Condensers | 0.3 |
| | Condensers/ multi-jets evaporation (1) | 2.00 |
| | Condensers/ multi-jets heaters | 4.00 |
| | Molasses dilution | 0.03 |
| | Crystallizer cooling (1) | 0.05 |
| | Sugar washing (1) | 0.01 |
| Electrical power generation | Steam production | 0.5 |
| | Turbo generator cooling | 0.2 |
| Fermentation | Juice cooling (2) | 1.00 |
| | Fermentation cooling (2) | 3.00 |
| Distillery | Condenser cooling (2) | 4.00 |
| Other | Floor & equipment cleaning | 0.05 |
| | Drinking | 0.03 |
| Total | | 21.00 |

*Notes: (1) in sugar production only, (2) in ethanol production only*
*Source: Moreira J. B., 2007*

The impact of sugarcane base ethanol production on water resources depends on the type of land allocated for ethanol production. While one cannot predict this with certainty, there are two possibilities: i) the diversion of existing sugarcane land to produce ethanol through cane juice root; and ii) adding new land to cultivate sugarcane. In the first case some sugar production will be displaced but there is no incremental increase in water requirements to meet ethanol production. In the second case additional water is required to produce ethanol. How much will depend on what type of land would be diverted for sugarcane cultivation. If land used for water intensive crops such as rice is converted for sugar producing ethanol, the incremental increase may be relatively little, but if the displaced cropland is less water intensive the incremental increase may be very high. There is a third possibility and that is to open new arable land to grow sugarcane but this may not be a possibility as India has already allocated most of its arable land for agriculture.

In regions where sugarcane is grown through ground water irrigation, wide spread cultivation can result in pressure on ground water resources. If there were an expansion of sugarcane, the current area under cultivation would either increase the stress on ground water, or other crops or user sectors. As discussed in Chapter 2 the water requirements for ethanol production through the tropical sugar beet (TSB) as well as sweet sorghum (SS) routes are relatively lower. In comparison to sugarcane based ethanol manufacturing focusing on sweet sorghum would entail lower water, fertilizer and pesticide consumption. The water requirement of sweet sorghum per hectare per year is 4 million liters for each cycle[6].

### 2.2. Biodiesel

Information on water usage is limited in the case of biodiesel mainly because the cropping patterns for biodiesel crops are still being developed. Studies carried out in a four-year non-irrigated and unfertilized jatropha plantation show that the water footprint is 8,281 liters of water per liter of oil and 128 $m^3$ of water per gigajoule (GJ)[7]. Note that the water footprint includes evapotranspiration, and hence is much higher than just the irrigation water requirement. During the first year of growth, the maximum water extraction observed in the Indian context was from the top 75 cm of soil. On average one jatropha plant requires two liters of water per round of watering for an estimated 10 rounds which means one hectare of jatropha would require as little as $50m^3$ of water per annum. But in reality furrow irrigation would be carried out resulting in evaporation losses in the order of 50%. So jatropha would require about $100m^3$ per hectare per annum. As a result water impacts heavily depend on the type of irrigation that is used. The irrigation water requirement is much less than that of many other crops and the impact on water due to biodiesel production would be at a minimum if there were limited use during the establishment of the crops.

## 3. Social Impact of Biofuels

The production and consumption of biofuel can directly or indirectly lead to the achievement of the Millennium Development Goals (MDGs) including, poverty reduction,

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[6] DBT & CII, 2010.

[7] Jongschaap, et al., 2009

gender equality, environmental sustainability, reduction of child mortality and the improvement of maternal health. The highest impact on poverty reduction is likely to occur where biofuel production focuses on local consumption, involving the participation and ownership of small farmers and where processing facilities are near to the cultivation fields[8]. Field observations in Uttaranchal, Chattisgarh, Andhra Pradesh, Maharasthra, Karnataka states revealed that women were employed in large numbers during the nursery development stage, planting, adding fertilizer, pruning, and seed collection whereas men are employed largely to work the land and in watering. In transportation and seed processing and biodiesel manufacturing men are employed in larger numbers than women. Overall there is gender parity with respect to biodiesel manufacturing across the value chain in terms of the number of people employed but the same cannot be said about wage parity as women are paid less than men. In the manufacturing of ethanol, owing to the fact that major employment is created at the distillery stage, men are employed in larger numbers in comparison to women. Hence, gender equality needs to be encouraged through sensitizing stakeholders across the value chain.

From a social perspective the major impact of biofuel production is the employment generation in regions which are experiencing high levels of unemployment and under-employment. The additional returns expected to be generated by biofuel cultivation, processing and manufacturing tend to be in the rural areas, which will result in higher incomes in comparison to conventional fossil fuels. Sugarcane is a labor-intensive crop and owing to the fact that only a small amount of incremental labor is required for ethanol manufacturing, employment generation possibilities are not high in molasses based ethanol. Interviews with ethanol industrial professionals have shown that about 80-100 skilled and unskilled workers (directly or indirectly) are employed by a typical 30 KL per day capacity ethanol plant. For sweet sorghum and tropical sugar beet, in a typical facility of similar capacity, the employment figures range between 90-110 skilled and unskilled laborers (both directly and indirectly) employed. Based on these figures, about 0.12 million jobs (each job meaning 280 days of work per year) will be created by the ethanol industry if it expanded to meet the blending target of 20%.

When it comes to biodiesel, given the large tracts of wasteland that are expected to be put under cultivation and based on data collected during field visits, it is estimated that a 30 ton biodiesel manufacturing industry would require about 40 skilled and unskilled workers on an annualized basis. Taking into consideration the entire processing supply chain for a biodiesel unit of 30 tons capacity it is estimated that a total of 860 unskilled and about 30 semi-skilled jobs can be created on an annual basis. The estimated 20% blend by 2017-18 would mean about 20.54 million KL of biodiesel need to be produced annually. It is estimated that by 2017-18 about 2.3 million jobs can be created across the processing part of the supply chain of biodiesel mainly in rural areas. At an approximate rate of 140[9] man days for maintenance and harvesting, 32 million ha of biodiesel plantations may create about 16 million employnment per

[8] Annie, 2008

[9] Labor use data on oil seed plantations are sketchy. The above estimate is based on a case study of an oil seed farm in Andra Pradesh. Actual level of labor use depends on many factors such as size of the farm, level of mechanization, availability of family labor, and cost of labor. Therefore location specific labor use in oil seed plantations can vary significantly and the estimate of employment is indicative only.

annum. Together with processing a total number of employments created in the biodiesel industry would be 18.3 million per annum. Thus, in comparison to the ethanol sector, the contribution of the biodiesel sector toward employment generation is much higher and the economy can expect larger positive benefits[10].

The use of wastelands may potentially have some adverse impacts on fuel wood users. Appendix 3 presents a review of the rural energy sector and analyzes the impact of the biodiesel sector on fuel wood use. The analyses show that most of the households in rural India continue to be dependent on fuel wood for meeting their cooking energy requirements. Fuel wood is often in the form of twigs and branches of trees or the agricultural waste that cannot be used as fodder. There could be conflicts between the land required for fuel wood and for biofuel plantations in some regions. However, from a macro-level analysis, there is sufficient land (especially wasteland), which can be allotted for biodiesel plantations without compromising fuel wood requirements in rural areas. In any case, proper land selection criteria should be adopted to avoid the use of environmentally and culturally important lands and lands currently being used by communities for fuel wood or grazing purposes.

## 4. Environmental Impacts of Biofuels

There is an interface of activities along the biofuel supply chain with the environment resulting in both positive and negative environmental impacts. Table 4.3 looks at the main environmental concerns posed by biofuels.

Both ethanol and biodiesel contribute to the reduction in the use of fossil fuels whose extraction as well as use has environmental implications. Wasteland without vegetation is vulnerable to natural degradation as well as degradation due to human intervention which results in dryland salinity and soil erosion. Utilizing wasteland for biodiesel plantations will result in the creation of tree cover for a minimum period of 30-40 years in the case of jatropha and 40-60 years for pongamia. This will contribute towards enhancing terrestrial carbon sinks and reservoirs. More importantly experience in the last eight years especially in project sites that undertook an experimental plantation program, has demonstrated the possibility of putting wasteland to productive use and also contributing towards enhancing biodiversity.

[10] These potential benefits of indirect employments are quantified in Chapter 7.

**Table 4.3: Positive Environmental Impacts of Biofuels**

| Environmental Externalities of Biodiesel Production & Consumption | Environmental Externalities of Ethanol Production & Consumption |
|---|---|
| Reduced pressure on exhaustible natural resources such natural gas and oil | Reduced pressure on exhaustible natural resources such natural gas and oil |
| Reduced dryland salinity and erosion | NA |
| Increased terrestrial carbon sinks and reservoirs | NA |
| Increased vegetation cover and potential for enhanced biodiversity | NA |
| Reduced greenhouse gas (GHG) emissions via fossil fuel substitution, and land use change | Reduced GHG emissions via fossil fuel substitution |
| Promote the use of organic fertilizers | Possible, but depend on the practice |
| Reduced risk of oil spills | Reduced risk of oil spills |
| Provide options for clean electricity generation in the rural areas. | NA |

In terms of greenhouse gas (GHG) emissions reduction, biodiesel contributes at the plantation stage and in the substitution of diesel whereas ethanol's contribution is limited to emission reduction primarily through fossil fuel substitution. Biodiesel plantations such as those carried out by Tree Oil India at Zaheerabad, Andhra Pradesh, have demonstrated that apart from the greening of wastelands they can also result in promoting organic fertilizers through the use of biomanure and biopesticides. Part of the biomanure comes from in-house oil extraction and the rest from vermin composting of the biomass. Petroleum fuels are one of the major internationally traded commodities that result in oil spills. Using biofuels will reduce the risk of oil spills in that the fuel will be used in those regions in which it is produced. There is also an option of producing renewable power in remote areas, which do not have access to grid-connected power by using biodiesel. Avoidance of long distance transportation of diesel also provides additional environmental benefits.

Most of the negative environmental impacts of biofuels in India emanate from sugarcane cultivation primarily due to its water demands as well as high usage levels of chemical fertilizers and pesticides in comparison to other biofuels that are in vogue. The environmental concerns of sugarcane cultivation include excessive water consumption in cultivation; soil erosion, declining soil health and fertility; agrochemical use; water pollution; soil salinity; soil acidification; and farming marginal land.

According to the WWF, the production of sugarcane has caused a great loss of biodiversity in many countries. However, this is of less relevance for India because there is no land to be cleared for sugarcane plantations. Surface sealing and crust formation can occur on heavily compacted cane growing soils, resulting in a relatively impermeable layer at the soil surface. Salinity is also a potential problem especially when over-irrigation, inadequate drainage or cultivation occurs in a flood plain. Similarly soil acidification is also more prevalent in cane growing areas due to excessive use of inorganic nitrogenous fertilizers such as urea and ammonium sulphate. The burning of fields after the harvesting of sugarcane is a prevalent practice in India, which results in air pollution and soil degradation.

## 5. Sustainability Assessment

The social and environmental externalities of biofuels are assessed in this following section. Table 4.4 briefly evaluates the role played by biofuels in contributing towards sustainable development keeping in mind local, national and global dimensions. The assessment was undertaken using the "do no harm" assessment framework of the UNDP**.**

**Table 4.4: Sustainability Assessment of Biofuels in India**

| Safeguarding principles | Impacts | Assessment of risks breaching it (low/ medium/ high) | Mitigation measure if any |
|---|---|---|---|
| **1. Human Rights** | Biofuel development activities are expected to respect human rights and do not violate human rights nor encourage either directly or indirectly human right violations. | Low | Not required |
| **2. Involuntary Resettlement** | Projects in biofuel rarely involve any involuntary resettlement | Low | Not required |
| **3. Cultural Heritage** | Use of cultural heritage cites can be avoided through necessary legal/regulatory measures | Low | Not required |

**Table 4.4: Sustainability Assessment of Biofuels in India, (cont'd)**

| Safeguarding principles | Impacts | Assessment of risks breaching it (low/ medium/ high) | Mitigation measure if any |
|---|---|---|---|
| **4. Labor Standards** | Some violations of applicable labor laws of the country may happen. | Medium | Enforcing legal provisions |
| **5. Forced/ Bonded Labor** | No forced or bonded labor involvement is expected in any stage of biofuels production and use | Low | Enforcing legal provisions |
| **6. Child Labor** | Use of child labor can happen though the possibilities are remote | Low | Enforcing legal provisions |
| **7. Discrimination** | Some discrimination based on gender, race, religion, sexual orientation or any other basis may occur | Medium | Voluntary Standards |
| **8. Safety and Health** | Workers might be exposed to unsafe or unhealthy work environments | Medium | Awareness creation and capacity building for stakeholders |
| **9. Environmental Protection** | Many environmental impacts are positive while some negative impacts may occur | Medium | Awareness creation for stakeholders |
| **10. Biodiversity and Ecological Degradation** | There is some chance of using ecologically sensitive areas such as (a) legally protected, (b) officially proposed for protection, (c) identified by authoritative sources for their high conservation value or (d) recognized as protected by traditional local communities for biofuel production | Medium | Compliance with existing environmental regulatory framework. |
| **11. Anticorruption** | There is a need to ensure that the project activities in biofuel development do not involve corruption. | Medium | Monitoring and Evaluation |

From social and environmental perspectives there are variations not only between ethanol and biodiesel but also with respect to the feedstock used for producing the end products. Tables 4.5 and 4.6 provide a broad assessment interfacing ethanol and biodiesel manufacturing where sustainable development is carried out. In the matrix below (Table 4.5) each of the sustainability indicators are noted with respect to ethanol and biodiesel together with mitigation measures for the negative impacts, if any. The impact of biofuel promotion on each indicator is assessed by giving significantly negative indicators a score of –2, moderately negative a -1, neutral 0, moderately positive +1, and significantly positive is +2; scores based on the authors' own assessment.

**Table 4.5: Sustainable Development Matrix- Ethanol**

| Indicator | Significance -2 to +2 Scoring | Mitigation measure |
|---|---|---|
| Air quality | 0 | Ensuring no burning of sugarcane fields and residue;<br>Distilleries control emitting foul smell in the neighborhood and air emissions are as per CPCB/SPCB* norms |
| Water quality and quantity | -1 | • Awareness of water use efficiency in cropping stage and promotion of drip irrigation;<br>• Reduced chemical fertilizer and pesticide usage by promoting integrated nutrient & pest management;<br>• Promoting zero discharge distilleries |
| Soil condition | 0 | • Ensure minimal soil losses during harvesting of sugarcane, tropical sugar beet crops and sweet sorghum crops;<br>• Industrial waste generated in distilleries are properly disposed off, consistent with prevailing environmental norms; |
| Other pollutants | 0 | There should be no scope for other major pollutants including noise and odor nuisance |
| Biodiversity | 0 | The areas chosen for bioethanol value chain activities should not have any endangered species nor be placed in protected areas |
| Quality of employment | +1 | Apart from ensuring that remunerative wages are paid across the value chain, safety and health aspects need to be addressed for involved employees. |

**Table 4.5: Sustainable Development Matrix- Ethanol, (cont'd)**

| Indicator | Significance -2 to +2 Scoring | Mitigation measure |
|---|---|---|
| Livelihood of the poor | +1 | Discourage usage of machines as much as possible for collection and loading and unloading of cane or biomass as much as possible so as to provide livelihoods to the poor. |
| Access to affordable and clean energy services | 0 | There is no scope for affordable energy through bioethanol promotion but on other environmental pollutants concerns, bioethanol blending is positively cleaner. |
| Human and institutional capacity | 0 | Capacity building activities across the value chain such as cropping, transportation, milling, distilleries, blending and distribution need to be created for enhancing productivity and reducing resource usage intensity |
| Employment and income generation | +1 | Additional employment generation and income generation in predominantly rural areas will result in income multiplication and contributing towards rural economic progress |

***CPCB = Central Pollution Control Board, SPCB = State Pollution Control Board**

**Table 4.6: Sustainable Development Matrix- Biodiesel**

| Indicator | Significance -2 to +2 Scoring | Mitigation measure |
|---|---|---|
| Air quality | +1 | • Transesterification units should control emitting foul smell in the neighborhood and adhere to air emissions CPCB/SPCB standards<br>• Reducing air emissions such as sulfur dioxide emissions in vehicles with blended biodiesel |
| Water quality and quantity | 0 | • Awareness of water use in nursery stage & promotion of drip irrigation;<br>• Reduced chemical fertilizer & pesticide usage by promoting integrated nutrient and pest management;<br>• Promoting zero discharge at biodiesel processing units |
| Soil condition | +1 | • Soil nutrients and soil health will improve in wastelands put to plantation use;<br>• Industrial waste generated in processing units are properly disposed of, consistent with prevailing environmental norms; |
| Other pollutants | 0 | • There should be no scope for other major pollutants including noise and odor nuisance |
| Biodiversity | +1 | The areas chosen for biodiesel plantation are expected to be wastelands that do not have endangered species or come under ecologically protected areas. |
| Quality of employment | +1 | Apart from ensuring remunerative wages are paid across the value chain, safety and health aspects need to be addressed for involved employees. |

**Table 4.6: Sustainable Development Matrix- Biodiesel, (cont'd)**

| Indicator | Significance -2 to +2 Scoring | Mitigation measure |
|---|---|---|
| Livelihood of the poor | +1 | Discourage usage of machines as much as possible for collection and loading and unloading of biomass as much as possible so as to provide livelihoods to the poor. |
| Access to affordable and clean energy services | 0 | There is no scope for affordable energy through biodiesel promotion but on other environmental pollutants concerns biodiesel blending is cleaner. |
| Human and institutional capacity | +1 | Capacity building activities across the value chain such as cropping, transportation, milling, distilleries, blending and distribution need to be created for enhancing productivity and reducing resource usage intensity |
| Employment and income generation | +2 | Additional employment generation and income generation in predominantly rural areas will result in income multiplication and contributing towards rural economic progress |

## 6. Climate Change Impacts of Biofuels

There has been a high level debate internationally about the net energy and carbon balance of biofuels. From an environmental standpoint it is critical to assess how much energy goes in or carbon gets released against the amount of energy generated or carbon emissions avoided by a product or service. The net energy balance of a product like ethanol or biodiesel produced through energy inputs at various stages of the supply chain is assessed by a net energy ratio. This is the ratio between the life cycle energy output and energy input. Similarly the net carbon balance would mean how much more carbon is being replaced by the end product in comparison to the carbon emissions released in the life cycle (from cradle to grave or well to wheel) of producing the product. While there are a large number of studies, which have calculated the energy and carbon balance of biofuels produced from different feedstocks in different regions, there are no such micro-level studies in the Indian context. The only one major macro-level study, which was carried out recently, is referred to extensively in the following sections of this chapter.

In collaboration with the Department of Biotechnology (DBT), Ministry of Science and Technology, the Confederation of Indian Industry (CII) has published a report called *Estimation of Energy and Carbon Balance of Biofuels in India*. The report uses prevailing practices in India in estimating energy and carbon balances. While there are some deficiencies in this estimation, overall the results are useful[11]. According to this study, the net energy balance per kiloliter of ethanol from molasses is 19.11GJ and the net energy ratio is 4.57. An assessment of energy and carbon balances carried for producing ethanol from sweet sorghum has shown that the net energy balance per kiloliter of ethanol is 21.57 GJ and the net energy ratio is 7.06. The net carbon balance (in terms of avoided carbon emissions) per kiloliter of ethanol produced through this route is 1.42 tons of carbon dioxide equivalent ($tCO^2e$). The net energy balance per kiloliter of biodiesel is 63.76GJ/ton and the net energy ratio is 3.41. Similarly the net carbon balance per kiloliter of biodiesel is 4.04 $tCO^2e$ of avoided carbon dioxide[12] (Table 4.7).

[11] In the DBT study, for example, in calculating the energy balance, inputs in terms of labor-power are included, but human labor is a renewable resource which need not be deducted in calculating the energy balance as done by this study. Similarly in calculating the carbon balance, while the study accounts for life cycle carbon emissions of each of the biofuels manufacturing it does not look into the life cycle emissions of refining fossil fuels nor into the potential of pongamia, perhaps biasing the results.

[12] DBT & CII 2010.

**Table 4.7: Net Carbon Balance of Different Biofuel Feedstocks**

| Biofuel Type | Feedstock | Net Carbon Balance. t/KL |
|---|---|---|
| Ethanol | Molasses (sugarcane) | 1.1 |
| | Sweet Sorghum | 1.4 |
| | Cellulosic Biomass (bagasse) | 1.7 |
| | Cellulosic Biomass (Rice Straw) | 1.6 |
| Biodiesel | Jatropha | 4.0 |

*Source: DBT & CII, 2010.*

Biofuels have the potential to reduce GHG emissions primarily due to the use of crops that are carbon neutral. However, GHG emissions are emitted at various stages of the crop production, processing and manufacturing of biofuels. For instance, in the crop production stage, activities such as the fuel used in planting, harvesting, and transportation, as well as in the production of inputs such as fertilizer and herbicides result in the release of GHG emissions. In the case of biofuel crops on cleared forests or grasslands, the release of GHG emissions from above and below the ground through vegetation and soils will far outweigh the emissions that could be reduced from the use of biofuels[13]. Clearing forestland for biofuel production is a very remote possibility in India and therefore this is of no importance in the Indian context.

Soil nitrous oxide ($N_2O$) emissions are likely to be the largest source of GHG emissions associated with bio-energy crop production which has not been given due attention. $N_2O$ is emitted both directly in soils from mineral nitrogen additions and microbial transformations of organic nitrogen, and also indirectly with nitrogen losses through volatilization, leaching and runoff of nitrogen compounds that are converted into $N_2O$ off-site. Using a top-down analysis based on the change in atmospheric concentrations of $N_2O$, it is estimated that 3% to 5% of the mineral nitrogen added to cropland soils is eventually emitted as $N_2O$, and only about 1% of total emissions is thought to be emitted directly in the soil. In addition to the availability of mineral nitrogen, $N_2O$ emissions will also vary with environmental conditions, such as temperature, precipitation and the soil acidity. Hence emissions will vary both spatially and temporally. In India, there are no primary studies so as to understand the extent of $N_2O$ emissions expected by biofuel crops.

## 7. Carbon Financing Opportunities

Biodiesel reduces carbon emissions on two fronts, first at the generation stage where plantations of jatropha and pongamia qualify for carbon credits under the LULUCF (Land use, Land Use Change and Forestry) accounting segment for greenhouse gas emissions and second

[13] UNESCO 2000.

at the consumption level when it replaces diesel and emits less carbon. Hence, it was anticipated that there would be enormous potential for biodiesel projects to receive Clean Development Mechanism (CDM) benefits. Unfortunately the developments over the last six years have demonstrated there are substantial barriers especially due to limited approved methodologies and lack of any registered CDM project in the biodiesel domain across the world to date. Some of the methodologies approved by United Nations Framework Convention for Climate Change (UNFCCC) applicable for biofuels are enlisted below:

AM0047 - Production of biodiesel based on waste oils and/or waste fats from biogenic origin for use as fuel

AMS-III.C - Emission reductions by low-greenhouse house gas emitting vehicles

AMS-III.T - Plant oil production and use for transport applications

ACM0017 - Production of biodiesel for use as fuel is a consolidated methodology which takes into consideration the following registered methodologies:

NM0180 - BIOLUX Benji Biodiesel Beijing Project;

NM0228 - AGRENCO Biodiesel Project in Alta Araguaia;

NM0233 - Palm Methyl Ester, Biodiesel Fuel (PME-BDF) production and use for transportation in Thailand.

ACM0017 adopted by CDM Executive Board in 2010 which allows for biodiesel production (not consumption) to be registered as a CDM project for generating certified emission reductions (CER) under the UNFCCC framework. It recognizes the potential role of biodiesel in combating climate change. But the new methodology has stringent criteria for ensuring GHG abatement potential such as:

Feedstock for biodiesel production needs to be from a new plantation on degraded/degrading land that has been dedicated to the production of biodiesel feedstock.

Methodology is only eligible for biodiesel produced and used within the host country and for vehicles it must be a captive fleet (agencies such as road transport with large fleet of vehicles blending biodiesel in place of fossil diesel).

The beneficiaries of this new methodology will most likely be biodiesel producers supplying to domestic public transportation, government vehicle fleets as well as hardy and locally consumed feedstocks such as jatropha that are more likely to grow on degraded land. More importantly this methodology is only applicable for blend levels above the mandated level in the host country, so its adoption might have an impact on the implementation of biodiesel mandates in countries like India. The oil manufacturing companies, which are designated to procure biofuels in India, have never interpreted government policies regarding the blending of biofuels as a *mandate* since there are no penal provisions in the policy nor is there a designated entity for enforcing any guideline. Unfortunately in assessing the CDM potentials of ethanol blending it is perceived by various players as *mandated* blending hence they have not made efforts to register their initiatives as CDM projects.

### 7.1. Energy Plantations

Energy plantation activity involves planting oil bearing plants, which generate oil and subsequently can be transformed into biodiesel. This activity serves a dual purpose as it meets the fuel needs and the plantation or forestry activities are eligible as a CDM project activity because the planted trees (or crops) sequester carbon dioxide and help reduce GHG emission into the atmosphere.

**Estimated CER generation potential for biodiesel:** A typical project of forestry or reforestation implemented in barren/waste/degraded land will have an average CER generation of 7 tons /hectare/year for 30 years of crediting period while the actual CER potential for a given plantation has to be site-specific based on soil conditions, type of tree species, tree canopy, and agronomical practices. One CER is one ton of carbon equivalent avoided or sequestered and is generated in a project activity that is verified by a third party and certified by UNFCCC

To calculate the total CER generation potential for biodiesel development activity, one needs to know the total area covered under the plantation and more specifically the species planted (jatropha, pongamia, etc.), baseline condition (soil type), and the package of practices followed.

The total land that is projected to be put under cultivation is about 32 million hectares. By taking a conservative estimate of 5 CERs/hectares/year an estimation of the total CER potential generation can be made. It shows that CERs to be generated could be as high as 160 million/year. At an estimated price of $5 per ton of CER, the revenue generation across India is estimated to be as high as Rs36,000 million per year.

### 7.2. Biofuel Blending

Although $CO_2$ will be emitted by combusting biodiesel, this emission is defined as "carbon neutral" under the Intergovernmental Panel on Climate Change (IPCC) guidelines. Because this $CO_2$ is deemed to have been absorbed and sequestered by plants during its growth, the net $CO_2$ emission can be counted as zero when it is burned in the atmosphere. Consistent with the new methodology proposed for blending of about 300 tons per day of biodiesel based on the Palm Methyle Ester project in Thailand, it is estimated that about 142,619 CERs can be expected per year at this level of operations.

In the Indian context, as mentioned earlier, the extent of carbon emission avoided by blending ethanol and biodiesel has been worked out by the Department of Biotechnology. Based on these figures a quick back-of-the-envelope calculation of the potential CERs can be estimated. By 2017 if 20% blending ethanol as projected in the National Biofuel Policy is achieved then the avoided carbon is estimated to be 6.51 million $tCO_2e$ per year. Similarly if the targeted 20% blend of biodiesel is achieved then the avoided GHG emissions are to the tune of 83.87 million $tCO_2e$ per year. If all these potential reductions are carried forward for CDM registration at an estimated rate of $5 per $tCO_2e$ (while the current market for the permanent CERs is about 12 Euros) the projected revenue earning potential per year is about Rs1,465.5 million from ethanol and Rs18,870.75 million from biodiesel.

There is a huge potential for earning carbon revenue through plantations as well as the blending of biofuels. Unfortunately due to the high transaction costs, involvement of small farmers, and the lack of institutional framework to facilitate the CDM transactions there has been limited success in registering CDM projects especially in the plantation domain. With respect to blending, given the existing norms of the UNFCCC, if blending is carried out to meet a national mandate then the emission reduction achieved to meet such obligations are not counted for CDM. As a result, the limited ethanol blending that is happening in India has not been taken forward for CDM registration. The lack of approved methodologies that capture biodiesel plantations has been a barrier hindering the uptake of CDM projects in India. More importantly the plantation CDM projects come under LULUCF, which by definition are considered as temporary CERs in CDM parlance due to non-permanency of the carbon storage (lifetime of plantation).

Currently there are instruments available at the UNFCCC, which facilitate in reducing transaction costs of multiple GHG emission reducing projects. These instruments include bundling of small-scale projects and programmatic CDM. There are advantages and disadvantages in going ahead with either of these instruments as explained in Appendix 4. While a local/regional/national policy or standard cannot be considered as a clean development mechanism project activity, the project activities arising out of a policy or a standard can be registered as a single clean development mechanism project activity under a program of activities (PoA). This registration requires approved baseline and monitoring methodologies for defining the appropriate boundary, avoiding double counting and accounting for leakages, to ensure net anthropogenic removals by sinks and emission reductions are real, measurable and verifiable, and additional to any that would occur in the absence of the project activity. For example the Government of India through the active involvement of the Bureau of Energy Efficiency has registered a CDM project for compact fluorescent light (CFL) bulbs by bundling large number of households together for a CDM project.

A new type of CDM was established in 2007 with the same objective, to bundle of small scale-projects, to enable economies of scale to overcome transaction costs by aggregating several small projects. The key difference between the new type - Programmatic CDM - and the bundling of individual activities is the fact that in bundling, the project proponent knows and defines in advance the number of project activities to bundle. In CDM PoA, the entity running the PoA does not know in advance the number of individuals/entities that will respond to the program (because the response to such a program is by definition, voluntary). Another difference is that the activities under such a program can have a different crediting period, while project activities under a bundled small scale CDM project must have the same crediting period. Institutionally either state governments or the nodal departments for the promotion of biofuels should take the lead in using the new approach for CDM projects in the biofuel domain so as to reduce the transaction costs and the associated risks to the individual farmers.

## 8. Concluding Remarks

This chapter has assessed the social and environmental impact of large-scale production of biofuels in India. The most difficult part of this assessment is predicting the future farming systems and use of various technologies. Given the difficulties involved in predicting future activities the assessment assumes a continuation of the current farming practices and technologies. This assessment is based on the available information and the information base is weak. Therefore research on the area of social and environmental impacts of biofuel production and use should continue.

The problems with water use and pollution seem to be less in the case of biodiesel production. Water use can potentially increase if new lands are brought under sugarcane cultivation adding to the increasing irrigation water demands. The actual increase will depend on the type of crops displaced and their water use patterns.

There are positive and negative environmental impacts of biofuel production and use. Biodiesel is in a nascent stage of development hence the environmental externalities are yet to manifest on a large-scale. However, relatively speaking biodiesel promotion has significant positive socio-environmental externalities and sustainability footprints in comparison to ethanol. Most of the negative impact of both ethanol and biodiesel can be mitigated with available technologies and prevailing legal and regulatory measures. Biodiesel production has the potential to enhance rural development in India through employment and income generation.

There is a large potential for obtaining CDM benefits for biodiesel plantations. In order to avoid the large transaction costs, some institutes, rather than farmers should prepare the CDM documents and the CDM project should be at a larger scale perhaps at district levels to reduce overhead costs. A suitable financing and institutional mechanism can be designed to distribute the CDM benefits among the farmers. Current rules may not allow receiving CDM benefits if blending is made mandatory. Some innovative methods should be designed to get around this rule to have access to blending CDM benefits.

**CHAPTER 5**

# Financial Analysis of Biofuel Production

## 1. Introduction

In the Indian context, the production and use of biofuels are primarily limited to a select few existing crops. For instance, ethanol production is at present primarily sourced from molasses, which is a by-product of the sugarcane industry, while sugarcane juice, sweet sorghum and tropical sugar beet are alternate crops for the production of ethanol. Similarly, jatropha and pongamia are the two main feedstocks used for the production of biodiesel. Although these crops have been established in India for some time, their commercial use and financial viability - which provide the incentive for private economic agents to engage in biofuel production - have yet to be established. Similarly, the financial viability of ethanol production from alternatives like sweet sorghum and tropical sugar beet are also virtually unexplored.

The main objective of the chapter is to examine whether biofuel production is profitable along the different segments of the supply chain. The analysis is undertaken at two levels: i) financial profitability at the prevailing administered price; and ii) financial analysis to derive the minimum required price at various levels of the value chain. The Government of India, as well as a few State Governments, has already announced the 'administered price' for the purchase of biofuels (Rs27 for ethanol and Rs26.50 for biodiesel). This chapter assesses the adequacy of the administered price to produce biofuel while meeting the minimum financial profit requirements across the value chain. If the administered or prevailing trading prices are not adequate to make acceptable profits, private economic agents will not produce biofuels. There is a need to provide financial incentives without which the target blending will not be achieved.

## 2. Financial Feasibility of Biodiesel

Considering the characteristic of the biodiesel supply chain, the financial analysis can essentially be undertaken in three main stages:

a) Plantation– production of oil seeds

b) Oil extraction - production of straight vegetable oil (SVO)

c) Transesterfication of SVO – production of biodiesel

### 2.1. Production of Oil Seeds

In general, the financial viability of a biodiesel project is based on its input costs and the overall financial revenues including income from the sale of the core product and all by-products. In the case of biodiesel seed plantations, regional differences in terms of yields as well as the scale of the plantation critically affect the financial viability and profitability of the projects. Moreover, the financial viability of cultivating various biodiesel feedstocks, i.e. jatropha and pongamia, differ from each other. As a result, the financial analysis of the plantation project has been undertaken with 12 scenarios, which consider three main factors as follows:

a) Source of seed – jatropha and pongamia

b) Regional differences – North India and South India

c) Scale of operation – 1 Hectare, 5 Hectares and 10 Hectares and above

Jatropha and pongamia plants can be cultivated in similar climatic conditions. Except for the physical differences, primary and secondary information sources have revealed that both of these feedstocks have a similar resource requirement in terms of total manpower, irrigation, fertilizers, etc. However, there are two other critical factors that affect profitability; crop density per hectare and yield (output per hectare). Given the difference in plant size (pongamia is a large tree and jatropha is a small shrub) plantation density varies from approximately 180-200 plants per hectare (ha) for pongamia to 2,000-2,500 plants/ha for jatropha depending on soil fertility and agro-climatic conditions. Likewise, the yield is likely to be in the range of 2-3 tons and 1-1.5 tons/ha for pongamia and jatropha respectively.

Given that jatropha and pongamia are perennial crops, the financial viability has been projected based upon 30 years of project lifespan. The project life cycle analysis for both crops takes into account the fixed capital expenditure during the gestation period (4-5 years for jatropha and 7-8 years for pongamia) and recurring annual operating expense for the remaining years of the project lifecycle. The cost computation is based on two constituents:

i) Capital cost expenditures for the first 3-4 years and;

ii) Operating cost constituents for the remaining project life.

Since jatropha and pongamia plantations are primarily located on wastelands, the land lease cost has been considered at a very nominal rate of Rs1,000/ha/yr. For instance, the Chhattisgarh State Government leases land at a marginal price of Rs500/ha/yr and increases the price to Rs1,400/ha/yr from the 8th year onwards. Capital cost expenditures include land development and planting for the first year, expenditures towards fertilizers for the first three years, and irrigation for the first four years. Operating costs consist of harvesting and routine maintenance. Most importantly, the entire financial analysis is based on basic accounting principles and hence takes into account all financial costs. Table 5.1 shows the details of the key assumptions across 12 scenarios.

**Table 5.1: Key Assumption for Financial Analysis of Biodiesel**

| Key Assumptions[1] | Jatropha | | | | | | Pongamia | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North | | | South | | | North | | | South | | |
| | 1 Ha | 5 Ha | 10 Ha | 1 Ha | 5 Ha | 10 Ha | 1 Ha | 5 Ha | 10 Ha | 1 Ha | 5 Ha | 10 Ha |
| Number of plants per hectare | 2500 | 2500 | 2500 | 2000 | 2000 | 2000 | 200 | 200 | 200 | 180 | 180 | 180 |
| Maximum seed production per hectare (in tons) | 1.2 | 1.2 | 1.2 | 1.5 | 1.5 | 1.5 | 2.2 | 2.2 | 2.2 | 2.5 | 2.5 | 2.5 |
| **Maximum Person days Requirement** | | | | | | | | | | | | |
| Person days for land development per hectare | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Person days for planting and filling | 88 | 88 | 88 | 88 | 88 | 88 | 20 | 20 | 20 | 20 | 20 | 20 |
| Person days for weeding/ plant protection/pruning | 30 | 25 | 20 | 30 | 25 | 20 | 15 | 14 | 14 | 15 | 14 | 14 |
| Person days for harvesting/ decortications | 25 | 22 | 20 | 25 | 20 | 28 | 125 | 110 | 100 | 125 | 110 | 100 |

*Note: In addition, the detailed assumption sheet for the cost benefit analysis has been presented in Appendix 5.*
*[The top three lines need explanatory notes, as the superscript "1" by Assumptions suggests notes.]*
*[1] For each crop, for each of the two regions, three different plantation sizes are examined.*

In real terms, the proportion of fieldwork done by the farmer and hired labor varies according to the size of the field. For example, a farmer with a small land holding undertakes a majority of the fieldwork by himself. On the other hand, farmers with larger holdings are expected to hire extra labor to carry out much of the fieldwork. However, for the calculation of the financial internal rate of return (FIRR), no distinction is made between these, i.e. family labor and hired labor. The financial analysis concludes that farmers with smallholdings have relatively lower FIRR than the farmers with larger land holdings. The difference in financial returns is attributable to the better resource optimization as land size increases. Table 5.2

[1] Key assumptions used in financial analysis are based on the primary survey and various literature survey reports

illustrates a range of FIRRs, at the oil seed price of Rs7.5.Kg, which vary due to the size of land, regional differences and type of plant.

**Table 5.2: FIRR for Oil Seed Plantations in different Regions in India**

| Jatropha | North | South |
|---|---|---|
| 1 Hectare | 15.33% | 17.77% |
| 5 Hectare | 17.07% | 19.76% |
| 10 Hectare | 18.23% | 19.53% |
| **Average FIRR** | 17.96% | |
| **Pongamia** | **North** | **South** |
| 1 Hectare | 14.39% | 14.90% |
| 5 Hectare | 16.59% | 17.16% |
| 10 Hectare | 17.86% | 18.45% |
| **Average FIRR** | 16.50% | |

Other than plot size, the cost of land leasing is one of the important factors affecting the effective FIRR. The cost of land leasing as an operational cost component directly impacts the profitability of cultivating seeds: increasing lease costs raise the sales price of seed. On the whole, the major findings of the financial analyses are as follows:

a) The prevailing minimum support price (MSP) (for instance Rs6/kg of oil seeds in Chhattisgarh) is inadequate to earn the required profits. At this price the FIRR is in the range of 13-15%, which is lower than the acceptable FIRR range at prevailing market standards. The financial analysis suggests that the sales price of jatropha oil seeds should be set at a minimum of Rs7.5/kg and pongamia oil seed at Rs8.5/kg to meet the acceptable range of FIRR at 16-18%, which in principle is the typical average rate of return generally used in tariff calculations in the energy sector.

b) Unlike ethanol, the higher gestation period of biodiesel crops (4-5 years for jatropha and 6-7 years for pongamia) results in a longer payback period. In general, the normal payback period for a jatropha plantation is approximately 9-10 years while the pongamia plantation has a payback period of 14-15 years.

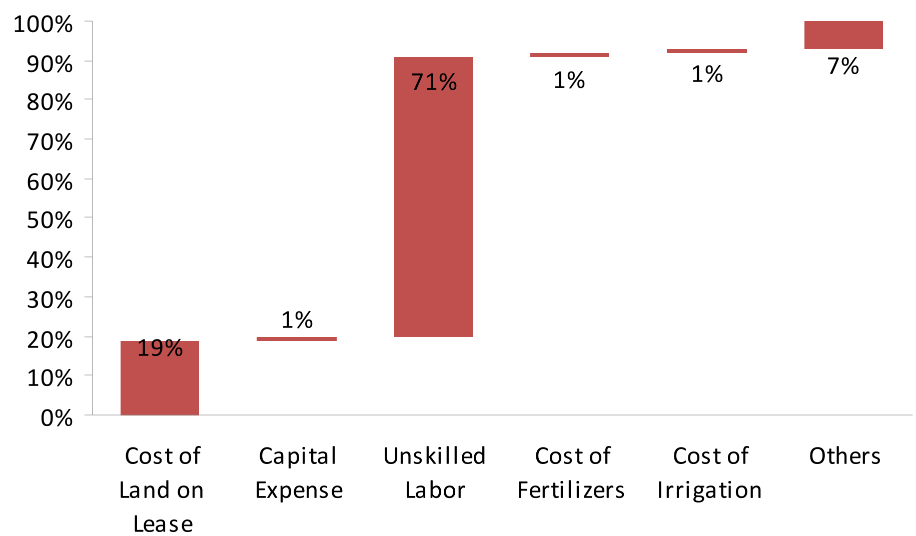
c) Both crops have a positive net present value (NPV) and an acceptable FIRR if the sale price of seeds is fixed at Rs7.5-8.5/kg.

d) In general, the FIRR of jatropha or pongamia plantations in southern India is relatively higher than a plantation located in the north due to climatic conditions.

e) A large-scale plantation results in better FIRR than a small-scale plantation.

f) In terms of average costs, the initial establishment only makes up approximately 30-35% of the total lifecycle costs; therefore, the operating cost is the most influential cost component in deciding project viability. Figure 5.1 presents the breakdown of costs incurred over the life cycle of the plantation.

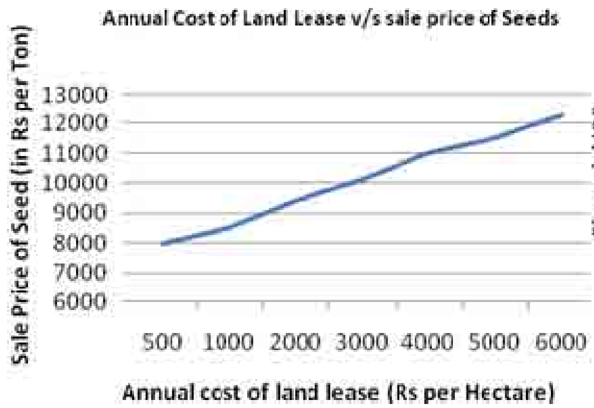
**Figure 5.1: Average Cost Factors for Jatropha/ Pongamia Plantations**




The profitability of oil seed plantations of jatropha or pongamia is highly sensitive to the variation in the costs of inputs as well as revenue streams. It is evident from Figure 5.1 that of the total cost, the greater part is made-up of recurring cost components, in particular, the labor cost of plant protection, pruning and harvesting and the lease cost of land, which remains significant throughout the project's lifecycle.

A sensitivity analysis considered the change in leasing costs, plantation density, seed yield, and seed prices. In the Indian economy, energy plantations for biodiesel production are primarily located on wastelands, which is largely under the control of State Governments. In fact, many states have been providing such land at a nominal lease rate. The lease value for land available in wetter areas is often higher than that for land available in areas with less rainfall. Figure 5.2 illustrates the relative change in the sales price of seeds to maintain the FIRR at the acceptable level. The same graph shows how the FIRR declines as the lease price increases.

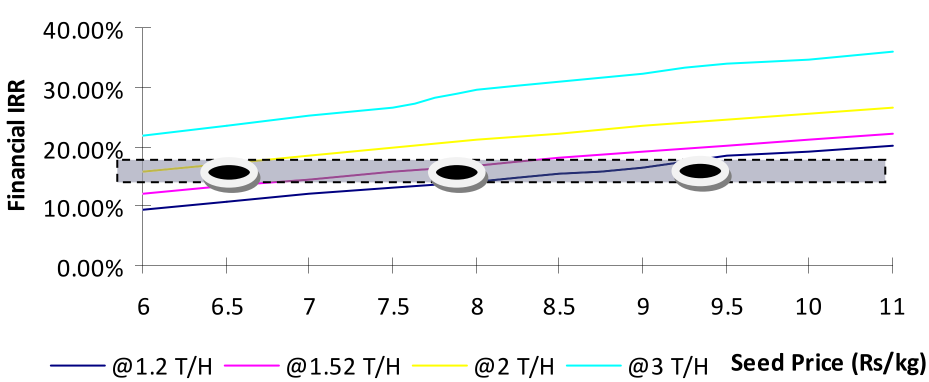
**Figure 5.2: Variations in FIRR for Jatropha Plantation Due to Change in Cost of Land Leasing**





The sale of seed is the only revenue component; hence any minor change in sales price would impact on the financial returns. Figure 5.3 clearly illustrates the relative variation between seed yield and sale price and the corresponding range of the FIRR. Assuming the minimum acceptable range of FIRR is between 16-18%, which is illustrated in the tinted box, Figure 5.3 gives an indicative price range against different assumptions concerning productivity. It is clear from the figure that if higher productivity can be achieved, the seed can be supplied at a lower price. For example, if a 2 ton/ha yield can be achieved, seed can be supplied at Rs6.5/kg.

**Figure 5.3: Variation in Market Price of Seeds with Productivity Improvements**




In conclusion, the production and use of biodiesel has not yet taken off due to the inadequate support price of oil seeds as a feedstock. In view of the prevailing low productivity, an oil seed price at Rs6.0-6.5/kg means that the plantation is not profitable. To achieve the envisaged targets, productivity increases and price revisions according to the prevailing productivity is necessary.

## 2.2. Production of Straight Vegetable Oils (SVO)

The oil extraction from seed is done to produce SVO, which is further transesterified and turned into biodiesel as a core product, with oil cake as a by-product. Oil cake is generally used as an organic manure or fuel for power generation. As a common practice, the oil extraction units are set up in a distributed manner to avoid excess transportation costs in bringing oil cake back to the farms: it is financially more feasible to set up small decentralized extraction units of 5-10 tons per day (TPD) rather than larger units. Table 5.3 illustrates the key assumptions considered in the financial model. Detailed descriptions are given in Appendix 5.

**Table 5.3: Key Assumptions for Estimation of SVO Cost**

| Assumption | 5 TPD | 10 TPD |
|---|---|---|
| Operating Days | 250 | 250 |
| Capital Expense (Rs) | 2,800,000 | 4,000,000 |
| Rate of SVO/CJO, (Rs/KL) | 28,000 | 28,000 |
| Rate of Oil Cake (Rs/ton) | 2,000 | 2,000 |
| Cost of seeds (Rs/tons)[2] | 8,500 | 8,500 |

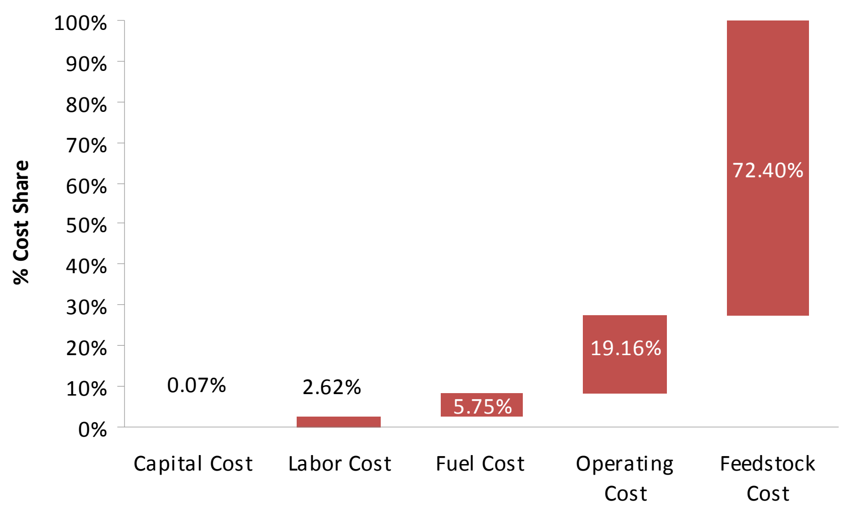
According to the analysis in the previous section, the average required market price of seed to ensure profitability is in the range of Rs7.5-8.5/kg. Besides the cost of oil seeds, given the scale of operation, it is assumed the feedstock will be collected from an average distance of 50 km, which in turn will add Rs1.0/kg to the transportation cost; hence the landed cost of seed-feedstock will be around Rs8.5-9.5/kg. Moreover, it is assumed that the sales price of seed will increase by 5% per annum. Likewise, it is assumed that the market price of SVO and its by-product oil cake will also increase by 5% per annum.

A comparative analysis between 5 TPD and 10 TPD shows that there are economies of scale for large capacity extraction units. The larger capacity units also mean increased transportation costs. If the scale of operations increases beyond a certain limit the transportation cost increases drastically. Therefore, the optimum size of the expeller unit would be around 10 TPD. The cost estimates illustrated in Figure 5.4 show that the initial capital outlay for setting up the expeller unit is low but operating expenses like fuel, labor, chemical, administrative, and operations and maintenance (O&M) costs build up to a significant part of

[2] This includes landed cost of seed including transportation cost of Rs 1 per kg.

the total SVO cost. The average cost structure of SVO production on a 20-year life cycle makes this clearly evident--approximately 72% of total cost is made up of the cost of seeds followed by the other operating and financing expenses.

**Figure 5.4: Cost Structure of SVO Production**

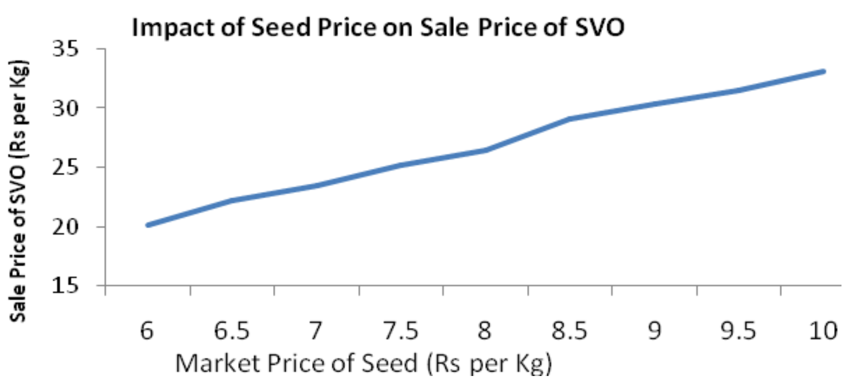



The revenue stream shows a steady source of income from the sale of SVO as a core product and oilcake as a by-product. In general, revenue from the sale of SVO and oil cake is realized in proportion of 95% and 5%, respectively. The findings of the financial analysis are:

a) The capital investment requirement for SVO producing units is comparatively lower than the operating expense for these units.

b) Given the market price of seed at Rs7.5-8.5/kg, the financial feasibility of the extraction project is viable only if the SVO is priced at least Rs28-29/liter and the producer realizes a market price for oil cake of at least Rs2.0/kg. Figure 5.5 illustrates the indicative sale price of SVO corresponding to the market price of seed.

**Figure 5.5: Impact of Variation in Seed Price on Sale Price of SVO**



c) The normal payback period for a small capacity seed extraction unit (5 TPD) is approximately 8-9 years while the payback period for a large capacity unit is slightly lower, 7-8 years.

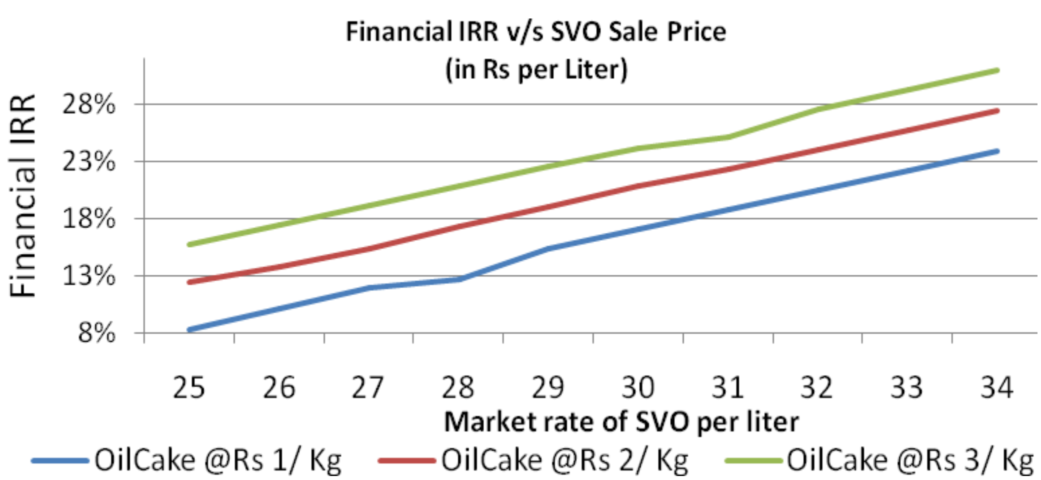
d) The FIRR ranges between 17-18% at the required price of Rs28-29/liter. Likewise, the financial NPV of a 5 TPD plant is Rs8.2 million against an investment of Rs15 million, and the NPV for a 10TPD plant is Rs20 million against an investment of Rs23 Million.

e) Currently, a few states have announced a support price of SVO at Rs16/l, which is much lower than the required price for financial viability (Rs28-29/l). It is evident from the financial analysis that with the prevailing market rates the production of SVO is financially not viable. To achieve the envisaged targets of biodiesel production and use, it is critical to provide a suitable price, depending on the productivity of oil seeds, to make SVO production financially viable.

The financial feasibility of seed extraction units is primarily determined by the input costs and the income stream. The average cost structure confirms that feedstock is the largest contributor in the overall cost; therefore, any fall in the market price of feedstock will drastically change project viability. Moreover, the market price of SVO is linked with the market price of oil cake. The subsequent section analyses these two scenarios: i) a variation in feedstock costs and ii) a change in the price of oil cake

As discussed before, the largest cost input in the overall SVO cost is the cost of oil seeds. To maintain an acceptable range for the FIRR (16-18%), Figure 5.6 shows the required corresponding price of SVO given the market price of seed. Moreover, it also illustrates the relative change in FIRR attributable to the market price of oilcake. With the current market price of Rs16/l, the FIRR is negative and hence not viable. To achieve an optimal and average FIRR requirement of 18%, the minimum price of SVO should be set at Rs27/l.

**Figure 5.6: Variation in FIRR vs. Seed Sale Price**



In light of the fact that the sale of oil cake presents an important revenue stream for the SVO manufacturer, the market price of oil cake plays a decisive role in determining project viability. At present, since the supply of oil cake is limited, it can realize a significant market price i.e. Rs2.0-3.0/kg. However, the rapid expansion of the biofuel sector in the near future may flood the market with oil cake, pushing down sales prices. Figure 5.6 shows the price variation in SVO in comparison with the price variation in seed cake.

### 2.3 Production of Biodiesel

A wide variation in transesterfication capacity has been seen across India ranging between 30 TPD to 300 TPD; hence, the present financial analysis considers three scenarios (30 TPD, 100 TPD and 300 TPD) to ascertain the financial viability of transesterfication plants. Across the globe, transesterfication technology of SVO is commercially proven and established; hence it is implicit that technical parameters would remain standard for all types of plants. The basic assumptions made in assessing the financial viability of biodiesel production units are shown in Table 5.4. It is generally assumed that the operating cost will increase at 5% per annum hence the price of biodiesel will also increase with the same escalation rate.

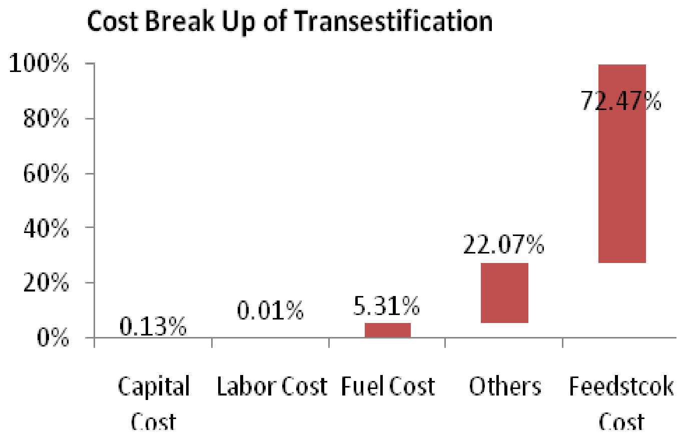
**Table 5.4: Key Assumption for Assessment of Financial Viability of Transesterfication Unit**

| Assumption | 30 TPD | 100TPD | 300TPD |
|---|---|---|---|
| Operating Days | 300 | 300 | 300 |
| Biodiesel Oil Recovery from SVO (%) | 95% | 95% | 95% |
| Proportion of Glycerol (%) | 12% | 12% | 12% |
| Capital expense (Rs million) | 27 | 44.20 | 132.20 |
| Assumed Market Price of SVO (Rs/KL) | 27,000 | 27,000 | 27,000 |
| Price of Glycerol (Rs/Ton) | 27,000 | 27,000 | 27,000 |

In general, the comparative analysis between 30 TPD and 100 TPD and 300 TPD shows relatively better cost economics for larger capacities than smaller ones due to economies of scale. At present, there is a shortage of oil seed availability in the market and therefore larger capacity plants could suffer from an under-utilization of capacity. Smaller capacity plants can function at full capacity and register better profitability.

At the outset, the cost structure mentioned in Figure 5.7 illustrates that feedstock cost is the largest cost component and has the largest impact on the overall manufacturing cost of biodiesel. Any change in the cost of feedstock will significantly impact on the cost of the end product. Unlike other components of the value chain, i.e., seed and SVO production, the transesterfication facility is relatively capital intensive. But, over the average 20-year project life, capital costs are minor contributors to total cost.

**Figure 5.7: Cost Structure of Biodiesel Manufacturing Through Transesterfication**




Besides the biodiesel as a core product, glycerine is a by-product, which also has some commercial value. In fact, at the prevailing market price of glycerine, it can contribute approximately 12% of the total revenue. The long term pricing of glycerine remains a debatable issue. As of now, glycerine is in relatively limited supply and it fetches a fairly attractive market price of Rs27/l. Considering the biodiesel production targets in medium to long term, glycerine supply may exceed the demand, which in turn will drastically diminish the market price of glycerine. Despite the possibility of this price decline, this analysis considers the market price of glycerine at a constant rate of Rs27/l throughout the project's life cycle.

In general, the financial analyses provide the following results:

a) The project life cycle cost assessment suggests that 78% of the total cost is made up of SVO cost.

b) The Government of India, along with a few State Governments, has already announced the administered price for biodiesel at Rs26.50/l, at which the financial return is negative. At the prevailing costs and productivity Rs37/l is required to provide 18% FIRR. The inadequate administered price of biodiesel is one of the key hindrances for the development of the biodiesel market in India.

c) Given the market price of SVO at Rs28/l[3], the financial feasibility of biodiesel production for a transesterfication extraction project is viable only if glycerine attracts the market price of Rs27/l throughout the project lifecycle.

d) The normal payback period for a small capacity seed extraction unit (30 TPD) is approximately 8-9 years while the payback for a large capacity unit (300 TPD) is 5-6 years at the required price of biodiesel.

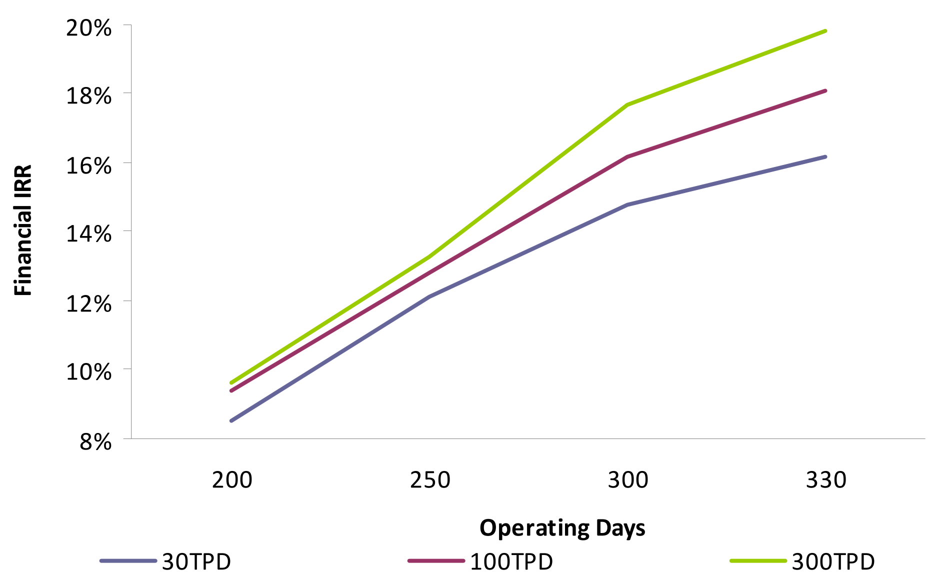
[3] This include the cost of transportation at Rs 1 per liter

e) For smaller capacity projects like 30 TPD, the project FIRR is approximately 14.80% at the price of Rs37/l, while for larger capacity projects like 300 TPS the FIRR is within the range of 18-19%. This result is obtained when the project capacity utilization is in the 80-85% range.

f) The NPV of the 30 TPD is approximately Rs78 million against capital investment of Rs303 million, NPV for 100 TPD is approximately Rs172 million against capital investment of Rs490 million and the NPV for 300 TPD is approximately Rs520 million against capital investment of approximately Rs1,390 million.

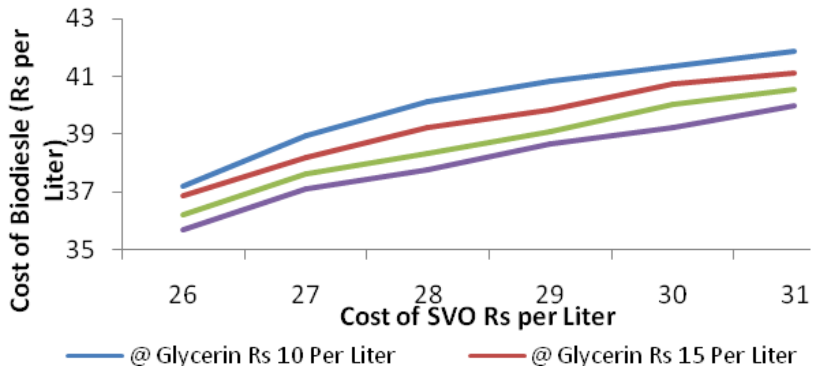
Since transesterfication is an established and proven technology, the operating cost would likely not undergo any major change in the future. Hence, the availability and cost of feedstock are two key variables that can affect the biodiesel ex-factory price. A key variable affecting plant viability is the extent that the plant can operate over the year. Figure 5.8 illustrates the variations in operating period and its corresponding impact on profitability.

**Figure 5.8: Impact of Variation in Capacity Utilization of Transesterfication Plant on FIRR**



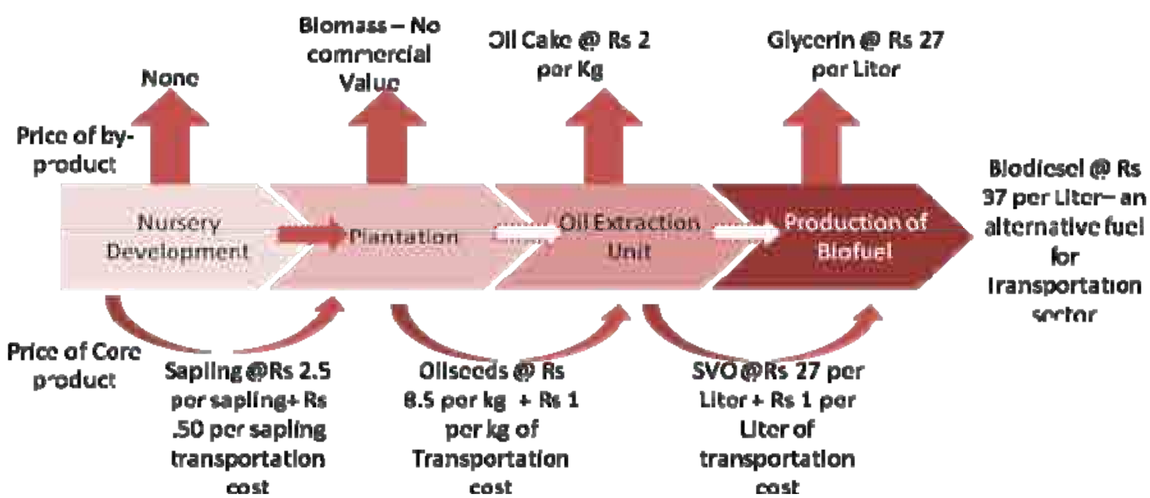

As mentioned previously, feedstock is the largest element of the cost and given the volatility of the SVO price in the market, therefore the price of biodiesel is directly coupled with the cost of feedstock. The diagram illustrates the impact of SVO price variations on the market price of biodiesel. Moreover, Figure 5.9 presents four scenarios depicting different market rates of glycerine and its relative impact on biodiesel pricing.

**Figure 5.9: Variation of Cost of Biodiesel vis-à-vis SVO Price and Glycerine Price**




To sum up, Figure 5.10 presents a summary of how prices are formed across the value chain. With the present cost situation, the detailed financial analysis recommends a minimum support price of biodiesel at Rs37/l, which provides sufficient financial returns to each and every stakeholder across the value chain. Note that this price is only indicative and productivity increases can bring this price down considerably. It is evident that the prevailing administered price of biodiesel at Rs26.5/l does not provide adequate financial incentives for the producer to manufacture biodiesel.

**Figure 5.10: Price Building Model of Biodiesel**




## 3. Financial Analysis of Ethanol

Unlike biodiesel, the production of ethanol has a well-established value chain. Although, ethanol is sourced through several feedstocks including sugarcane, sweet sorghum (SS) and tropical sugar beet (TSB), the process of making ethanol is common for all feedstocks. Essentially, the production of ethanol is a two-step process thus the financial analysis has been undertaken at two stages as follows:

a) Cultivation of feedstock crops

b) Production of ethanol

### 3.1. Cultivation of Feedstock Crops

Sugarcane is one of the key sources of sugar and also the primary raw material for ethanol. The production of ethanol is largely through molasses, which is one of the by-products in the sugar manufacturing process. Recently, the industry has brought in a few more alternative sources of feedstock like SS and TSB for the production of ethanol. However, the financial viability of ethanol production from SS and TSB has yet to be proven commercially. In view of the current developments of these alternative sources, the following analysis presents the financial viability of producing ethanol from different sources; hence the analysis has been undertaken with 27 scenarios, which would consider three main factors as follows:

a) Feedstock – sugarcane, sweet sorghum, and tropical sugar beet

b) Regional differences – 3 regions in India (north, south, and west India)

c) Scale of Operation – 1 hectare, 5 hectares, and 10 hectares and above

#### 3.1.1 Sugarcane Production

Across the country the economics of producing sugarcane is enormously different in terms of costs and benefits. Regional differences and differences due to the varied climatic conditions result in different costs for growing sugarcane. Given the intricacies of the data, an exhaustive reference table has been provided in Appendix 5 with details estimating the various costs of production. Besides the standard costs, the market price of sugarcane is used to estimate the revenue. In brief, the financial analysis of sugarcane cultivation resulted in the following findings:

a) As a result of high yield in the western states; especially southern Maharashtra and northern Karnataka, returns are very attractive there in comparison with north and south India;

b) At the prevailing market price of Rs2,250/ton, sugarcane gives very attractive returns ranging between 20-31%. At a few sugar belt regions in Maharashtra and Karnataka, the financial returns are to the tune of 30% whereas in northern states financial returns are around 25%. Essentially, higher returns are attributable to higher yields and higher market prices in these regions.

c) The sugar industry has a typical ‘sugarcane production cycle’. Seeing the increasing price of sugarcane, consecutive years would lead to a surplus in production and, in turn, see the price of sugarcane drop drastically, leading to lower production and eventually an increase in price. This whole cycle takes about 5-7 years to complete.

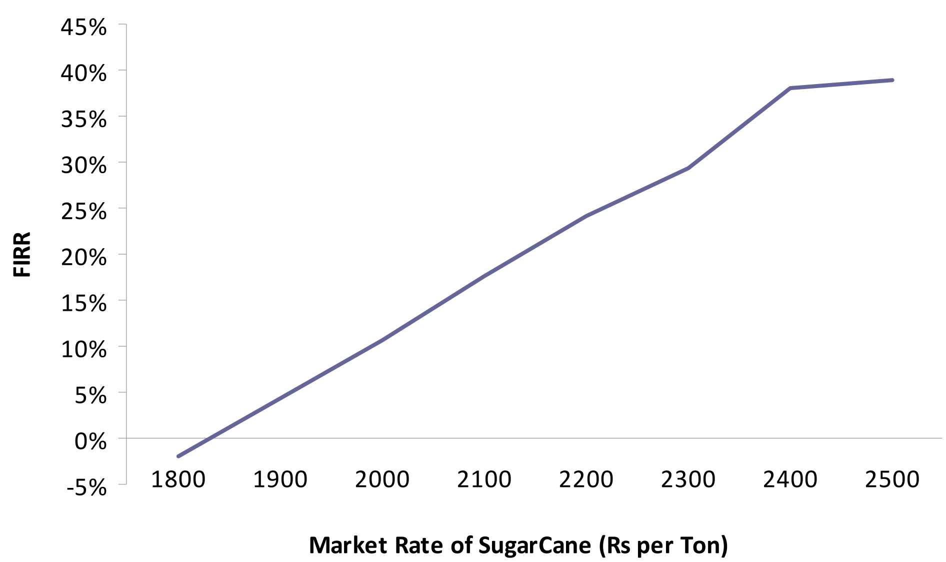
d) Most importantly, the price of sugarcane across the country is highly volatile and varies drastically year-on-year. The price is directly influenced by the demand-supply scenario of sugarcane. This analysis uses market prices for FY 2009-10.

e) Similar to biodiesel crops, the financial returns for small farms (1-5 hectare) are lower than for large farms (above 10 hectare) due to economies of scale[4].

f) Across the country, cost inputs remain largely the same. The difference in profitability is due to the yield and market price of sugarcane.

With the prevailing market rate of Rs2,250 per ton in Uttar Pradesh, sugarcane profitability is very high vis-à-vis other crops. The fluctuation in price is the main determinant of profitability. Figure 5.11 illustrates the impact of the market price and the resulting change in FIRR.

**Figure 5.11: Market Rate of Sugarcane and Change in Effective FIRR**




### 3.1.2. Sweet Sorghum Cultivation

Although sweet sorghum is one of the most promising alternative sources of ethanol the crop is still in the pilot stages of development. The data used for estimating cost and revenue is based on the primary surveys through field visits and secondary literature surveys. All the assumptions used for financial analysis have been provided in the Appendix 5. Most importantly, sweet sorghum is a biannual crop that produces grain as well as cane twice a year. In the first period, the yield of grain and cane during the rainy season is 1 ton and 15 tons respectively and in the consecutive season, the yield of grain and cane is 2 tons and 25 tons per hectare respectively. Apart from basic cost inputs, the crop yield and the market price of grain

[4] The profitability or financial analysis of each crop is based on proper accounting and considers the costs incurred for the particular activity. For instance, even though the farmer owns the land and provides his own labor, the costs of land and labor are taken into account to estimate the financial viability of cultivation.

and cane are two decisive factors that decide the financial profitability of producing a sweet sorghum crop. Unlike sugarcane, the market for sweet sorghum is not well defined and the price discovery of grain as well as cane has yet to be established.

The financial viability of sweet sorghum cultivation is estimated based on the above mentioned assumptions with respect to yield of grain and cane. To achieve the acceptable range of FIRR; or more precisely financial returns of 16%-18%, the recommended market price needs to be at least Rs1,400/ton and Rs9,000/ton for sweet sorghum cane and its grain respectively. Until now, the yield has been calculated based on experimental plot data, which has been recorded at very high levels in comparison to the actual yields under field conditions. The primary survey of southern states shows that the actual yields are much lower than those recorded in the literature.

It is evident from Table 5.5 that land and labor are two key cost contributors. As mentioned in the previous section, if the farmer owns the land and cultivates it himself, approximately 60% of the total cost is saved; hence the private annual returns—ignoring land and own-labor costs—would be in the range of 50%-60%. Moreover, the cost of cultivation is highly sensitive to yield. Table 5.5 illustrates the indicative price of grains and cane with different variations to achieve the acceptable range of FIRR of 16-20%.

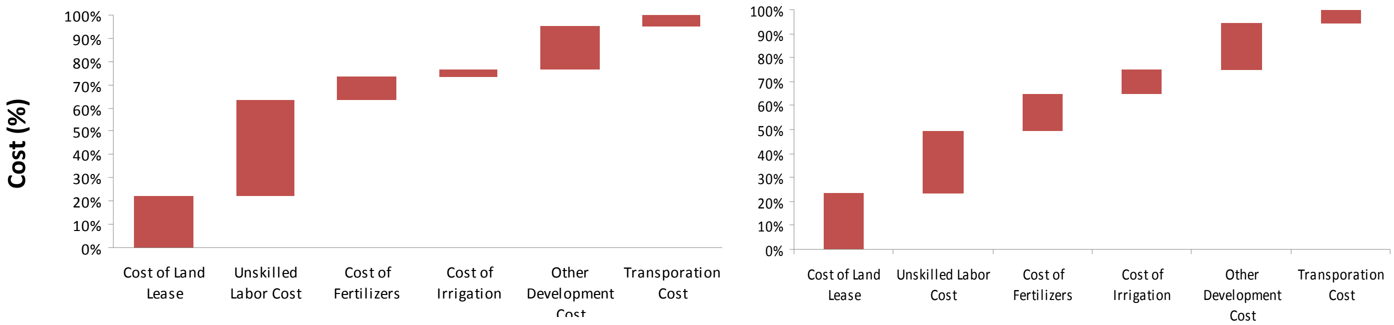
**Table5.5: Assumptions for Financial Analysis of Sweet Sorghum Cultivation**

| | | | | | |
|---|---|---|---|---|---|
| Grain – Yield: tons per hectare | 2.5 | 3 | 3.5 | 4 | 4.5 |
| Grain – Indicative market price Rs/ton | 9,000 | 8,600 | 8,100 | 7,700 | 7,430 |
| Cane – Yield tons per hectare | 30 | 35 | 40 | 45 | 50 |
| Cane – Indicative market price Rs/ton | 1,500 | 1,410 | 1,330 | 1,260 | 1,180 |

### 3.1.3 Tropical Sugar Beet Cultivation

Similar to SS, TSB is also a recently introduced crop. Although the cultivation of the traditional beet is widespread in India the commercial viability of the tropical sugar beet is yet to be proven. The cost of land on lease and labor are two major contributing factors that account for 45% of the total cost.

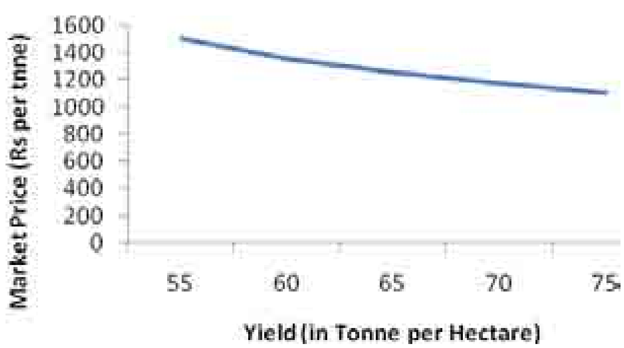
**Figure 5.12: Cost Structure of Sweet Sorghum and Tropical Sugar Beet Cultivation**




With the current experience, the market price of the TSB root is assumed to be at Rs1,250/ton. Akin to SS, TSB also does not have a well established market and commercial prices for the TSB root are yet to be established. In the context of this analysis, the recommended price of TSB root is based on the minimum and acceptable range to realize a long-term rate of return of between 16-18% for the farmers.

The financial viability of TSB is estimated on the above assumptions with respect to yield of grain and cane. To achieve the acceptable range of FIRR; or more precisely financial returns of 16%-18%, the recommended market price needs to be at least Rs1,250/ton for the TSB root. In the future, if the yield happens to improve, the market price could be below this.

**Figure 5.13: Variation in Market Price vis-à-vis Yield of TSB**




### 3.2. Financial Analysis – Production of Ethanol

Although, ethanol conversion technology using alternative feedstocks is similar to ethanol conversion from sugarcane, there are few commercially viable production plants established in India. In brief, the financial analysis undertaken here is prepared through four techniques

A. Ethanol production using molasses; a by-product of sugar production

B. Ethanol production using direct sugarcane

C. Ethanol production using sweet sorghum grain and cane

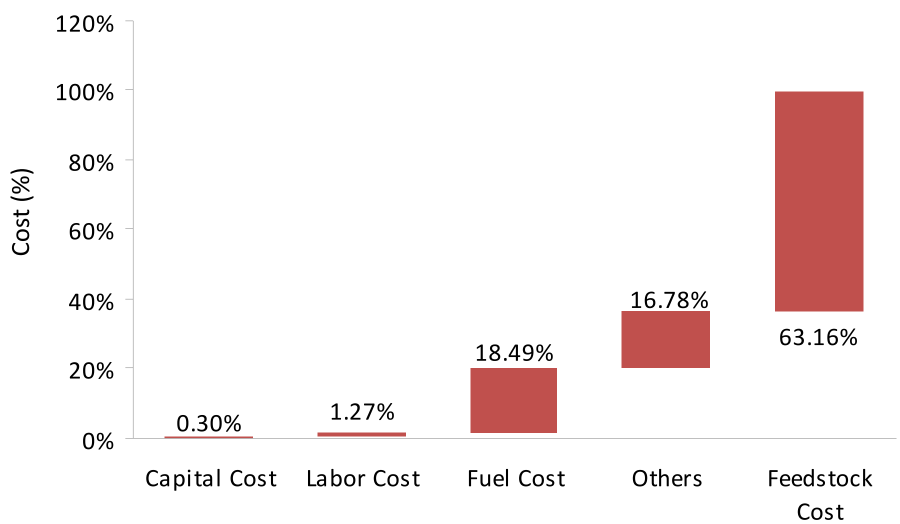
D. Ethanol production using tropical sugar beet root

### 3.2.1. Ethanol Production Using Molasses

In India, ethanol is largely produced using molasses, which is a by-product of sugar manufacturing. To earn higher revenues, most of the sugar mills have integrated distilleries. Typically, these modular distilleries are set up with a capacity of 50-100 kiloliters per day (KLPD). For this financial analysis, two scenarios have been developed to estimate an FIRR - 50 KLPD and 100 KLPD. Even if the distillery units are integrated with sugar mills, the molasses is valued at the market price of Rs3.5/kg.

The financial analysis shows that across the lifecycle cost, molasses is the most critical and largest cost factor, at more than 60% of the total cost. In fact, distillation is an established technology so there is little chance of any cost reduction. Moreover, the price of ethanol is directly coupled with the trading price of molasses as a feedstock. It has been learnt that given the alternative use of molasses, its market price varies between Rs3,200-3,600 per ton.

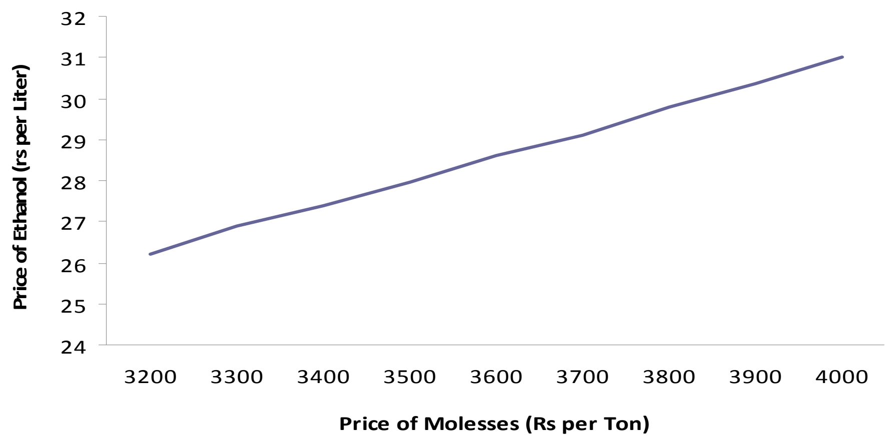
**Figure 5.14: Breakdown of Cost Components of Ethanol Production from Molasses**




With the prevailing market rate of molasses (Rs3.2 - 3.6/kg), the production of ethanol is viable only if the minimum price realized for ethanol is Rs27-28/l. The prevailed market price of Rs21.50/l (the tendering rate in 2009) results in an average FIRR of 1.38%. Moreover, the market price of molasses is an important factor in the market price of ethanol. Any change in molasses price would significantly impact the price of ethanol.

As mentioned in the previous sections, although there is a government mandate towards blending of ethanol in petrol, due to the lack of supply such a mandate has not been entirely met. Keeping the FIRR level at 18% in all cases, Figure 5.15 shows the change in ethanol prices due to the variation in the price of molasses.

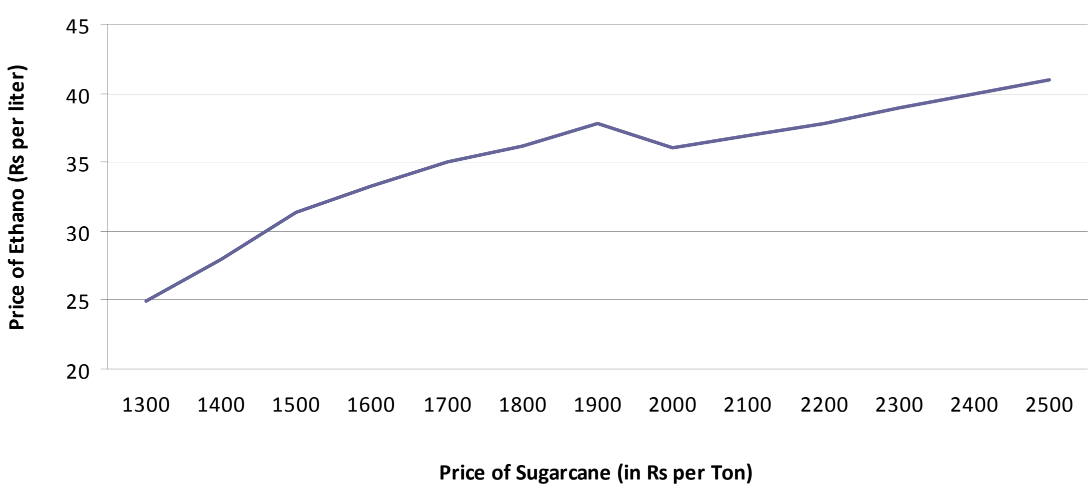
**Figure 5.15: Variation in Ethanol Price due to Molasses Price**




### 3.2.2 Ethanol Production Using Sugarcane Juice

In addition to the molasses route, ethanol can directly be produced through sugarcane. The commercial viability of producing ethanol only from sugarcane is not feasible due to the unavailability of sugarcane throughout the year. In general, this route is commercially viable only if there is a partial utilization of the sugar mills which otherwise produce ethanol through stored molasses for the remaining year. This financial analysis assumed a capacity fragmentation of 50-50 in the percentage of ethanol production directly through sugarcane and molasses respectively. Figure 5.16 illustrates the required change in the price of ethanol attributable to any price change in sugarcane.

**Figure 5.16: Relative Price Movement of Ethanol with Price Movement in Sugarcane**



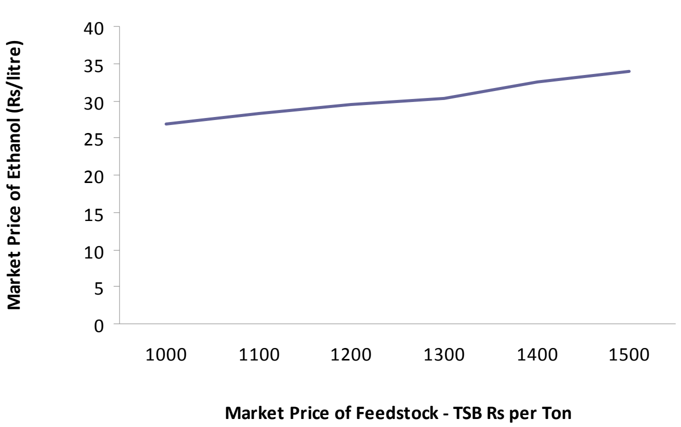
A joint financial analysis of producing ethanol, partially from sugarcane and in part from molasses, yields a negative FIRR at a prevailing market price of Rs21.5/l for ethanol, which makes ethanol production financially unattractive. The adequate financial viability, of producing ethanol from the combined route (partially from sugarcane and molasses) is viable only if the producer realizes a minimum market price of Rs40/l. Similar to producing ethanol from molasses, the process is by and large optimized therefore the cost of ethanol is directly coupled with cost of sugarcane as a feedstock. As a result, the variation in ethanol price is mainly attributable to the feedstock costs.

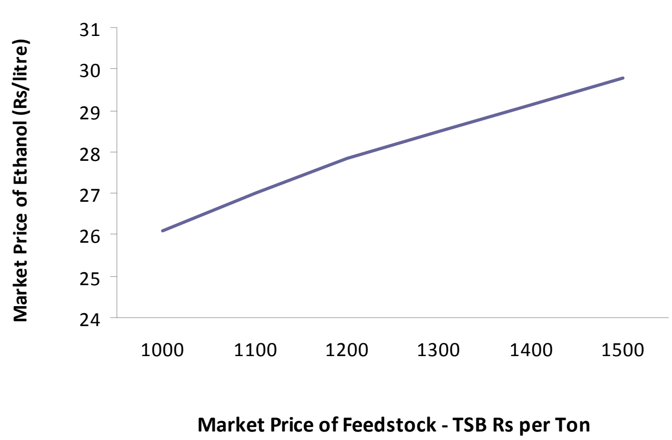
### 3.2.3. Ethanol Production Using Sweet Sorghum and Tropical Sugar Beet

Typically, the conversion process of juice to ethanol using the stalk of SS and root of TSB is the same and therefore the basic capital and operating costs remain same for both. In particular, the difference in operating cost is due to the feedstock cost and recovery rate (the proportion by weight of sugar realized from the raw plant). For SS, the recovery rate is assumed as 5.5% whereas the recovery rate for TSB is about 7%. For SS, the landed cost including transportation cost of feedstock is assumed at Rs1,480 per ton which is in line with the prevailing market price. Similarly, the trading price for TSB is assumed at Rs1,330 per ton. In view of the current market prices, the ethanol cost would be about 31/l and 34/l for SS and TSB, respectively, which is higher than the current ethanol trading price and the price announced by government.

The cost of ethanol is highly sensitive to the cost of feedstock and the recovery rate. For instance, if the recovery rate for SS is increased from 5.5% to 6%, the financial return of a 100 KLPD capacity unit will increase from 16.35% to 20.53%. Similarly, if the recovery rate increases for TSB from 7% to 8% it will increase the financial return of a 100 KLPD capacity plant from 16.5% to 19.4%. In addition to the yield, the feedstock price is the most important factor in determining the price of ethanol. Figure 5.17 illustrates the relative change in the ethanol supply cost due to changes in the feedstock price.

**Figure 5.17: Price Movement of Ethanol vis-à-vis Price of Feedstock**

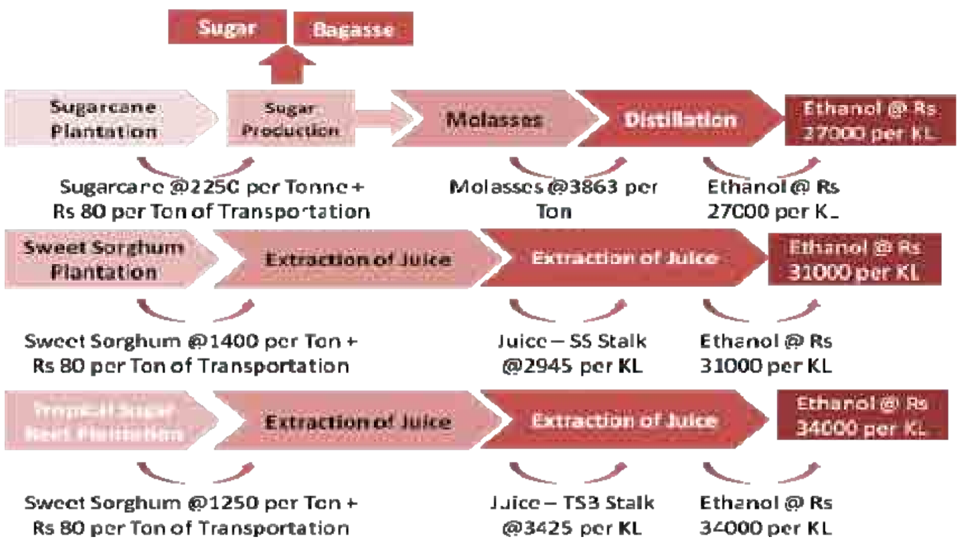


## 4. Cost Building Model of Ethanol Production

To sum up, Figure 5.18 presents the price structure across the value chain of producing ethanol from alternative sources. With the present productivity and cost scenarios, the detailed financial analysis shows that the price of ethanol produced by molasses should be Rs27/l, to provide sufficient financial returns to each and every stakeholder across the value chain. It is evident that the prevailed administered price of ethanol at Rs21.5/l results in inadequate returns (~1.5%) for the ethanol manufacturer, which in turn has led to the short supply of ethanol for blending with gasoline or petrol. The recent increase in the ethanol purchasing price may have resolved this issue.  Note that the required price estimated here is indicative and considers only the costs from the producer's side. In addition to the costs, the benefits or the consumer's willingness to pay for blended petrol should also be considered.

**Figure 5.18: Price Building Model of Biodiesel**




In addition to molasses as a primary feedstock for ethanol production, sweet sorghum and tropical sugar beet are alternative feedstocks that can be used. With the current cost and yield inputs, ethanol production from these alternative feedstocks is slightly costlier than through molasses, i.e., the indicative prices for providing financial incentives for SS and TSB are Rs31/l and Rs34/l respectively. Given these prices, the production of ethanol from SS and TSB can be commercially viable with producers getting adequate returns.

## 5. Oil Prices and Profitability of Biofuels

The approach taken in this chapter has relied on the actual cost of production as the basis for forming the required price of biofuels.  However, a price of a commodity is jointly determined by the interaction of its cost (supply side) and the willingness to pay (demand side). In the case of biofuels demand originates from the demand for petrol and diesel. Since, biofuels are substitutes for these petroleum products, the price of biofuels is closely linked to petroleum market prices. In this section we use this alternative price mechanism to examine the profitability of ethanol and biodiesel.

According to Figure 5.10, at the required market price of Rs37/l for biodiesel, the SVO and seed prices are respectively, Rs27/l and Rs8.5/kg of seed. This shows the SVO price is 72.9% of the biodiesel price and the oil seed price is 22.97% of the final price of biodiesel. If the basic cost structure and technology does not change, this proportion would remain more or less unchanged. With this assumption one can derive the price of SVO and oil seeds starting from a biodiesel price that is based on the prevailing market price of conventional diesel. For example if the current diesel price is Rs38/l, based on the energy content, the equivalent price of biodiesel is Rs34.2[5] per liter. At this price the corresponding price of SVO and oil seeds would be Rs24.96/l and Rs7.86/kg respectively. Re-estimating the FIRR of oil seed plantations, SVO production and biodiesel production using the above derived prices provides the results in Table 5.6[6].

**Table 5.6: Diesel Pricing Scenario and Relative FIRR of Biodiesel Production**

| Diesel Price (Rs per Liter) | Average FIRR from Jatropha Feedstock | | |
|---|---|---|---|
| | Oil seed | SVO Production | Biodiesel Production |
| 38 | 14.56% | 13.23% | 16.01% |
| 42 | 20.45% | 19.89% | 21.86% |
| 48 | 29.4% | 27.75% | 31.56% |

The results show that if the market price of biodiesel is fully aligned with the prevailing diesel price, the returns are adequate for biodiesel. However, oil seed and SVO returns may not be adequate at this price. As diesel prices increase the FIRR also increases and at the diesel price of Rs40.3/l all the segments of the supply chain provide returns of 18%. Up to this breakeven price, the biodiesel industry will not take off without government interventions such as subsidies. If biodiesel is priced at Rs37/l, and sold at the current market price (Rs38)[7] OMCs should pay taxes to the government. As of March 2010, the diesel price includes about Rs6.08 of net taxes. This means if the OMC pays Rs37 to the biodiesel producers, they will have to pay Rs6.08 net taxes to the government. One way to provide a subsidy is to exempt biodiesel from taxes and give a tax rebate for OMCs based on the quantity of biodiesel purchased by them.

The fiscal implication of such a subsidy depends on oil prices and the quantity of biodiesel produced in the country. Therefore it is hard to estimate the government revenue loss with any accuracy. If a tax rebate at 6.08/liter of biodiesel is implemented at the current diesel price, the revenue loss to the government is about Rs32.45 billion a year at the quantity required for 20% blending. It is highly likely that oil prices increase in the near future and that the subsidy requirement would fall over time. In fact once oil prices go beyond the breakeven price, the government would collect additional revenues from biodiesel taxes.

[5] This price was obtained assuming the energy content in 1 liter of biodiesel is equal to 0.9 liter of diesel.
[6] The analysis assumed there would be a 100% tax exemption for biodiesel.
[7] The weighted average price of blended diesel is Rs37.8. if one blended liter contains 20% biodiesel.

## 6. Concluding Remarks

This chapter assessed the financial feasibility of various segments of the biofuel supply chain to examine the financial incentives under the prevailing administrative prices of ethanol and biodiesel. As shown in the summary Table 5.7 neither ethanol nor biodiesel production is profitable under the current administratively determined price regime. These results clearly demonstrate the biofuel industry will not take off under the current pricing mechanism and 20% blending of ethanol and biodiesel is not feasible without a major price revision. Recent price revision may have resolve this issue for ethanol. Pricing issue of biodiesel is yet to resolve.

**Table 5.7: FIRR at Current Prices and Required Prices for Profitability**

| Biodiesel | | | Ethanol | | |
|---|---|---|---|---|---|
| Segment of Supply Chain | FIRR under current price | Required price for 18% returns | Segment of Supply Chain | FIRR under current minimum price | Required price for 18% returns |
| Oil Seed | 1.22% | Rs7.5-8.5 per kg | Sugar Cane production | 4% | Rs2250 per Ton |
| SVO | Negative | Rs27 per liter | Ethanol from Molasses | 1.58% | Rs3.86/l of molasses<br>27.0/l of ethanol |
| Biodiesel | Negative | Rs37 per Liter | — | — | — |

The analysis shows that the biodiesel industry may requires some initial subsidy to ensure financially viablility This would result in a revenue loss to the government at the beginning. However, as diesel prices increase, subsidy requirements decline and once oil prices increase beyond the breakeven price, the government may collect tax revenue from biodiesel. The price also depends on the productivity of oil seed crops. If the productivity can be increased substantially, biodiesel could be supplied at a lower price while maintaining profitability (Table 5.8)

**Table 5.8: Productivity Rate of Return and Prices of Biodiesel**

| Biodiesel Price Under Different Rates of Return, Rs./liter | | | | Price for 16% Returns | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rate | 14% | 16% | 18% | Yield t/ha | 1.2 | 1.5 | 2.0 | 2.5 | 3.0 |
| Price Rs/l | 35.9 | 36.5 | 37.9 | Price Rs./l | 36.5 | 35.9 | 32.3 | 28.7 | 25.1 |

As the analysis shows, there are economies of scale in most of the segments of the supply chains of biofuels. They are usually easy to be realized by processing units whereas they are not that easy to identify at the plantation level, especially in the case of biodiesel. A suitable model of farming maybe with a large-scale nucleus farm together with a seed expelling unit and a number of small farmers around this nucleus farm: this may allow for a realization of economies of scale. Further studies on farming models may be required to fully understand the potential for economies of scale.

The cost of land is an important part of the overall costs of biodiesel plantations. Therefore, as a part of the package, subsidized land leases may deserve attention and further research.

## CHAPTER 6

# Economic Feasibility of Biofuel Production

### 1. Introduction

The financial analysis models for biofuel production and processing in India were aggregated and expanded to develop economic feasibility analysis models. The analysis was undertaken at the national level and the results highlight the overall welfare implications of biofuel production and use. In aggregating the different costs and benefits along the supply chain the 20% blending target was used to define the scale of biofuel production in India. In other words the two biofuel "projects" – ethanol and biodiesel - were defined based on the 20% blending target. Therefore, the realization of welfare implications shown in this chapter is conditional upon meeting the blending targets. A detailed cost-benefit analysis of various environmental implications of the biofuel sector was not considered in the economic feasibility analysis presented in this chapter mainly because of data limitations. Only the benefits of carbon emission reduction were incorporated.

The market for biodiesel production in India is immature in its present state. Jatropha and pongamia are both being planted on marginal land, but the seed is often left unharvested, unprocessed, or is sold for purposes other than the extraction and transesterfication of the oil. In order to realize the social, economic, and environmental potential of fuels with a biodiesel blend, India needs to implement policies that encourage extraction and transesterification, while enabling the various stakeholders to withstand market fluctuations. Today, such a policy environment is not fully functioning in the Indian biodiesel sector. However, the ethanol market is relatively more mature. Ethanol is produced in large quantities, mainly as a by-product of the sugar industry and for various industrial uses other than blending with gasoline.

A major series of assumptions were made in performing the economic feasibility analysis of biofuel production in India. The assumptions used to build the financial analysis continue to hold for the economic analysis. However, certain additional assumptions are also necessary for the conversion of financial parameters to economic values. All economic costs and benefits are valued at 2010 prices and are expressed in domestic currency, the Indian Rupee. Tradable commodities were valued at the border price. Non-tradable commodities were valued through shadow prices using a standard conversion factor of 0.93[1], and specific conversion factors: 1.0 for equipment, 1.5 for steel, 0.76 for cement, 0.82 for timber, 2.0 for skilled labor, and 0.67 for unskilled labor. These conversion factors were taken from previous ADB project preparatory documents or from other published data.

[1] ADB. 2004. ERD Technical Note Series No. 11, Shadow Exchange Rates for Project Economic Analysis: Toward Improving Practice at the Asian Development Bank, Anneli Lagman-Martin. Manila.

## 2. Economic Feasibility of Ethanol

The economic feasibility analysis for ethanol has focused on three feedstocks; sugarcane, sweet sorghum (SS), and tropical sugar beet (TSB). In all these cases, costs and benefits have been considered on an *incremental basis*. The rationale for using the incremental approach starts from the *without-project* situation. Given that India's fixed arable land is already under cultivation, ethanol production cannot be undertaken without displacing some other crops. When the sugarcane that is used to produce sugar is diverted to produce ethanol, there is an opportunity cost of the lost sugar production. The incremental approach allows the analyst to properly incorporate this cost in the cost benefit analysis. Benefits were estimated as the resource cost savings equivalent to the shadow value of gasoline minus the economic value of sugar. The same principle applies for the costs. In the case of sugarcane, costs were derived by considering the incremental cost of ethanol processing from molasses or cane juice.

As discussed earlier, there are two possibilities for meeting the 20% target of ethanol: i) divert existing sugar land to produce ethanol, or ii) set aside an additional 1.18 million ha of land for sugarcane based ethanol production. In the second case some other irrigable croplands such as wheat or rice should be converted to sugarcane. Since which croplands will be converted cannot be determined with any accuracy the analysis of sugarcane based ethanol considers only the first option. For other crops such as SS and TSB an alternative crop (e. g. wheat or maize) was assumed to replace each initial feedstock in estimating the incremental costs and benefits. For example, if maize is the alternative crop for SS, benefits were assessed as the economic value of replaced gasoline minus the economic value of maize. Incremental costs are the cost differences between SS ethanol production and maize cultivation.

### 2.1. Molasses Based Ethanol

Demand studies quoted in this report indicate gasoline consumption would be around 21.6 million tons by 2017-18 and a 20% ethanol blend target would mean 5.76 million kilolitres (KL) per year. The ethanol project assumes that this amount of ethanol will be produced by 2017 with a gradual increase from 2010. Ethanol production up to 2.88 million KL was assumed to be accomplished using only molasses. The total quantity of molasses currently produced in India is about 8.4 million tons/year. This amount is not adequate to meet the 20% blending requirement. At the current rate of growth, by 2017 the total molasses quantity will be 17.6 million tons and the use of the full amount will make it possible to blend 11.64%. The analysis assumes that 10% ethanol blending will be achieved by production of 2.88 million KL of ethanol from molasses[2]. The molasses ethanol conversion rate used in the analysis is 0.22 KL of ethanol for 1 ton of molasses. The rest of the ethanol to meet the 20% blending requirement comes from the use of cane juice without going through the sugar production process.

Ethanol is used for three purposes in India: transport fuel, industrial use, and as potable alcohol. There is no reliable information on the quantity of alcohol used for industrial use or

[2] Given the current production molasses and demand for industrial and potable alcohol. 10% ethanol for transport is unlikely. However assumed scale does not affect the conclusions and it allows incorporation of opportunity cost of diversion of industrial and potable alcohol for transportation.

human consumption. There is limited verifiable data on the production and use of ethanol by different sectors. According to one of the available estimates[3] about 70% of the ethanol produced in India is currently used as potable alcohol and for industrial uses. Given the recent increase in the price of ethanol, it is assumed in the economic model that about 50% of the total will be used for blending. Ethanol is a by-product of sugar production but it has a market and therefore it has an opportunity cost. The Appendix Table 7A.1 provides the financial cost of producing ethanol from molasses and sugarcane juice.

The total gross benefit of ethanol is estimated as resource cost savings because every liter of ethanol displaces 0.67 liters of petrol. The market price of petrol as of March 2010 was Rs47.43/liter. This includes Rs14.78 of excise duty and educational levy. On top of these taxes another value-added tax is levied on petrol at the supply point. The value-added taxes vary from state to state. In the present calculation, the Rs7.90 (20%) rate applied in Delhi was used. Altogether the total tax will be about Rs22.68/liter. Once all these taxes are added to the refinery gate price oil companies incur a loss, which is known as under recovery. As of March 2010 under recovery was Rs4.18/liter and the government pays this amount to the oil companies. Deducting the taxes from the market price and adding the subsidy (under recovery) the shadow price was estimated to be Rs28.84/liter. These calculations provide the shadow price coefficient of 0.6, which was used in estimating the benefit of ethanol.

Appendix Table 7A.2 shows the cost benefit stream of molasses based ethanol. Table 6.1 provides a summary of these results. Note that since the net benefit stream is positive throughout (see Appendix Table 7A.2) the economic internal rate of return (EIRR) estimate was not possible and the economic feasibility assessment is based on the net present value (NPV). The base case provides an NPV of Rs25229 million at the Government of India's official social discount rate of 12%. This indicates molasses based ethanol production generates social benefits in excess of costs, and so improves social welfare. The base case result is stable against the change in the discount rate.

By 2017 if 20% blending of ethanol as projected in the National Biofuel Policy is achieved, then the avoided carbon is estimated to be 6.51 million tons of carbon dioxide equivalent ($tCO_2e$) per annum[4]. If all these potential reductions are carried forward for clean development mechanism (CDM) registration at an estimated rate of $5 per $tCO_2e$ the projected revenue earning potential is about Rs1,300 million per annum from ethanol. However eligibility for this benefit depends on the mandatory blending requirement. If 20% blending is made mandatory, only the carbon reduction over and above the 20% requirement will be eligible for CDM benefits. Therefore, realization of this benefit is unlikely. However, as part of the sensitivity analysis we incorporated the CDM benefits and the results show that adding the CDM benefit increases the NPV.

[3] Indian Chemical Council (2010) estimates total ethanol production in India to be 3.4 million KL of which 41% and 29% are respectively used as potable alcohol and in the industrial sector. The remaining 30% is available for blending with petrol.

[4] Details of this estimation are given in Chapter 4.

**Table 6.1: Results of the Economic Analysis of Molasses Based Ethanol**

| Scenario | NPV (Rs. Million) | | |
|---|---|---|---|
| | 10% discount rate | 12% discount rate | 15% discount rate |
| Base Case | 29612.43 | 25228.93 | 20375.33 |
| Base Case + Opportunity cost of industrial/potable ethanol | -77390.49 | -65934.45 | -53249.83 |
| Base Case + CDM benefits | 32348.03 | 27360.53 | 21872.75 |
| Cost increase by 20% | -52216.04 | -44486.55 | -35928.13 |
| Gasoline price increase by 15% | 95425.64 | 81299.88 | 65659.22 |
| Gasoline price increase by 25% | 139301.12 | 118680.51 | 95848.48 |
| Gasoline price increase by 40% | 205114.33 | 174751.46 | 141132.37 |

As a part of the sensitivity analysis, the potential opportunity cost was deducted from the benefits. It is assumed that the industrial or potable use of ethanol will be displaced by using it as a transport fuel and that only about 20%[5] of the current quantity of industrial ethanol would be displaced for transport ethanol. This opportunity cost was estimated at Rs25 per liter, which is the current average price of industrial ethanol. The results show negative NPV indicating molasses based ethanol is economically feasible only if incremental production (over and above industrial and potable alcohol) is used as a transport fuel. If any of the other current uses are displaced, the use of ethanol as a transport fuel is not socially desirable. Six percent of the industrial/potable ethanol displacement is sufficient to make negative NPV. Oil prices should increase by about 20% to off-set the negative impact of opportunity cost of industrial/potable alcohol. Note here that the analysis makes very conservative assumptions regarding the opportunity costs for molasses based ethanol. The clear message is that India should try to use only the excess ethanol for blending. Diverting industrial or potable alcohol will not benefit the country.

A 20% increase in cost will make molasses based ethanol economically unfeasible: the ethanol industry is quite sensitive to cost escalations. The major cost in the ethanol industry is the cost of molasses and cyclical fluctuations in sugar production make the price of molasses

[5] This is based on the composition of current use of molasses ethanol.

higher in some years bringing some instability to the industry. The benefit of ethanol depends on the price of oil. As shown in the table, the NPV increases as the price of oil goes up. Given the price of oil will continue to increase in the future the molasses based ethanol industry most likely will provide higher net benefits than those indicated by the base case. .

### 2.2. Sugarcane Juice Ethanol

In the above model it was assumed molasses based ethanol will provide half of the ethanol for 20% blending requirements[6]. In the overall (national) model the other half is assumed to come from sugarcane juice. Here, sugarcane juice is assumed to be directly used for ethanol production without going through the sugar production process. The cost of producing ethanol in this direct route is given in Appendix Table 7A.1. Since this sub-model of ethanol production displaces sugar, a better understanding is needed about the 'with' and 'without' project models. In the case of 'without' project, sugar is produced and molasses comes as a by-product and the analysis assumes that the molasses is used for ethanol production. Let us assume that under the without project scenario:

Total cost of sugar production = $C_s$

Cost of ethanol production = $C_{me}$

Benefits of sugar = $B_s$

Benefit of ethanol = $B_{me}$

Net benefit without project, $NB_1$ = $(B_s + B_{me}) - (C_s + C_{me})$

Under the 'with' scenario sugar will not be produced and hence no molasses is produced, all the cane juice will be used for ethanol production. Let us assume:

Total cost of ethanol Production = $C_e$

Total benefit of ethanol = $B_e$

Net benefit with the project $NB_2$ = $B_e - C_e$

Since the net benefit without the project ($NB_1$) is the opportunity cost of producing ethanol from cane juice, the incremental net benefit ($NB_{INC}$) will be:

$$NB_{INC} = NB_2 - NB_1 = \{B_e - C_e\} - \{(B_s + B_{me}) - (C_s + C_{me})\}$$

The above incremental net benefit is the benefit of producing ethanol from sugarcane juice.

In the sugarcane juice based model, ethanol production reaches 2.88 million KL (half the 20% blending requirement) in 2017 with a gradual increase from 2013. One ton of sugarcane produces 100 kg of sugar and 45 kg of molasses, which contains about 25 kg of fermentable sugar. One kg of fermentable sugar produces about 0.56 liters of ethanol. Therefore, the total

[6] In reality the molasses based ethanol contribution can be as low as 5% depending on the total production and alternative uses. However this assumption does not affect the policy direction.

quantity of ethanol from one ton of cane is about 70 liters. Ten tons of sugarcane produce one ton of sugar. Therefore, one ton of sugar produces 0.7 KL of ethanol. These parameters were used in the sugarcane based ethanol model. In addition, the cost of the production of sugar was estimated to be Rs23,723 per ton and the market value was estimated to be Rs30,000 per ton. The cost benefit stream of the 'without' project scenario is given in Appendix Table 7A.3.

In the without project model the total quantity of ethanol produced from molasses is used for industrial and potable alcohol purposes and its value was estimated at Rs25/liter. Table 6.2 shows the results of the 'without' project model. This model gives the NPV of Rs166,126 million at the 12% discount rate indicating sugar production together with ethanol for industrial and other purposes is economically feasible. Sugar production shows cyclical fluctuations and prices drop in excess production years. The net benefits under the without project scenario are quite stable to price drops and cost escalations, but a drop in the price of sugar to Rs23,000 (23% drop in price) makes sugar plus ethanol production economically infeasible. Overall, the results show that the without project scenario is economically quite attractive.

**Table 6.2: Results of the Economic Analysis for Sugarcane Based Ethanol without Project Scenario**

| Scenario | NPV (Rs. Million) | | |
|---|---|---|---|
| | 10% discount rate | 12% discount rate | 15% discount rate |
| Base Case | 202,324.92 | 166,126.56 | 126,601.42 |
| Sugar price decrease by 20% | 58,268.13 | 47,843.26 | 36,460.31 |
| Total cost increase by 20% | 43,709.93 | 35,889.70 | 27,350.75 |
| Ethanol price decrease by 20% | 185,518.29 | 152,326.84 | 116,084.96 |

Appendix Table 7A.4 shows the cost and benefit stream of the sugarcane juice based ethanol model. As is evident from the table the net benefits ($NB_2$) of sugarcane based ethanol are negative. This is because the shadow value of ethanol at current prices is lower than the cost of production. This clearly demonstrates that the use of sugarcane for ethanol production is not economically feasible. Once the opportunity cost of sugarcane based ethanol - displaced sugar and molasses based ethanol,- is incorporated into the model the negative benefits ($NB_{INC}$) or the economic losses become larger. The economic feasibility of sugarcane based ethanol should be determined based on the last column of the Table 6.3. The negative values indicate it is not worthwhile to convert sugarcane juice to ethanol.

The results shown in Table 6.3 clearly show converting sugarcane juice to ethanol is not socially desirable. Adding CDM benefits or a decline in the sugar and industrial ethanol price do not change the basic conclusion. An increase in petrol price by about 25% makes the conversion of sugarcane to ethanol feasible but once the opportunity costs are added, NPV remains negative. This situation does not change even if petrol prices increase by 40%. Therefore, converting sugarcane to ethanol will not be economically feasible even in the future with higher oil prices. Cyclical drop in sugar cane prices will only have a marginal impact on the economic feasibility of cane juice based ethanol because opportunity cost is very large compared to the cost of production of ethanol. About 40% drop in the sugar prices is required to make cane juice based ethanol economically viable. Even in surplus years, that type of a drop is highly unlikely.

**Table 6.3: Results of the Economic Analysis of Sugarcane Juice Based Ethanol**

| Scenario | NPV (Rs. Million) | |
|---|---|---|
| | Without Opportunity Cost, $NB_2$ (12% discount rate ) | With Opportunity Cost, $NB_{INC}$ (12% discount rate ) |
| Base Case | -687,48.42 | -234,874.98 |
| Base Case + CDM benefits | -65,211.57 | -231,338.13 |
| Sugar and Industrial ethanol price decrease by 20% | - | -201,649.67 |
| Sugar price decrease by 40% | - | 1,691.62 |
| Gasoline price increase by 15% | -26,310.14 | -192,436.71 |
| Gasoline price increase by 25% | 1,982.04 | -164,144.52 |
| Gasoline price increase by 40% | 44,420.31 | -121,706.25 |

The results clearly show that the cost of ethanol production using sugarcane juice exceeds the social benefits; hence there is no economic justification for expanding ethanol production using sugarcane juice. Therefore, there is no justification for a promotional program or any government support for sugarcane juice based ethanol production in India. In contrast to these results, the molasses based ethanol model is economically attractive provided that only excess ethanol is used for blending. If sugar production increases at around 4% to meet growing demand, there will be some excess molasses for ethanol blending. However, potable alcohol and industrial alcohol demands are also increasing. Therefore how much excess alcohol is available for blending is highly uncertain. As the results clearly show, diversion of industrial and potable alcohol is not socially desirable and only excess alcohol should be used for blending. Blending of molasses based ethanol is not only economically feasible but also does not have adverse food security implications. Moreover, molasses based ethanol blending will have a stabilizing effect on the sugar industry which shows a cyclical behavior.

### 2.3. Economic Feasibility of Alternative Feedstocks

This section assesses the economic feasibility of two alternate ethanol feedstocks: tropical sugar beet (TSB) and sweet sorghum (SS). Today, there is no SS or TSB production on a commercial scale in India. However, research trials have been undertaken by agencies including the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The two basic financial models were built upon data from those trials, and this database was used for economic analysis with the necessary modifications. Sweet sorghum can be cultivated under harsh conditions, but still it will have to compete with rain-fed food or feed crops such as corn or millet. Tropical sugar beet generally requires more water and other soil nutrients to produce an economically attractive yield. So, the opportunity cost of TSB would be higher than SS because it replaces more profitable crops like legumes, onions or high value vegetables. So for both crops we have assumed a positive opportunity cost in calculating economic indicators.

It is assumed in the analysis that molasses based ethanol production meets 50% of the requirement for 20% blending while the two other sources jointly produce the rest. It is also assumed that SS will contribute 30% and TSB will contribute 20% of the overall requirements. A similar set of assumptions, as in the case of sugarcane juice based ethanol, were used for the analysis. The results are given in Tables 6.4 and 6.5.

In the base case, without the opportunity costs, the NPV is positive. When we include the CDM benefits, the NPV is even more attractive. However, when the opportunity costs are included with the base case, the NPV becomes negative. Note that economic decisions should be made on the results of the model with the opportunity cost. The results basically show ethanol based on SS is not economically feasible at current oil prices. However, when gasoline prices increase, in all cases the NPV becomes positive or economically viable, with or without considering the opportunity costs. Gasoline prices must increase by at least 15% for SS to become a part of India’s biofuel industry with justifiable economic benefits. Regardless of oil prices, SS for fuel is competing with food crops; hence promotion of SS for fuel may conflict with the government policy of not compromising food security for promoting energy crops.

**Table 6.4: Results of the Economic Analysis of Sweet Sorghum Based Ethanol**

| Scenario | NPV (Rs. Million) | |
|---|---|---|
| | Without Opportunity Cost, $NB_2$ (12% discount rate ) | With Opportunity Cost, $NB_{INC}$ (12% discount rate ) |
| Base Case | 4,487.67 | -40,027.60 |
| Base Case + CDM benefits | 6,619.27 | -37,895.95 |
| Opportunity cost decrease by 20% | N/A | -31,124.51 |
| Gasoline price increase by 15% | 195,216.06 | 150,700.84 |
| Gasoline price increase by 25% | 212,191.37 | 167,676.15 |
| Gasoline price increase by 40% | 237,654.33 | 193,139.11 |

**Table 6.5: Results of the Economic Analysis of Tropical Sugar Beet Juice Based Ethanol**

| Scenario | NPV (Rs. Million) | |
|---|---|---|
| | Without Opportunity Cost, $NB_2$ (12% discount rate) | With Opportunity Cost, $NB_{INC}$ (12% discount rate) |
| Base Case | 2,991.78 | -24,402.20 |
| Base Case + CDM benefits | 5,123.38 | -22,270.60 |
| Opportunity cost decrease by 20% | N/A | -18,923.41 |
| Gasoline price increase by 15% | 130,144.04 | 102,750.06 |
| Gasoline price increase by 25% | 141,460.91 | 114,066.93 |
| Gasoline price increase by 40% | 158,436.22 | 131,042.24 |

Just as in the case of SS, opportunity costs cause the NPV to become negative in the case of TSB. However, increases in gasoline prices likewise cause TSB to become economically viable. Just as with SS, gasoline prices must increase by at least 15% for TSB to become a part of India's biofuel industry with adequate economic benefits. Even at higher prices, TSB still competes for the agricultural resources, despite being economically attractive.

## 3. Economic Feasibility of Biodiesel

For the base case it was assumed the entire volume of biodiesel was produced using wastelands - fallow land without any productive use at present. Therefore, there is no opportunity cost of land as in the case of ethanol. As in the case of ethanol, costs were aggregated along the supply chain to obtain the total costs. Resource cost savings were estimated based on the quantity of displaced diesel. Similarly, if the targeted 20% blending of biodiesel is achieved by 2017, it is estimated that about 20.54 million KL of biodiesel should be produced annually. The biodiesel project assumes that starting from 2010, production will gradually increase to 20.54 million KL. Biodiesel crops are long-term crops and therefore, the project period was considered to be 25 years.

The national biodiesel project assumes the required quantity of biodiesel to meet 20% blending in 2017 will be produced by two species – jatropha and pongamia. It was assumed 60% of the biodiesel would be produced by jatropha while the rest comes from pongamia. This assumption is based on a better information base in the case of jatropha in comparison to pongamia and consequent preference for jatropha expressed by some oil seed plantation owners[7]. Appendix Table 7A.5 presents the cost benefit stream of the jatropha subproject. Note that in estimating the benefits the market price of diesel was considered as Rs38 per liter. The shadow price of diesel was estimated deducting the excise tax and educational levy (Rs4.47/liter), value added tax (Rs4.20) and adding the under recovery (Rs2.89). These are the taxes and subsidies that applied in March 2010. The estimated shadow price coefficient was 0.84. Moreover, it was assumed that one liter of biodiesel will displace 0.9 liters of diesel.

Table 6.6 presents the results of the economic analysis of the jatropha subproject. The base case provides the 13.61% EIRR which is higher than the Indian government's cut off rate of 12%. At the 12% social discount rate jatropha provides a positive NPV. Biofuel plantations are eligible for CDM benefits under two categories: i) emission reduction through afforestation (planting of trees where there had been none previously) or reforestation (replanting trees to replace previous growth) and ii) blending. Here, the analysis considers only the more certain afforestation option. A typical project of afforestation implemented in barren, waste, or degraded land will have an average certified emission reduction (CER) generation of 7 tons/hectare/year for 30 years of crediting period while the actual CER potential for a given plantation has to be site specific based on such things as soil conditions, type of tree species, tree canopy, or agronomical practices. CDM benefits were incorporated considering a conservative estimate of $5/ton of CER. The benefits increase considerably and the NPV becomes positive at a higher discount rate of 15% when the CDM benefits are included. Oil price rises will substantially increase the project's returns. Overall, the results show that

[7] However there are some reports that cast doubt about the potential of jatropha to produce high yields.

jatropha is economically feasible but benefits are sensitive to social discount rates and cost increases.

**Table 6.6: Economic Feasibility of Biodiesel – Jatropha Subproject**

| Scenario | EIRR | NPV Rs Million at varying discount rates | | |
|---|---|---|---|---|
| | | 10% | 12% | 15% |
| Base Case | 13.61 | 161,282.89 | 59,226.21 | -38,985.39 |
| Base Case + CDM | 16.35 | 299,744.22 | 168,609.82 | 39,637.47 |
| 20% Cost Increase | 6.96 | -139,549.62 | -192,066.91 | -235,921.31 |
| Diesel Price increase 15% | 18.37 | 411,099.71 | 256,579.99 | 102,868.75 |
| Diesel Price Increase 25% | 21.18 | 577,644.26 | 388,149.17 | 197,438.17 |
| Diesel price increase 40% | 25.02 | 827,461.08 | 585,502.94 | 339,292.30 |

Tables 6.7 shows the economic analysis results of the pongamia subproject (see Appendix Table 7A.6 for details). The results are very similar to those of jatropha, except that pongamia provides better economic returns. Even under a 15% social discount rate pongamia provides a positive NPV. The pongamia crop starts out a slow beginner, but it has a higher probability to provide more economic benefits in a stable manner compared to jatropha. The positive scenarios such as the inclusion of CDM benefits or increasing diesel prices will make pongamia based biodiesel economically more attractive.

**Table 6.7: Economic Feasibility of Biodiesel – Pongamia Subproject**

| Scenario | EIRR | NPV Rs. Million at varying discount rates | | |
|---|---|---|---|---|
| | | 10% | 12% | 15% |
| Base Case | 17.76 | 153,214.4 | 92,071.0 | 32,808.2 |
| Base Case + CDM | 21.35 | 238,067.4 | 158,387.8 | 79,681.2 |
| 20% Cost Increase | 8.98 | -20,269.2 | -49,049.7 | -73,390.1 |
| Diesel Price increase 15% | 23.99 | 306,309.3 | 211,722.1 | 117,378.1 |
| Diesel Price Increase 25% | 27.64 | 408,372.5 | 291,489.6 | 173,758.1 |
| Diesel price increase 40% | 32.57 | 561,467.3 | 411,140.7 | 411,140.7 |

Table 6.8 shows the economic feasibility of the national biodiesel project, which includes both jatropha and pongamia to meet the 20% blending target by 2017. The results show the biodiesel project is economically feasible with a 15% economic internal rate of return (EIRR). The NPV for the base case is negative for a 15% discount rate indicating that the results are sensitive to the discount rate. The inclusion of the afforestation CDM benefits (with a very conservative CER price of $5/ton) increases the economic attractiveness of the project and the NPV becomes positive even at a 15% discount rate. The project becomes economically unattractive under the unlikely circumstance of a 20% increase of costs. However, even then, about a 12% productivity increase is adequate to bring the project EIRR to 12%. Moreover, there is some uncertainty about the yields of the two oil seed species – particularly for jatropha. In order to address this concern it was assumed that yields would drop by 25% from the base case. Results show that with such low yield biodiesel is economically feasible if CDM benefits are realized. The results clearly demonstrated the economic feasibility of biodiesel under current diesel prices. As diesel prices increase the magnitude of the economic benefits become larger. Given the very high likelihood of oil price increases in the future, the results warrant a proactive promotional program for biodiesel in India.

**Table 6.8: Economic Feasibility of Biodiesel National Project**

| Scenario | EIRR | NPV Rs. Million at varying discount rates | | |
|---|---|---|---|---|
| | | 10% | 12% | 15% |
| Base Case | 14.85% | 398,364.16 | 151,297.19 | -6,177.20 |
| Base Case + CDM | 26.48% | 855,440.55 | 550,279.29 | 322,670.22 |
| 20% Cost Increase | 7.59% | -112,900.12 | -241,116.59 | -30,9311.40 |
| 20% Cost Increase + 10% productivity Increase | 12.21% | 241,662.15 | 1,487.34 | -128,172.15 |
| 25% Yield drop +CDM | 12.45% | 92,192.44 | 13,952.69 | 58,836.19 |
| Diesel Price increase 15% | 20.10% | 841,567.00 | 468,302.11 | 220,246.86 |
| Diesel Price Increase 25% | 23.04% | 1,137,035.56 | 679,638.72 | 220,246.86 |
| Diesel price increase 40% | 27.17% | 1,580,238.39 | 996,643.64 | 597,620.31 |

If the target 20% blending of biodiesel is achieved by 2017, it is estimated that about18.3 million direct jobs can be created across the supply chain of biodiesel, especially in rural areas. Similarly if the 20% blend of biodiesel is achieved then the avoided GHG emissions could be 83.87 million $tCO_2e$ per annum. If this potential reduction is carried forward for CDM registration at an estimated rate of $5/$tCO_2e$ the projected revenue earning potential per year would be about Rs18,871 million from biodiesel. In addition, 32 million ha of plantation will provide 160 million CER from land use changes (LULUCF) with revenue of Rs36,000 million a year.

## 4. Limitations of the Analysis

The data used for the analysis was taken from public sources and limited field investigations were performed to supplement the data. Where applicable, the publicly collected data was crosschecked with the limited data collected from field visits and investigations. When doubts concerning the accuracy of data arose the more conservative values were used. As the economic feasibility analysis carried out is an extension of the financial analysis, all relevant limitations (data quality, data limitations, limited field data collection) applicable to the latter are also applicable to the former. The economic life of project-related facilities was assumed at 25 years. If any facility's life span is expected to go beyond a 20-year period, a salvage value should be added to the economic feasibility model. However, such salvage values often give only a marginal change in NPV. Therefore, the salvage values were not incorporated in the analysis.

No environmental benefits or costs were quantified and used in the economic feasibility analysis or for calculation of the EIRR or NPV in this exercise, except for the GHG emission reduction. A comprehensive quantification and estimation of all benefits from the project was not possible due to various factors, including time, resources and data limitations. Thus, the benefits estimated in this analysis can be interpreted as conservative. There are many positive environmental benefits to be realized by shifting from traditional hydrocarbon-based fuels to fuels consisting of a higher blend of biofuels. Among these environmental benefits, the most prominent are: improved human health from avoided morbidity and mortality from fine petroleum fuel-particulates, improved human welfare due to improved visibility and reduced material damage from air pollution, and positive impacts on environmental resources due to avoided emissions. In addition conversion of barren lands without vegetation to biodiesel plantations may bring a number of environmental benefits. The analysis, however, excludes quantification of all such benefits.

Ideally the refinery gate price should be used in estimating the shadow price of petrol and diesel. This price varies with crude oil prices and it is not easy to track as governments do not adjust petroleum prices at regular intervals. Therefore, available information on taxes and subsidies were used to estimate the shadow prices of petrol and diesel. Moreover, there is a large variation in the value-added taxes of different states. These differences were ignored to keep the analysis to a simple and manageable level.

## 5. Concluding Remarks

The economic analysis in this chapter was conducted from the perspective of the nation and it focuses on the potential welfare increase or decrease due to interventions on biofuels. In the case of ethanol the analysis was conducted separately for molasses and sugarcane juice based ethanol assuming 50% of the required ethanol comes from each route. Results show molasses based ethanol is economically feasible at the current price of oil. However, if industrial and potable ethanols are displaced, the costs exceed the benefits. Therefore the drive to blend ethanol should not result in displacing the current use of alcohol for potable and industrial purposes. CDM benefits and oil price increases makes molasses based ethanol economically more attractive.

In contrast, sugarcane juice based ethanol results clearly show that the cost of ethanol exceeds the social benefits, even without considering the opportunity cost of sugar. Once the opportunity cost of displaced sugar is added, the already negative net returns increase making sugarcane juice based ethanol economically even more unattractive. Higher oil prices up to 40% cannot make sugarcane juice based ethanol economically attractive; hence, sugarcane based ethanol will not be economically attractive even in the future. The use of sugarcane to produce ethanol also compromises food production. Hence, the present study does not recommend sugarcane juice based ethanol production as a socially desirable or economically feasible program in India.

As stated earlier 20% blending of ethanol cannot be achieved only from molasses. Given that molasses based ethanol is economically feasible and that it does not compromise food security, blending only from molasses based ethanol is recommended. Ethanol blending up to 10% can be achieved without any major change in vehicle fleet. The sugar industry is well established and a vibrant molasses based ethanol industry may also have a stabilizing effect on the cyclical sugar industry. However, if the use of ethanol for transport displaces industrial and potable uses, the costs will exceed the benefits. Therefore excess ethanol should only be used for transport. Data on supply, demand, and the prices of ethanol in industry and potable alcohol sectors are not readily available. The available data is presented in Appendix 6. A detailed study on the current alternative uses of ethanol is necessary to determine the level of blending that can be achieved without displacing the current uses. Available information suggests that 5% blending only using molasses ethanol as a pragmatic target.

The economics of biodiesel is much different from that of ethanol because both jatropha and pongamia provide acceptable returns and increases in diesel prices make biodiesel economically attractive. This difference arises mainly due to the higher shadow value of biodiesel (Rs28.73/iter) compared to ethanol (Rs19.32/liter). Thus, the economic analysis in this chapter shows convincing evidence of social welfare improvements from biodiesel. If confined to wasteland with limited irrigation only at the beginning of the planting season, biodiesel will not compete with food crops for land or water in a significant manner. Employment generation and CDM benefits are also significant in the case of biodiesel. Therefore, the results support an aggressive support program for biodiesel production in India.

While the results on the economic feasibility of biodiesel are promising, they are based on a major assumption that about 32 million ha of wasteland will be put under non-edible oil plantations. The biodiesel industry in India is at an infant stage of development and an enormous amount of work on land allocation, selection and breeding, nursery development, research on agronomy, and pest and disease control still needs to be done. Identifying and providing necessary incentives to various segments in the supply chain, creating an enabling business environment for the private sector, coordination among a large number of producers spread all over the country and the introduction of necessary regulatory measures have to be undertaken to realize the potential of biodiesel production in India.

One of the major findings of this chapter is that biodiesel has promising economic feasibility, the benefits of which increase as oil prices increase. Ethanol, however, needs to be treated with some caution because of its mixed economic feasibility and possible impact on the food sector and possible negative impacts on the industrial and potable ethanol sectors. In particular, the use of sugarcane juice for ethanol will not provide adequate benefits to justify the costs and it will compromise food production in India. Alternative feedstocks such as SS and TSB are not economically feasible either. Therefore, one of the main policy directions emanating from the analysis of this chapter is the need to deal with ethanol and biodiesel separately in the biofuel policy of India.

## CHAPTER 7

# Economy Wide Impact of Biofuels

### 1. Introduction

The financial and economic feasibility of biofuel production and use was examined in Chapters 5 and 6. These analyses were undertaken in a partial equilibrium setting, ignoring the interactive and multiplier effects. In this chapter the economy wide impact of biofuel production and use are examined using a general equilibrium framework. Two Computable General Equilibrium (CGE) models were developed for this purpose. The first is an Indian CGE model, while the second is a global CGE model. The main objective is to examine the impact of biofuel production and use in India in both a static and dynamic modeling context. The static model[1], the details of which are presented in the first part of this Chapter, examines a one-time impact of increasing biodiesel production to the level of 20% blending on the economy. The second model uses a dynamic approach and, incorporating international trade, examines the impact of blending at 20% of both ethanol and biodiesel on the Indian economy. The second model also examines other policy options available to the Indian government for counteracting the impact of energy price hikes.

### 2. Indian CGE Model

As shown in Chapter 6, the economics of ethanol are mixed with economically attractive molasses based ethanol and unattractive sugarcane juice based ethanol. The use of second generation ethanol technology may become feasible in India only in the future. Therefore, India's biofuel sector relies largely on biodiesel at this point in time. As shown in the previous chapters, the economic returns to the two biodiesel feedstocks, jatropha and pongamia, are very similar and hence the analysis here considers only jatropha. A salient feature of India's biodiesel program is the utilization of wasteland for the cultivation of oil seeds. As a consequence, the issue for biofuel versus food security is not really relevant in the Indian context.

Although India started looking at biofuels back in 2003 it only approved a National Biofuel Policy in December 2009. For lack of clarity in the intervening period, India has achieved only limited progress in this sector. India's biodiesel processing capacity is estimated at 1,000,000 tons per year. However, it is only producing 70,000 tons. The shortage of feedstock is a major bottleneck in the growth of the industry. Most of the jatropha seeds are now being

[1] The Static models are timeless models, which take a snap shot of the economy including policy interventions. In contrast the dynamic models involve time in an explicit manner and can generate time paths of economic variables of policy interests

used for plantation purposes limiting their use for production of biofuels and pushing their selling price up. As shown in previous chapters, the current administrative price does not provide financial incentives for producing biodiesel. Once the necessary price revisions and other incentives are provided, growth in the biodiesel sector should accelerate. In this context, the analysis below shows the implications of biofuel production using a national CGE model for India.

### 2.1. The CGE Modeling Framework

The impact of growth of the biofuel sector and the role of various policy instruments to facilitate its growth are analyzed using an economy wide CGE model of India. The model has a number of features that make it suitable for economy-wide impact analysis, such as:

- It simulates the functioning of different markets in the economy, including markets for labor, capital and commodities and provides a useful perspective on how changes in economic conditions will likely be mediated through prices and markets.
- Its structure permits a consideration of an expansion of the economy in a new venture such as biodiesel.
- It assures that all economy-wide constraints are respected. In the Indian context, for instance, biodiesel production and use are expected to reduce partially the demand for imported fuel, provide a better use for degraded land and raise the demand for labor in rural areas.
- As the model can be fairly disaggregated (compared to econometric models), CGE models can provide an economic *simulation laboratory* to examine how different factors and channels of impacts will affect the performance and structure of the economy, including how they will interact and, most importantly, how to quantify the interactive effects of welfare indicators such as GDP growth and income increases.

In a CGE model, economic decision-making is the outcome of decentralized optimizing by producers and consumers within a coherent economy-wide framework. A variety of substitution mechanisms are specified including substitution among labor types, between capital and labor, between imports and domestic goods, and between exports and domestic sales all occurring in response to variations in relative prices. The model of the Indian economy consists of 30 sectors or commodities, consisting of 9 agricultural related sectors, 7 service sectors and 14 manufacturing sectors. Four factors of production are identified, i.e. 2 types of labor (unskilled and skilled), land, and capital. The details of the sectoral classification are shown in Table 7.1

**Table 7.1: Sectoral Classification of the Indian CGE Model**

| No. | Description | No. | Description |
|---|---|---|---|
| 1 | Paddy | 16 | Biodiesel |
| 2 | Wheat | 17 | Diesel and other Petroleum Products |
| 3 | Other cereals | 18 | Chemicals |
| 4 | Cash crops | 19 | Paper and Paper Products |
| 5 | Jatropha | 20 | Fertilizer |
| 6 | Animal husbandry | 21 | Other Manufacturing |
| 7 | Forestry | 22 | Machinery |
| 8 | Fishing | 23 | Electricity |
| 9 | Coal | 24 | Biomass |
| 10 | Oil | 25 | Water distribution |
| 11 | Gas | 26 | Construction |
| 12 | Food and Beverages | 27 | Land Transport |
| 13 | Textiles and Leather Products | 28 | Air Transport |
| 14 | Wood | 29 | Sea Transport |
| 15 | Other Minerals | 30 | All Other Services |

As shown in Table 7.1, feedstock cultivation and the processing sectors of biodiesel are modeled as separate entities. It must be mentioned that the processing sector of biodiesel consists of two parts: extraction and transesterification, but in the model, both are included in the biodiesel sector. Sector 17 includes various petroleum products apart from transport fuel like diesel, petrol, kerosene, etc. Out of the total domestic consumption in this sector, the share of diesel and petrol comes to about 45% of which diesel corresponds to about 40%.[2] While it is

[2] India generally imports crude oil and hence the share of diesel and other petro-products in the above table amount to be small. [meaning unclear; is this a reference to Sector 10? If so we might say: Sector 10 comprises imports of petroleum and products, but India imports largely crude oil and the share of refined product imports such as diesel is relatively small.]

acknowledged that further decomposition of this sector would enrich the analysis, the data constraints do not permit it. The basic structural features for the major sectors at this level of disaggregation of the Indian economy are presented in Table 7.2. Currently, the shares of jatropha as well as biodiesel sectors in total are near zero, and so are not shown separately in the table.

**Table 7.2: Structure of India's Economy in 2006-07**

| | Share to Total (%) | | | |
|---|---|---|---|---|
| | **GDP** | **Export** | **Imports** | **Domestic Consumption** |
| **Total GDP** | **100.0** | 100.0 | 100.0 | 100.0 |
| **Agriculture** | **18.2** | **3.4** | **1.8** | **17.2** |
| **Food Crops** | **9.8** | **2.1** | **0.7** | **9.1** |
| **Cash Crops** | **2.5** | **0.4** | **0.4** | **2.4** |
| **Mining** | **2.8** | **0.4** | **15.5** | **6.6** |
| **Manufacturing** | **16.3** | **61.4** | **74.9** | **21.5** |
| **Diesel, Other Petro-products** | **1.3** | **3.0** | **3.3** | **1.4** |
| **Machinery** | **2.2** | **6.9** | **11.1** | **3.5** |
| **Services** | **62.8** | **34.8** | **7.7** | **54.7** |
| **Transport services** | **6.4** | **5.2** | **0.4** | **5.1** |

The analysis is based on a static CGE model with 2006-07 chosen as the base year. The model structure is described in Appendix 8. Since India is a small player in the global market, it is assumed that India is a price taker in line with other CGE models. The stocks of endowments (land, capital, and skilled labor) are assumed to be fixed and equilibrium ensures that there is full employment of factors. Barring land, we have assumed that there is mobility of factors between sectors and so the returns to each are the same across sectors at full equilibrium. However, land is assumed to be a sluggish factor, which is immobile across sectors. This is a realistic assumption since it takes a long time to change land use from one use to another. Contrary to other endowments, we have however assumed that the supply of unskilled labor is not fixed. India is a labor surplus economy. So, it is assumed that there is an infinitely elastic supply of unskilled labor at any given real wage. At equilibrium, the supply of factors or commodities must be equal to the demand of those factors or commodities.

It must be mentioned that that infinite supply of unskilled labor in rural India is changing. Agricultural operations have been affected due to seasonal shortages of unskilled labor in many parts of India and there is seasonal variation in agricultural wages. Biofuel plantations could result in the shortage of unskilled labor for other agricultural operations to some extent. So, we have also undertaken a simulation where we have assumed that the supply of unskilled labor is fixed. In this case, the real wage of unskilled labor would rise due to competitive pressure. This could provide useful insights regarding the impact of the expansion of jatropha production vis-à-vis other agricultural sectors and the economy as a whole.

### 2.2 Biodiesel Scenarios

The main objective of this analysis is to assess the potential economic impacts of the growth of bio-diesel in India. Since India has already announced a National Biofuel Policy, it makes sense to assess the impact of alternative policy prescriptions drawn from the Biofuel Policy document. We have considered three indicative policy scenarios for drawing our assessment:

- *Scenario 1*: The area under jatropha cultivation is increased from the base year value to the amount that is required to meet the 20% blending target of the biofuel policy target. It is also assumed that the increased land comes from the pool of fallow land, wasteland or degraded forest. This means that land under jatropha cultivation is increased to 32 million hectares (ha).
- *Scenario 2*: Scenario 1 plus the assumption that overall land productivity in the jatropha and biodiesel sector has been enhanced because of technology improvement, such as improved varieties, better access to fertilizer, and better agricultural practices. The extent of productivity increases is assumed to be 20% in the biodiesel sector that includes both the feedstock sector as well as the processing sector.
- *Scenario 3:* Scenario 2 with the assumption that the supply of unskilled labor in the economy is fixed. In this case, the real wage of unskilled workers increases or declines to attain equilibrium.

In the above three simulations, we have assumed market-driven price regimes in all sectors except in the biodiesel sector and the feedstock sector (jatropha). The biodiesel sector price is aligned to the diesel price in calorific terms. If the market-driven price differs from the diesel price in calorific terms, the government intervenes with a tax or subsidy to maintain this price level. This type of policy intervention is envisaged in India's biofuel policy document. Moreover, presently, the biodiesel price is administered by the government. The same is also true of the feedstock sector where the jatropha seed is bought at a government determined price. This is done to make the pricing mechanism more in tune with reality. An infinitely elastic demand for biodiesel and the feedstock is assumed together with the administratively determined prices. This means any quantity of biodiesel can be supplied under the given price. The model restricts biodiesel production at the 20% blending level by limiting the land availability to the corresponding level.

It should be mentioned that CGE model scenario results only provide indicative directions and should not be considered as forecasts. Furthermore, in a transition sector like biofuel, where little information is available, the results should be taken with caution. The analysis of scenario results are grouped into two: overall impacts (welfare, climate change, and fiscal impacts), and sectoral and impacts on rural development.

## 2.3. Summary of the Results

### 2.3.1 Welfare Impacts

An increase in the allocation of land for jatropha implies that one of the sluggish factors of production, i.e. land, is increased. To what extent jatropha supply would increase depends on the administered price, the cost function, and the prices of other primary factors. Since this additional land is not coming from land allocated to other agricultural sectors, the production of other agricultural products, a priori, would not fall unless other primary factors, such as prices for labor or capital, rise significantly due to an increased demand for jatropha. Apart from land, the principal primary input required for jatropha cultivation is unskilled labor, which is assumed infinitely elastic. Thus, economic intuition indicates that the increased cultivation would not have a significant effect on other agricultural sectors.

Table 7.3 summaries the results showing that overall GDP increases by 0.96% or by Rs377 billion. Moreover, India's income rises by Rs361 billion in terms of an equivalent variation that can be interpreted as the change in household income at constant prices as a result of the proposed change in jatropha production. The factors of production gain from the transformation to jatropha. When productivity increases as together with increased area under jatropha cultivation, the economic gains get magnified (see Scenario 2 in Table 7.3). Real GDP now increases by about 1%. In absolute terms, it amounts to Rs393 billion. As this table shows, real returns to factors increase marginally.

However, if we drop the assumption of an infinitely elastic supply of labor as in scenario 3, the picture becomes less rosy. Now, increased jatropha plantations push up the real wage of the unskilled workers, which in turn affects other agricultural sectors. As a result, GDP increases by 0.74% in contrast to 0.96% in scenario 1. The smaller increase in GDP occurs due to the decline in the output of other agricultural sectors. However it is unlikely that the total amount of labor for biodiesel will be taken out from other agricultural sectors because there is some surplus labor in rural areas. Therefore the actual impacts on the economy would be between scenario 1 and 3, when there is no productivity increase.

**Table 7.3: Impact on Economy of Jatropha Cultivation in India**

| | Scenario 1 (%) | | Scenario 2 (%) | | Scenario 3 | |
|---|---|---|---|---|---|---|
| Equivalent Variation (Rs Millions) | 360,878 | | 374,845 | | 278,095 | |
| GDP | 0.956 | | 0.997 | | 0.737 | |
| Change in value of GDP (Rs Million) | 376,842 | | 393,004 | | 290.397 | |
| Real Return to Factor | | | | | | |
| Land | 1.72 | | 1.74 | | 1.41 | |
| Unskilled Labor | ** | | ** | | 0.48 | |
| Skilled Labor | 0.81 | | 0.84 | | 0.44 | |
| Capital | 0.64 | | 0.71 | | 0.48 | |
| Fiscal Deficit | 0.27 | | 0.28 | | 0.26 | |
| Reduction in GHG Emission (Mil. tons) | 12.12 | | 13.21 | | 11.11 | |
| Employment Generation (Million) | 30.11 | | 33.21 | | ** | |
| | | | | | | |
| Sectoral Effect | Output | Price | Output | Price | Output | Price |
| Jatropha | 3,010.01 | ** | 3,220.11 | ** | 2,760.1 | ** |
| Biodiesel | 770.29 | ** | 777.53 | ** | 650.01 | ** |
| Paddy | 0.29 | 1.29 | 0.31 | 1.3 | 0.18 | 0.88 |
| Wheat | 0.33 | 0.87 | 0.35 | 0.91 | 0.22 | 0.59 |
| Cereals | 0.3 | 1.17 | 0.31 | 1.18 | 0.21 | 0.82 |

**Table 7.3: Impact on Economy of Jatropha Cultivation in India, (cont'd)**

| | Scenario 1 (%) | | Scenario 2 (%) | | Scenario 3 | |
|---|---|---|---|---|---|---|
| Cash crops | 0.09 | 1.1 | 0.11 | 1.14 | 0.05 | 0.77 |
| Diesel, Pet. Products | 0.84 | -0.08 | 0.87 | -0.1 | 0.62 | -0.03 |
| | | | | | | |
| | Agro Sectors | Non-agro Sectors | Agro Sectors | Non-agro Sectors | Agro Sectors | Non-agro Sectors |
| Distribution of Gains (Rs Million) | | | | | | |
| Unskilled Wage Income | 54,656 | 11,380 | 58,912 | 11,321 | 42,111 | 8,770 |
| Skilled Wage Income | 1 | 3317 | 1 | 3293 | 1 | 2556 |
| Non-wage Income | 163,067 | 144,432 | 175,794 | 143,684 | 125,660 | 111,300 |

** Not applicable. The price is fixed.

Note: All variables are in percentage form unless specified

### 2.3.2. Fiscal Deficit

Scenario 1 increases the public sector fiscal deficit by 0.27% whereas in scenario 2 it rises by 0.28%. Here fiscal deficit is not computed as a share of GDP but as an absolute percentage change, which implies that there is a very low level of increase in the fiscal deficit. In the base year, most of the agriculture sector, including the fertilizer sector, receives a subsidy. When outputs of agricultural sectors expand, subsidies also expand due to effects within the sector and also due to increased subsidy going to the fertilizer sector. Moreover to maintain the biodiesel price in alignment with the price of diesel, the government's subsidy bill also increases. If the increase in government revenue (due to overall growth) is relatively less than that of the subsidy payments, the overall fiscal deficit would increase. In scenario 2, we find a small increase in the fiscal deficit. In scenario 3, the fiscal deficit grows less. This happens mainly due to the lower growth of the economy.

### 2.3.3 Sectoral Effect

On the sectoral or domestic output effect, the result of scenario 1 shows that the output of the jatropha sector rises by 3,010% whereas the output of the biodiesel sector increases by 770.1%. The results also show that there is no decrease in the output of other major agricultural sectors since the augmentation of area under jatropha cultivation is done by making use of degraded land. When overall agriculture productivity increases as in scenario 2, the results show an additional significant increase in the output of jatropha and biodiesel on top of the large increase in scenario 1.

There is also a small increase in the output of food crops as a result of the spillover impact of technological improvements in the jatropha sector. The prices of paddy, wheat, cereals and other cash crops increase respectively by 1.29%, 0.87%, 1.17% and 1.10% in scenario 1. A productivity increase in the jatropha sector marginally increases these price effects. These marginal price increases may be due to increases in input demands due to jatropha intervention in the economy. The results clearly show that increasing biofuel production significantly improves social welfare without having any significant negative effects on the agricultural sectors.

A fixed supply of unskilled workers in the economy implies that an expansion in the jatropha plantation would have a cost-push effect on other sectors of the economy that depend on unskilled workers. With limitations in supply, the increased demand for unskilled workers would push up the real wage of unskilled workers. This would in turn affect the growth of other agricultural sectors. The data in Table 7.3 indicates all agricultural sectors grow at a slower pace in scenario 3. However, the good news is that all the agricultural sectors still register positive growth.

### 2.3.4 Rural Development

Compared to the wage income increase in both agricultural and non-agricultural sectors, the non-wage income increase is much higher. In the agriculture sector, including jatropha, the wage income increase of unskilled workers is in the range of Rs54.6 billion. The same in non-agricultural sectors is about Rs11 billion. However, the income increases for skilled workers in both agricultural and non-agricultural sectors are not high. This is because non-edible oil seed production and its processing to produce biodiesel do not require much skilled labor. However, they register a Rs3.3 billion increase in income due to their employment in the biodiesel sector (see Table 7.3). This significant income for non-skilled workers is an important element in inclusive rural development for which the Indian government is pursuing with considerable effort.

Gains accrue as non-wage incomes in the agricultural (Rs163 billion) and non-agricultural (Rs144.4 billion) sectors are large compared to wage income increases (Table 7.3, scenario 1 and scenario 2). Agricultural sectors gain from higher non-wage income increases compared to non-agricultural sectors. Non-wage incomes in the non-agricultural sectors also gain significantly due to the growth of the biodiesel sector and also due to the overall growth of the economy. The major portions of non-wage income are profits accruing along the various segments of the supply chain. Therefore, the biodiesel sector will provide adequate income incentives to entrepreneurs to engage in this sector making it a feasible venture for rural development in India. Both wage and non-wage increases occur mainly in the rural economy providing a boost to the rural sector. In scenario 3, the economy registers lower growth. Consequently, all factors register lower growth in income. However, the trend is similar to that of scenarios 1 and 2.

The increased productions in the feedstock (jatropha) sector and biofuel processing sectors obviously have employment implication. Furthermore as overall economy registers small positive growth, it implies that there are indirect/induced employment expansions as well in other sectors. In our model, we have assumed that the total supply of skilled labors is fixed whereas there is infinitely elastic supply of unskilled labor force in the economy. Thus, it is possible estimate the amount of new unskilled jobs that would be created under scenarios 1 and scenario 2. According to our model estimates, about 30 million additional jobs for unskilled workers would be created in scenario 1 if 20% blending target is implemented. If productivity effect is enforced in scenario 1, the number of new created would obviously be increased since the economy now registers addition growth. According to model run, about 33.3 millions additional jobs for unskilled workers would be created in scenario 2.

## 3. Global CGE Model

Over the last generation, global energy and food prices have followed opposing trends, with energy prices rising and food prices falling nearly monotonically, except for the 2007-08 surge in food prices. Now biofuel substitution may create significant linkages between the two markets, and this divergence might be reversed or at least attenuated. Thus the link between food and energy securities through biofuels opens up an important policy challenge and its importance magnifies for a country like India for two major reasons. First, India has a very large population living in poverty who spend a large proportion on their income on food and as their income increases food[3] demand will increase substantially. Moreover, population growth will add to the increasing food demand. Second, much of India's arable land is already under cultivation and to meet growing food demand, local food production will require increased productivity.

[3] We refer to agricultural food (food) in this discussion, because food can come from other sources such as marine fishing.

On a global scale, the energy-food trade-off can be thought of in terms of a single production possibility frontier, shifting resources to balance price changes between the two products. For an individual country, however, the decision framework is very different, depending on the relative sizes of domestic and foreign markets. Because India imports over two–thirds of its conventional energy and produces most of its own food to meet the basic needs of a poor majority, it has limited control over conventional fuel prices and little flexibility to substitute agricultural resources for energy crop production. While India can develop significantly greater hydro, solar, and some other renewable energy alternatives, it is constrained primarily to land classified as marginal for biofuel production.

An economy the size of India cannot ignore global market conditions, but neither does it need to accept them as given. In the case of conventional fuel energy, India's long-term position may be that of a price taker, but in agricultural food, the domestic capacity is such that India can significantly buffer itself against external shocks. This is true, in fact, both for direct (food price) and indirect (other essential commodity) price shocks, as we shall see below.

To assess India's policy options with respect to global energy price trends, we apply a global dynamic forecasting model, calibrated to a custom version of the Global Trade Analysis Project (GTAP) 7 database. The model is a global, multi-region, multi-sector, dynamic applied general equilibrium model - a version of the World Bank's LINKAGE Model. The model is described in Appendix 8. This global economic forecasting model fully assesses the complex domestic and international welfare effects of the modern biofuel economy. In particular, the analyses examine how international food and fuel trends may influence the domestic policy options open to India. The base data set—GTAP Version 7.0—is defined across 118 country or regional groupings, and 57 economic sectors. For this paper, the model has been defined for an aggregation of 13 countries or regions and 10 sectors, including sectors of importance to developing countries—grains, textiles, and apparel.

To better understand the influence of global energy price uncertainty on the Indian economy and options available to policy makers, we consider a set of three basic scenarios. The first of these is a business-as-usual reference case, calibrated to independent consensus growth rates around the world and assuming a 50% increase in the price of oil by 2030. The model considers four types of domestic policies. Scenario 2 assumes a scaling up of biofuel production to meet 20% blending of biodiesel. Scenarios 3 assumes a scaling up of both biodiesel and ethanol production to meet 20% blendingtargets. Scenario 4 and 5 will add energy efficiency standards and food productivity growth on top of the biofuel intervention. In the fourth case, we assume that government policies achieve annual gains in overall conventional fuel use efficiency of 1%, a demand side management target that has been achieved or exceeded in many economies. In the fifth scenario we assume that a combination of agricultural policies leads to 1% annual growth of agricultural productivity. The results of all these for the Indian economy are then assessed by a variety of macroeconomic indicators.

**Table 7.4: Policy Scenarios**

| | |
|---|---|
| S1: | Reference case, Global oil price increase by 50%, 2010-2030 |
| S2: | Scenario 1 with 20% biodiesel and standards. |
| S3: | Scenario 2 with 20% biodiesel and ethanol standards |
| S4: | Scenario 3 with 1% annual energy efficiency gains. |
| S5: | Scenario 4 with 1% food productivity growth. |

**Table 7.5: Macroeconomic Results (Percent Change from Reference Level in 2030)**

| | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|
| Real GDP | -4.8% | -0.5% | -0.5% | -0.4% | 2.9% |
| Real Cons | -6.6% | -1.0% | -1.0% | 1.6% | 6.2% |
| Exports | -4.1% | -0.9% | -1.0% | 2.4% | 1.3% |
| Imports | -9.3% | -0.0% | -0.1% | 2.7% | 3.2% |
| Food Imports | -8.3% | 2.3% | 3.0% | 9.5% | -29.5% |
| Energy Imports | -27.6% | -10.6% | -12.5% | -19.0% | -13.0% |
| GDPPC_PPP | -4.1% | -0.9% | -0.9% | 1.3% | 5.1% |
| CPI | 3.0% | 0.7% | 0.8% | 4.6% | 1.7% |
| Food CPI | -2.6% | 0.4% | 0.6% | 1.9% | -11.9% |
| Energy CPI | 48.6% | 5.4% | 5.8% | -9.0% | 0.4% |
| Real HH Income | -4.7% | -0.4% | -0.4% | 2.3% | 4.2% |
| Real Wages | -5.9% | -0.2% | -0.3% | 3.7% | 7.9% |
| GHG Emissions | -26.2 | -6.7% | -7.5% | -18.1% | -15.6% |

Table 7.5 summarizes the macroeconomic impacts of the four counterfactual scenarios. The reference scenario (S1) shows that a 50% increase in oil prices during the next two decades will have significant negative macroeconomic impacts on India. The biodiesel intervention would offset more about 90% of the adverse macroeconomic effects of higher energy prices in GDP terms and 78% in GDP per capita terms. Consumption losses are compensated by about 84% while the household income losses and negative wage impacts are offset by over 90%. Biodiesel intervention reduces the inflationary pressures brought about by about 77%. Thus, comparison of the macroeconomic indicators of S1 and S2 confirms that biodiesel intervention can counteract the negative economic impacts of oil price hikes to a considerable extent, though not completely. This finding is in agreement with the previously presented results of the Indian CGE model. Aggregate emissions would be substantially reduced, first by higher oil prices, second by biofuel introduction. The former being contractionary, but the latter expansionary: biofuels are a growth catalyst, but a greening one.

The results of S3, show the macroeconomic indicators when both biodiesel and ethanol interventions are applied together. A comparison of the results in S3 with S2 shows that ethanol intervention makes marginal or no improvements. For example, GDP growth, per capita GDP, and household income do not show any improvements with the ethanol intervention Within India, because ethanol diverts agricultural resources, they undermine food security to some extent. This can be seen in a significant (5.3%) food import increase and a modest (0.2%) food CPI increase. The increase in food imports is also partly due to higher incomes among the rural populations who spend a larger share of their incomes on food. Note that in S1 we keep food productivity constant at the 2010 level. Scenario 5 addresses this challenge constructively, since only moderate productivity growth would neutralize this impact. It must be recalled, however, that we are assuming the vast majority of biofuel, jatropha based diesel, is produced on marginal land that does not compete directly with food. Were this not the case, the fuel-food impact would be much more adverse.

The results show that biodiesel intervention in India offsets the negative impact of oil price increases to a significant extent whereas the impact of ethanol in counteracting the effect of oil price increases is marginal. Anticipating escalating energy prices, what would then be an appropriate policy response? Many believe energy security should be achieved from the supply side and for some people, renewables with significant growth potential and perhaps nuclear power provide the solutions. The use of agricultural resources for energy production has two disadvantages. First, the availability of agricultural resources is constrained in a country like India because the natural resource base, especially arable land, is fully utilized to meet current food needs. Second, supply elasticities are further limited by such natural resources constraints when the production of biofuels is confined to marginal lands. Taken together, these circumstances impose limitations on the efficacy of agricultural solutions to the problem of higher energy prices or energy security.

An alternative approach to energy security is to recognize the rationing signal embodied in escalating energy prices and promote demand side solutions like energy efficiency. Development and diffusion of more efficient technologies may entail costs, but the benefits can justify these costs. Even with modest improvements, 1% annually, energy efficiency can be a potent catalyst for employment creation and growth. The conventional energy supply chain in any country is less employment intensive than most other consumption categories. Thus, if you can save a household one rupee on energy, this money will then be diverted to customary expenditure categories (largely food and services), which can be an order of magnitude more job intensive. Moreover, efficiency moderates energy price inflation and adverse real income effects while it is creating jobs elsewhere in the economy.

The demand side approach is illustrated in Scenario S4, where we assume 1% annual energy efficiency gains across the economy. While the cost/price distortion from biofuels remains in place, real incomes, consumption, and employment all rise as households and firms save money on energy. Overall trade increases in both directions, but energy imports fall considerably. Food security appears to be undermined as food imports increase with domestic purchasing power, but we have assumed static food productivity in this scenario. The general price level of the economy also increases significantly. One very important gain is an 18.1% reduction in economy-wide GHG emissions; nearly three times the benefit attributable to the biodiesel expansion alone. Again, with the right combination of demand- and supply-side policies, just less than one month's delay[4] in growth over 20 years enables the economy to achieve significant climate mitigation.

One of the drawbacks in the biofuels and energy efficiency scenario is the adverse impact on food security; food imports increase by 9.5% and the food price index increases by 1.9%. A third line of attack, addressing both energy and food security, is captured in scenario S5, where public resources are targeted at both energy demand and food productivity increases by 1% year. Simulation results show that all the macroeconomic indicators have improved; real GDP, consumption, employment, and all other living standard-related macrovariables rise substantially. At the same time, imported food dependency falls by about 30%, food prices are substantially lower, and we can expect national health indicators would improve accordingly. Moreover, GHG emission reduction is also very high although slightly lower than that for scenario S4. Energy imports still fall relative to the baseline, but somewhat less because of economic expansion. Overall, however, we have a virtuous cycle of greater national self-sufficiency in food and energy, higher incomes and employment, lower GHG emissions, and full economic accommodation of the biofuel agenda. Therefore biofuel expansion together with energy efficiency and food productivity improvements provide a win-win option for India to counteract the negative impacts of energy prices hikes.

How feasible is the last scenario? Data on the experiences of other countries with energy efficiency suggest there is plenty of low hanging fruit for India to harvest such improvements. For agricultural productivity, history also suggests that the right policy initiatives can do as well or better than we have assumed. As Table 7.6 suggests, this improvement is well within the historical potential in the region. The growth effects are dramatic not only because of expansion in the primary sector of the world's second most populous economy, but because they again reverse the net effects of substantial energy price inflation. Because they are combined with energy efficiency policies, the real output gains from productivity growth lead to

[4] Under the S4 scenario, a -0.4% growth will result. With the average growth of 6%, this delays economic expansion by one month.

falling resource costs, greater international competitiveness, and even higher real incomes across India's vast low income rural sector.

In a very real sense then, combined policies of this kind lead to sustainable energy, environmental, and food security. Demand-side solutions are promoted on the energy fuel side, where India has a relatively limited market power as a supplier. This attenuates and even reverses energy price escalation; averting resource pulls to this activity that would simply promote greater energy use. At the same time, promoting productivity growth across the country's still dominant food economy increases output, employment, and lowers relative prices of this essential category to substantially offset price increases in energy commodities.

**Table 7.6: Average Annual Growth of Agricultural Output**

| | 1970–1979 | 1980–1989 | 1990–1999 | 2000–2006 |
|---|---:|---:|---:|---:|
| **Sub-Saharan Africa** | 1.31 | 2.6 | 3.1 | 2.2 |
| **Latin America and Caribbean** | 3.07 | 2.37 | 2.87 | 3.13 |
| **Brazil** | 3.83 | 3.73 | 3.29 | 4.41 |
| **Middle East and North Africa** | 2.94 | 3.37 | 2.73 | 2.34 |
| **NE Asia, High** | 2.15 | 1.03 | -0.01 | -0.01 |
| **NE Asia, Low** | 3.11 | 4.55 | 5.06 | 3.85 |
| **PRC** | 3.09 | 4.6 | 5.17 | 3.87 |
| **SE Asia** | 3.68 | 3.59 | 3.13 | 3.54 |
| **South Asia** | 2.56 | 3.39 | 3 | 2.19 |
| **India** | 2.69 | 3.52 | 2.94 | 2 |
| **North America** | 2.17 | 0.73 | 2.03 | 1.1 |
| **Oceania** | 1.79 | 1.25 | 2.93 | -0.04 |
| **Western Europe** | 1.54 | 0.94 | 0.46 | -0.35 |
| **Eastern Europe** | 1.8 | 0.25 | -2.18 | -0.19 |
| **Russian Federation** | 1.32 | 0.98 | -4.62 | 2.7 |

**Table 7.6: Average Annual Growth of Agricultural Output, cont'd.**

| | 1970–1979 | 1980–1989 | 1990–1999 | 2000–2006 |
|---|---|---|---|---|
| **Developing countries** | **2.82** | **3.46** | **3.64** | **3.09** |
| **Developed countries** | **1.88** | **0.86** | **1.21** | **0.39** |
| **Russian Federation and Eastern Europe** | **1.47** | **0.77** | **-3.88** | **1.81** |
| **World** | **2.23** | **2.13** | **2.04** | **2.22** |

*Source: Jha, Roland-Holst, and Sriboonchitta (2009).*

## 4. Concluding Remarks

In this chapter two CGE models were developed to examine the economy wide impacts of biodiesel in India. The first model, which used a static framework that considered only the Indian economy, showed that biodiesel provides India with an opportunity to enhance economic growth and the well being of rural workers. Since the well being of rural populations are a problem in India the biodiesel program can be used as an avenue for poverty reduction within an *inclusive growth* policy framework. Moreover, the minimum support price scheme commonly adopted in the agricultural sector together with a mandatory blending requirement can augment the production of the biodiesel sector. The negative impacts of the program, such as a higher fiscal deficit, seem not to dampen the growth effects. In sum, the policy of using degraded land for biodiesel production enhances economic growth while providing opportunities for inclusive economic growth in India.

Energy is closely linked with historical prosperity, but energy dependence also confers important risks. Primary among these are risks to real incomes from escalating energy prices and global warming pollution from conventional energy use. The second part of this Chapter evaluated these issues for India from the perspective of global market forces and domestic policy responses. There is convincing evidence that oil prices may establish substantially higher trends over the next two decades and this will have substantial negative macroeconomic impacts for India. Biofuels have the ability to partially counteract these negative effects and the findings of the Global CGE model confirm the results of the previous model. At the same time, however, the findings show that India has more options in addressing this challenge.

In particular, our analysis supports the wisdom of policy packages that combine supply-side energy solutions, like biofuel development, together with demand-side management, and inflation hedging in other essential commodities through productivity improvements. In the former case, we show that promoting energy use efficiency can save households and enterprises money, create more jobs elsewhere in the Indian economy, and stem the erosion of real incomes from more expensively imported energy or less efficient domestic substitutes, while at the same time reducing long term environmental risks.

A second, more indirect response to energy price inflation is to promote food productivity growth. This has the primary benefit of reinforcing food security and traditional livelihoods across the country, but indirectly it also disciplines prices of another essential commodity group, food, where price deflation can substantially offset energy price inflation in the budgets of poor households. Even modest assumptions about energy efficiency and food productivity gains can reverse negative shocks to per capita incomes for the majority of India's population. The promotion of biodiesel together with energy efficiency and agricultural productivity is the correct policy package for India to counteract energy price increases.

**CHAPTER 8**

# Conclusions and Policy Implications

## 1. Major Findings

India's biofuel policy is comprehensive and gives a broad outline to all the major areas that need attention. These guidelines have to be translated into a set of actions in order to reap the potential benefits of the biofuel sector. In this context what is required is a comprehensive biofuel program with adequate details and a series of projects to implement the policy. The findings of this report and its recommendations will contribute towards that end.

Simple natural resource accounting shows that 20% blending of ethanol can be achieved by 2017, if a sufficient quantity of sugar cane juice is converted to ethanol to supplement molasses based ethanol. The sugarcane sector is well organized and there are no major technological or other constraints, which prevent meeting the blending target. The basic two problems of meeting the ethanol blending target are: i) the conversion of cane juice to ethanol will affect food production unless crop productivity is significantly increased; and ii) the diversion of ethanol from industrial and potable alcohol sectors, when adequate quantities are not available, which adversely affect these industries. Other potential ethanol crops such as sweet sorghum (SS) and tropical sugar beets (TSB) are still at the initial stage of development and face major technological and financial constraints. These crops also use arable land and therefore compete with food crops for land and water resources. Therefore meeting the target of 20% blending of ethanol is unlikely if the Government of India's principle on not compromising the food security for biofuel production is strictly followed.

The ethanol and biodiesel supply chains show some similarities but the major constraints faced by the two are quite different. In the case of ethanol the supply chain is fully developed for sugarcane. In comparison the SS and TSB supply chains are yet to be fully developed and matured. The agronomy of these crops has been studied but so far has not been taken up at the farming level so no commercial ventures have started. The major bottleneck along the supply chain occurs at the juice extraction level. The seasonal yield comes to the mill in a short period of time and juice extraction should be undertaken within this period. Mills operate for only one to two months of the year and this seasonality makes the juice extraction unit financially unattractive. Such a bottleneck in one segment of the supply chain may break it completely.

About 32 million hectares of wasteland are required for biodiesel production together with yield improvements to meet the 20% blending target. Unlike the case with sugarcane based ethanol a lot more groundwork needs to be done to realize the potential of biodiesel. In contrast to the sugarcane ethanol supply chain the biodiesel supply chain is in its infancy. Nursery and plantation stages need immediate attention because without high yielding varieties and a proper understanding on suitable agronomic practices the industry cannot take off as a commercially successful national scale venture. Processing and other downstream segments will quickly develop if the pricing issues are properly resolved.

In both ethanol and biodiesel, retailing could be a potential problem. The mandatory requirements for blending may force OMCs to blend biofuels. However, the real incentives for biofuel blending – profits for OMCs – should be adequate to make the OMCs whole heartedly support the biofuel industry. This aspect, however, will require further analysis.

An assessment of the social and environmental impacts of large-scale ethanol and biodiesel production shows they are quite different. Given the weak database and difficulty in predicting changes in future farming systems, the predicted impacts should be viewed with caution. There are positive and negative environmental impacts of biofuel production and use. Biodiesel is in its nascent stage of development; hence the environmental externalities are yet to manifest themselves in large scale. However, biodiesel has significant positive socio-environmental externalities and sustainability footprints in comparison to ethanol. The main conclusion of the social and environmental assessment is that there are no major negative impacts and most of the negative impacts of both ethanol and biodiesel can be mitigated with available technologies, and legal and regulatory measures. However, research in this area should continue as the database is weak and potential impacts will evolve with future expansion of the industry.

The financial analysis shows biodiesel production has not been profitable under the Government's administratively determined pricing regime, although the recent price increase for ethanol has changed this situation for this fuel. The results clearly demonstrate that the biodiesel industry will not take off under the current pricing mechanism and 20% blending of biodiesel is not feasible without a major revision in pricing.

The economic assessment shows that molasses based ethanol is economically feasible at the current price of oil. CDM benefits and oil price increases make molasses based ethanol economically more attractive. The economic attractiveness disappears if industrial and potable sector alcohol is diverted for transport use. In contrast, the cost of sugarcane juice based ethanol exceeds the social benefits, even without including the opportunity cost of displaced sugar. Once the opportunity cost of displaced sugar is incorporated, the economic losses increase making sugarcane juice based ethanol further unattractive. Oil prices as high as 140%

of current prices cannot make sugarcane juice based ethanol economically attractive. Therefore, sugarcane based ethanol will not be economically attractive even in the future. The use of sugarcane juice to produce ethanol also compromises food production. Hence, the present study does not recommend sugarcane juice based ethanol production as a socially desirable activity in India. Alternative feedstocks such as sweet sorghum and tropical sugar beets are not economically feasible either at current oil prices and their supply chains face major technical barriers.

Given that molasses based ethanol is economically feasible and it does not compromise food security in India, the ethanol industry should rely on molasses based ethanol. In the meantime research should continue on second generation ethanol technology with which the ethanol industry can be up-scaled as technologies become commercially viable. The sugar industry is well established. If the price is fixed at a level that provides incentives along the supply chain, it can survive on its own without assistance from the public sector. A 10% blending can be achieved without any major change in the vehicle fleet. A vibrant molasses based ethanol industry may also have a stabilizing effect on the cyclical nature of the sugar industry. However, given the growing attractive alternative uses of ethanol in industry and the potable alcohol sector, 10% blending cannot be achieved without significant productivity increases. Given the current productivity growth of sugarcane and blending quantities in the previous years, a 5% blending of ethanol produced from molasses seems to be the pragmatic national target.

The economics of biodiesel are very different from that of ethanol as jatropha and pongamia both provides acceptable returns at current oil prices. An increase in the price of diesel makes biodiesel more attractive. If confined to wasteland with limited irrigation only at the beginning of the planting season, biodiesel will not compete with food crops for land or water in any significant manner. Employment generation and CDM benefits are also significant in the case of biodiesel. Therefore, the expansion of biodiesel production is socially desirable and the results of this report justify a support program for biodiesel in India.

There is a large potential for obtaining CDM benefits for biodiesel plantations. In order to avoid the large transaction costs, some government or non-governmental agencies should prepare the CDM documents and the CDM project should be on a larger scale perhaps at district levels to reduce overhead costs. A suitable financing and institutional mechanism can be designed to distribute the CDM benefits among the farmers. Current rules may not allow receiving CDM benefits if blending is made mandatory. Some innovative methods should be designed to get around this rule to have access to blending CDM benefits.

The economy wide impact of biodiesel in India was studied using two general equilibrium models. The first model considered only the Indian economy with only a biodiesel intervention, and showed that biodiesel could provide India with an opportunity to enhance economic growth and the well being of rural populations. A national biofuel program has the potential to create about 18 million direct jobs with significant real wage increases. Since economic conditions of the rural poor are the worst in the Indian economy, the biofuel program can be used as an avenue for poverty reduction within an *inclusive growth* policy framework. The negative effect of the program, i.e. higher fiscal deficits, seems not to dampen the growth effect. In sum, the policy of using degraded land for biodiesel production enhances the opportunities for economic growth and reducing rural poverty in India.

While the results on the economic prospects of biodiesel are promising, they are based on a major assumption that about 32 million hectares of wasteland will be brought under non-edible oil plantations. The biodiesel industry in India is at an infant stage of development and an enormous amount of work on land allocation, selection and breeding, nursery development, research on agronomy, pest and disease control, identifying and providing necessary incentives to various segments in the supply chain, creating an enabling business environment for the private sector, coordinating among large numbers of producers spread across India, and introducing necessary regulatory measures have to be undertaken to realize the potential of biodiesel in India.

Financial analyses of various activities along the two biodiesel supply chains show there are economies of scale to be realized with the appropriate size of plantations and processing units. Processing units are generally quick in realizing such cost savings whereas at the plantation level they are not so easily found, especially in the case of biodiesel. One model that may help realize suitable economies of scale would be to have a large-scale core farm with a seed expelling unit and a number of small farms around the core. Further studies on farming models may be required to fully realize the potential economies of scale. The lease cost of land is an important part of the overall costs of biodiesel plantations. Therefore, any promotional package for biodiesel should consider providing subsidized land leases. Further research is also needed to understand the feasibility of the provision of public lands for biodiesel production at subsidized rates.

There is convincing evidence that oil prices may trend higher over the next two decades and this would have a substantial negative macroeconomic impact for India. The expansion of biofuels is one policy response India can adopt to counteract the economic impact of oil price hikes. Combining supply-side energy solutions, like biofuel development, together with demand-side management and productivity improvements in agriculture will provide better results. Even modest assumptions about energy efficiency and food productivity gains can reverse negative shocks to per capita incomes for the majority of India’s population.

This report asserts that biodiesel has promising economic prospects whereas ethanol shows mixed economic results and possible negative impacts on the food sector. In particular the use of sugarcane juice for ethanol will not provide adequate benefits to justify the costs and it will compromise food production in India. Therefore, one of the main policy directions emanating from the analysis of this report is the need to deal with ethanol and biodiesel separately in the biofuel policy of India. While first generation ethanol seems to have limited scope in India, the second generation ethanol should be given further consideration, particularly in terms of adaptive research.

## 2. Conclusions

The major conclusions, which can be drawn from the above results, can be summarized as follows:

- Biofuel policy in India is comprehensive and it provides the necessary broader guidelines for the sector. However, separation of the policy for ethanol and biodiesel will serve the needs of the two sectors better.
- Ethanol production using sugarcane juice is not justifiable on economic grounds and food security. The ethanol sector should be confined to molasses based production and its future expansion should be based on second generation ethanol technology.
- The molasses based ethanol sector is well developed; therefore it can survive on its own, when reasonable prices are provided to producers.
- Administratively set, current biodiesel prices are inadequate to meet financial costs. A revision of prices is necessary for the sector to survive.
- Biodiesel production is economically feasible; its benefits exceed the costs. It has a potential to enhance inclusive rural development. Expansion of the biodiesel sector has significant positive macroeconomic impacts without any negative impacts on the food sector.
- The environmental impacts of the biodiesel sector are largely positive and its limited negative impacts can be easily mitigated with existing technologies. The sector also provides large potential for CDM benefits. Expansion of the biodiesel sector does not have foreseeable negative social impacts.
- In addressing the economic impact of future oil price hikes, India can achieve better results if supply-side responses such as the expansion of biodiesel, are applied in conjunction with energy efficiency and agricultural productivity improvements.

- The biodiesel sector in India is in its infancy and an enormous amount of work on many aspects of production should be undertaken to facilitate the sector's takeoff.
- The implementation of a biofuel policy requires a detailed program and projects for specific targets. This program and related projects can mainly focus on the biodiesel sector.

**3. The Role of Public Sector**

Based on the above, the ethanol sector should be limited to the use of molasses and the sector requires limited public support, mainly in pricing and making blending mandatory. Therefore, discussion in this section mainly deals with the biodiesel sector.

The biodiesel sector should remain a regulated sector because without making certain levels of blending mandatory, the sector will not develop. Moreover, under high oil price scenarios, biodiesel production might be expanded to utilize arable land, the prevention of which requires continuous monitoring. Most of the activities in the biodiesel supply chain can be undertaken by private economic agents but the legal, institutional and regulatory framework for the enabling business environment has to be created by the government. Thus, the government's role here should be limited to correcting the market and non-market failures, which prevent the development of the biodiesel markets.

In order to encourage the growth and development of the biodiesel sector the Indian government should create an enabling environment that allows biofuel producers and other stakeholders to withstand market fluctuations. Sustainable long-term biodiesel friendly policies rather than the stop/start approach (which coincides with oil price fluctuations) are required for the sector to grow at a steady pace. The increase of social benefits of biodiesel as oil prices increase provides additional justification for long-term proactive biodiesel policy actions. The biodiesel market will not emerge automatically and regulatory mandates to blend together with other supportive activities are necessary for the sector to develop.

Oil seed research will play a vital role in the development of the sector. Agronomy, pest and disease control, the optimal level of irrigation under dry land conditions, and more importantly selection and breeding to increase the yields (both seed yields and oil content) have to be undertaken immediately to ensure the biodiesel sector takes off. Large number of research initiatives is already in place. However, proper coordination and a realist and urgent target of the research for commercialization of the sector is still lacking. Research, being a quasi-public good, will not be undertaken by the private sector at an optimal level. Private research findings, if available, can become too costly. Therefore, support for biodiesel research is one area that the public sector can pay immediate attention to. Research on the adaptation of second generation biofuels should also continue while aggressively pursuing the above stated research for biodiesel.

Public private partnerships should be sought for field level application of research findings. The targeted research should be undertaken in a coordinated manner with the industry. For example, improved planting material from research should be directly supplied to selected private sector nurseries for propagation. Here the assistance for the private sector in terms of the provision of information, dedicated credit lines, equity investments, and risk guarantees can play an important role. These instruments should not be confined to nurseries, but made available to other needy segments of the supply chain.

Land markets are generally not functional and in the case of wasteland, government intervention is necessary to allocate land for biodiesel. Land suitability studies, mapping of the wastelands and resolving property rights issues are of vital importance as well as urgent. Land lease cost is a prominent part of the cost of biodiesel production. Given the large amounts of inclusive social benefits, the provision of land at subsidized leases can be part of the incentive package for the promotion of biodiesel.

The CDM benefits of biodiesel are large enough that policy makers should pay attention to them. The high transaction costs of obtaining carbon credits can be avoided by scaling up CDM projects. The public sector can consider a district or a similar unit to develop CDM projects. If prices are revised to provide adequate incentives for biodiesel and subsidies are provided at the initial phase (up to the break even diesel price), the government can use the CDM benefits as part of its cost recovery. Government expenditures on subsidies during the initial years can be recovered in later years by imposing taxes on the sector as oil prices increase.

The biodiesel sector will involve a large number of farmers, processors and blending outlets spread across many parts of the country. The early stages of such a development will face information and coordination failures[1]. For example, an investor interested in establishing an oil seed plantation may want to know the availability and quality of land he can use, ground water availability for limited irrigation, the availability of grid electricity and other infrastructure facilities, information on suitable varieties and how will they perform under given specific conditions, what are the registration or licensing requirements to commence the business, what are the future prospects for biodiesel markets, and about the adequacy of downstream processing and other developments. Markets generally fail to provide such information and coordinate among the different stakeholders.

[1] See Rodrick 2004 for details.

Moreover, information failures and cost discovery[2] problems in new markets create additional risks to entrepreneurs who invest in new products or services. If the effort on innovative products fails, he or she will bear all the costs, but if the effort succeeds, many others will follow and share the benefits. Due to such problems, there will be inadequate efforts to introduce innovative instruments or products in new markets. These problems are relevant to emerging sectors such as biodiesel and public sector intervention will be required to correct them. A central public agency, with branches at the state level will be necessary if these problems are to be avoided. But further studies will be needed to examine the organization and financing structures of such an agency.

The biofuel policy envisages the support of donor agencies for the development of the sector. Technical assistance should be sought to further refine and develop the above cited public sector roles. Once the necessary details are available, public sector projects can be formulated and some of them can be financed by donor agencies.

## 4. Recommendations

The following are the recommendation from the above discussion:

- **Separation of Policy for Ethanol and Biodiesel:** Biofuel policy in India should have separate sections for ethanol and biodiesel.
- **Focus on Molasses based Ethanol:** Ethanol production should be limited to molasses based ethanol and the ethanol blending targets should accordingly be at 5%.
- **Limited Public Support for Molasses based Ethanol:** Public support should include regulatory measures for blending and the revision of prices to make the industry financially viable.
- **Research on Second Generation Biofuel:** Research efforts on both second generation ethanol and biodiesel should continue.
- **Public Sector Support for Biodiesel:** At this point in time, the main focus of public support should be on biodiesel. The following are the specific areas that require attention:

  a) Land use mapping and land allocation study and the necessary legal, institutional and other provisions to make wasteland available for biodiesel production.

[2] See Hausmann et al. 2005. The basic idea here is if an entrepreneur fails in his attempt to use innovations he bears the cost whereas if he succeeds, others also get the benefits.

b) Develop and implement land selection criteria to avoid negative social and environmental impacts of biodiesel plantations.

c) Revision of biodiesel and oil seed prices and creation of a stable policy environment for the biodiesel sector to develop.

d) Accelerate the research program on agronomy, including selection and breeding, pest and disease control and other management practices and the propagation of high yielding planting materials for plantation development.

e) Incentive packages for the private sector to establish plantations and processing units.

f) Further studies on potential synergy between India's rural development programs such as the Mahatma Gandhi National Rural Employment program for the biodiesel sector. In particular rural development programs should focus on the support for small-scale farmers during the gestation period of the crops.

g) The establishment of a national agency with branches in relevant states to design and implement the above stated public support program, oversee and monitor the biodiesel industry, periodically review the cost of production and prices, and design and recommend subsidies and taxes based on the changes in oil prices.

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## Appendix 1

# Global Biofuels Policies & Lessons

Although a very large number of countries have a biofuels program and most of them have some policies in place to promote biofuels. In this appendix only those selected region and countries are covered that have major successful program and well defined policies which include Brazil, USA and Europe. While Brazil and USA are the two largest producers and consumers of Ethanol, Europe leads the world with respect to production and use of biodiesel. The main drivers of biofuel development globally have been the economic benefits in terms of enhanced incomes to rural communities, enhanced energy security and assistance in addressing climate change issues.

**Policy Scenario & Initiatives of Brazil**

The creation of the National Alcohol Programme (NAP) in 1975, commonly known as ``ProAlcool'', provided the world one of the most innovative and successful biofuel programmes seen globally[1]. ProAlcool went through a number of changes and modifications mirroring the political, economic and energy priorities of Brazil; however the ethanol production and consumption over the last few decades has proved that the programme has been successful in achieving its basic aim, i.e. of providing Brazil with a better energy security and stronger rural economy.

Despite the fact, that Brazilian program is an supposed to be a shining example of successful biofuel programme but it went through its own rough spots which can be gauged by the fact that in the mid-1980s, more than three quarters of all cars in the country were operating on neat ethanol in addition to the cars using blended gasoline whereas in 1989, when Brazil faced an acute economic crisis, subsidies were removed and sugar prices rose sharply, sales of neat ethanol cars dropped to less than 1 % of total annual auto sales. Brazil was able to overcome these hurdles and today, is the second largest and most efficient producer of ethanol from sugarcane[2]. Over time Brazil has used a number of incentives. The programme has moved from a 5% blending mandate at the start of the programme to 20-25% blending mandate in 2007-08 along with use of flex fuel vehicles that use any blend of Ethanol and petrol.

The economic and energy crisis ('oil shock') of the 1970s along with the threat to the sugar industry in the form of falling sugar prices, provided the two major factors that were the

[1] Source: Frank Rosillo-Calle et all
[2] Source: World Energy Outlook 2006

main stimulants for the creation of ProAlcool Programme. The roll out of this programme can be broken up into a number of phases based on the political and economic climate in Brazil.

**Phase I, 1975-1979** - **Creation and establishment of ProAlcool:** – The programme was launched in November 1975. The government created a new institutional framework around the programme to facilitate its implementation with an inter-ministerial commission called CINAL. This phase saw the government taking up certain major policy interventions for promoting the production and use of ethanol. Some of these were:

- Mandated blending of ethanol with gasoline (gasohol)
- Tax reduction on ethanol fueled cars and reduction on annual license fee on cars
- Low-interest loans for development of distilleries
- Guaranteed purchase of bio-ethanol
- Regulation of pricing and adoption of production quotas of bio-ethanol to make bio-ethanol competitive with gasoline
- Production quotas for sugar production and export controls.

**Phase II (1979-1985) - Consolidation of ProAlcool**: - 1979 saw the creation of the National Council for Alcohol (CNAL) and the National Executive Commission (CENAL), both of which were responsible for over-seeing the development and achievement of ethanol production targets. This phase, assist by large subsidies, also saw an increase in the production of ethanol due to increases in productivity and large-scale production of ethanol.

**Phase III, (1985-1989) - Expansion and constraints**: - The third and fourth phase saw the programme adopting financial incentives to keep the programme going in the face of fluctuating oil and sugar prices as Brazil also grappled with important economic and political changes. The economy had serious problems with very high inflation rates and foreign debt. In 1984, the new democratically elected government cut public investment and subsidies. As a result by 1989, only 51% of new passenger cars were neat ethanol powered. To encourage cost reduction of ethanol, the government stipulated that the guaranteed minimum price for producers would only be provided if production costs were evaluated properly.

**Phase IV, (1990-1994) - Political uncertainty:** - The Brazilian government provided new incentives to revive falling sales of cars. However, these benefits actually helped cars using gasoline ethanol blends and not neat ethanol-powered cars.

**Phase V, (1995-present) -** targeted policy interventions: The fifth phase saw the Brazilian government focusing on targeted policy intervention factors as the macro-economic outlook was stabilized. However the major market turning event was the introduction of flex fuel vehicles in 2003 and increase in global oil prices has meant that the government does not need to hand hold the sector. Government control in terms of subsidies, quotas and price controls have been done away with from 2002. The government is now only active is specifying the definition of content of ethanol and the specifications of the alcohol used in transport. Prices have been freed from controls at all levels and no subsidies exist for ethanol.

The flex fuel car (FFV) has been a significant development as it provides consumers the choice to buy any combination of ethanol and petrol. As a result in 2008, FFV's accounted for over 90% of all auto sales in Brazil and were priced almost the same as conventional fuel cars. Today more than 50% of demand of fuel for spark ignition engine base vehicle is met by ethanol. This along with increasing exports resulted in spurt in Brazils's ethanol production. In 2005, Brazil accounted for 50 % of the global ethanol exports with India and the U.S being its biggest customers.

The Brazilian Biodiesel program has also been a great success since it was introduced in 1975. The biggest benefits of the programme have been the foreign exchange savings (projected to be over US$100 billion), a cut in emissions[3] (by 574 million tonnes) between 1975 and 2005 and large-scale rural employment created by the sector. At the same time, with increasing efficiency, the cost of production decreased steadily resulting in larger consumption of ethanol[4], which resulted in ethanol competing, without government subsidies, with gasoline. The average price of ethanol has been around US$ 0.35-0.4 per litre in the last seven years About one percent of arable land used for sugarcane plantation has replaced more than 50% of consumption of petrol and is going to add 12,500 MW in power generation.

**Policy Scenario & Initiatives of United States of America (USA)**

The US Ethanol program has been one of the most successful ones, especially in the last decade which resulted in its becoming the largest producer and consumer of Ethanol. The United States has been using facilitating legislation as the driver for bio-ethanol consumption for over 20 years. The use of ethanol had by 2008 allowed the US to import about 5 percent less gasoline. The US hopes that going forward, this share will rise dramatically as new policies are being implanted. The biodiesel program has also taken off in the last few years with capacity and production rising dramatically. Till the end of 2008, the following were the main legislations that facilitated the development of the biofuel and ethanol market in the United States:

**1990 Clean Air Act Amendments:** The 1990 Clean Air Act Amendments required that cleaner-burning reformulated gasoline (RFG) be sold in nine areas with the worst ozone pollution with effect from January 1, 1995. One of the options for the RFG was Ethanol.

[3] World Resources Institute
[4] J.D. van den Wall Bakea et al, 2007,

**American Jobs Creation Act of 2004:** This Act extended the Volumetric Ethanol Excise Tax Credit (VEETC) until 2010, eliminated any impact of the ethanol program on phasing out of the Highway Trust Fund, modified the Small Ethanol Producer Tax Credit, which allows cooperatives to fully participate in the program and created Tax Credit for biodiesel.

**The Energy Policy Act of 2005:** The Energy Policy Act of 2005 was passed by President George W. Bush on August 8, 2005. The nationwide renewable fuels standard (RFS) under the Energy Policy Act of 2005 focuses on procuring a percentage of the US fuel supply from renewable domestic fuels including ethanol and biodiesel and thereby providing a roadmap for reduced consumer fuel prices, increased energy security, and growth of rural America. The law included a $14-billion national energy plan to promote energy efficiency and conservation, modernize energy infrastructure, and provide incentives for conventional and renewable energy sources. The Act had a number of sections pertaining to the development and management of biofuels:-

*Section 942* of the Act authorizes the establishment of incentives to ensure that annual production of one billion gallons of cellulosic biofuels is achieved by 2015.

*Section 1501* of the Act establishes the Renewable Fuels Standard (RFS) which requires a players selling gasoline in the United States to mix increasing amounts of renewable fuel (usually ethanol) into the gasoline to promote biofuel use.

**Energy Independence and Security Act (EISA) of 2007:** This landmark legislation, was enacted with the stated purpose of “moving the United States towards greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes. The Act focuses on ensuring higher usage of biofuels and requires the US increase ethanol blending in gasoline by 36 billion gallons, or 25% of the total fuel consumption, in 2022, up from 4.7 billion gallons in 2007. The Act further specifies that 21 billion gallons must be derived from non-cornstarch products (e.g. sugar or cellulose). The RFS and the EISA 2007 have made fuel blenders or distributors accountable for achieving these targets and if the distributors are unable to meet requirements they would face penalties and fines associated with the shortfall. EISA has also established mandatory greenhouse gas (GHG) emissions reduction thresholds for these fuels, which they have to meet to qualify as a renewable fuel. These fuels need to meet a minimum threshold of lifecycle greenhouse gas emissions reductions compared to emissions from standard gasoline.

It was estimated that Ethanol helped support nearly 400,000 jobs and added $53.3 billion of Gross Domestic Product (GDP)[5]. The federal blending subsidy, the federal and state governments also provide bio-ethanol a range of other subsidies. For example, it was estimated that in 2006, the total subsidy for ethanol ranged between $1.05 and $1.38 per gallon of ethanol[6]. However, it is claimed that in 2009 a combination of increased GDP and higher household income generated an estimated $8.4 billion in tax revenue for the Federal government and nearly $7.5 billion of additional tax revenue for State and Local governments'. The estimated 'cost of the two major Federal incentives in 2009, the Volumetric Ethanol Excise Tax Credit (VEETC) and ethanol Small Producer Credit, totaled $5.0 billion'.

**Overview of EU Biofuels Policy Scenario and Initiatives**

EU biodiesel production has increased from 1.1 million tonnes in 2002 to about 4.9 million tonnes in 2006. The Biofuels Progress Report of the European Commission (EC) 2007 estimates that biofuels constituted about 0.5% share of transport fuel in 2003 and about 1% of the total consumption of transport fuel in 2005 as against a national indicative target set by MS of 1.4% and directive target of 2.0% for 2005. Germany and Sweden were able to achieve the directive target. Biofuels production picked up momentum in 2006 and 2007. In 2007 the share of biofuels in road transport was 2.6% (8.1 Mtoe) with biodiesel accounting for about 75% of the total; bio-ethanol about 15%; and pure vegetable oils and biogas the rest 10%. Biodiesel and bio-ethanol imports accounted for 26% and 31% of the total consumption requirements. The EU went from being an exporter of biodiesel to being an importer between 2005 and 2007. While EU exported a net of 0.355 Mtoe in 2005, it imported 1.8 Mtoe of biodiesel in 2007. At the same time, the installed capacity of biodiesel was about 10 mill tonnes in 2007.

**European Union Policies and Initiatives**

The EC policies initiatives to promote RE were launched in the 1990s. The ECs White Paper on "Energy for the future: Renewable Sources of Energy" envisaged a share of renewable energy at 12% by 2010 [EU Com (97) 599]. Subsequently, the ECs Green Paper "Towards a European Strategy for the Security of Energy Supply", released in 2000 provided the rationale for promoting the use of biofuels in the EU. :

- Climate protection & environmental sustainability - in line with Kyoto Protocol
- Diversifying fuel supplies for the transport sector – Energy security
- Developing the rural areas

[5] Renewable Fuel Association

[6] U.S. Ethanol Policy — Possibilities for the Future; Wallace E. Tyner, Department of Agricultural Economics, Purdue University, 2007

The cornerstones of policy are the various “Directives” of EC governing the use of biofuel in the EU. Some of the major ones are listed below:

- Directive no.2003/30/EC of May 8, 2003 addresses the promotion of the use of biofuels and sets a target regarding use of 2% and 5.75% of biofuels in petrol and diesel vehicles by Dec 31, 2005 and Dec 31, 2010.
- Directive 2003/96/EC of October 27, 2003 “Energy Taxation Directive” that restructures the Community framework for the taxation of energy products by encouraging member states (MS) to grant tax reductions and exemptions in favour of biofuels.
- The “Fuel Quality Directive 2003/17/EC” of 2003 amends the environmental specifications of petrol and diesel. The European Committee for Standardization limits the biodiesel blending to 5% by volume.
- The production of energy crops in the EU is encouraged by the Common Agricultural Policy and “Single Payment Scheme” (SPS) helps to facilitate the supply of energy crops.
- In the beginning of 2007 “Renewable Energy Roadmap” and the “Energy Policy for Europe” were published, aspiring for a 20% share of renewables in the EU´s energy mix and a minimum target of 10% for biofuels in transport by 2020 with each MS required to establish National Action Plans, the need for international standardization and changing fuel standards to accommodate up to 10% biodiesel in diesel fuel and 10% bio-ethanol in gasoline. Sustainability Criteria developed by the EC emphasized on the requirement of a minimum GHG savings of 35% by 2010 and 50% by 2017 as compared to fossil fuels.
- Directive 2009/28/EC restates that the European Council’s goal “that it is essential to develop and fulfill effective sustainability criteria for biofuels and ensure the commercial availability of second-generation biofuels.” It also states that mandatory provision of 10% is for renewable energy sources, which includes biofuels.

Within the frame work of laws, rule, regulations of the EU, each MS has developed its own biofuels program which encourages biofuels by giving various incentives and the progress has varied between MS. Thus while the ethanol program has taken off in Sweden, ethanol based ETBE is popular in Spain and France. On the other hand, Germany is largest producer of biodiesel. The main reason for the difference in progress has been listed by EU RE Progress report of 2009. “Tax relief and biofuel obligations” remain the two most common instruments used by MS to promote biofuels. In 2005-2006 all MS, except Finland, used excise tax exemptions as the main support measure, while biofuel obligations were only used by 3 countries. Since 2007 more than half of MS have adopted obligations to blend, in most cases, combined with partial but increasing levels of taxation. Some countries use a quota mechanism and tendering. This mechanism allows governments to decide the amount of biofuels that has to be supplied each year, thus creating some regulation of the market. However, it also highlights that some of the EU MS are making little or no progress towards their national targets, raising concern about whether those targets will in fact be achieved.

**Global Lessons from Biofuel Policies**

The Global experience shows that nowhere in the world biofuel program has been successful without incentives in the initial phase. The development of biofuels is a long term program which can take several decades. Biofuel can supplement the fossil fuels and provide a risk management option to countries which predominantly rely on important crude oil. Availability of land with suitable agro-climatic and soil conditions is essential. The main lessons from experience of successful countries has been that for the bio-fuel industry to take off, there is a need for sustained and strong legislative support to the programme backed up by a flexible approach keeping in view developing economic realities. These programmes also provide critical lessons on how the governments need to engage all stakeholders, especially private sector ones to ensure their participation such as auto manufacturers on board for producing flex fuel vehicles. There a need for long-term ambitious but realistic targets with clear cut road map for increasing of blends and yearly targets. There is a need to invest in R&D in increasing productivity of feedstocks as they are the main constraint in expansion of biofuel program. In EU, which comprises of a large number of member states, tax relief and blending obligations are the main instruments for promotion of biofuels. These have been used on conjunction with increasing levels of taxation on fossil fuels. Some countries are also using quota mechanisms and tendering, which tend to regulate the market according to realistic situation.

## Appendix 2

# Policy and Other Initiatives by Selected States

Various states in India have already formulated the strategies on biodiesel and have started working under the National Mission on biodiesel. As examples this section covers some of the major states in some detail and then highlights the main interventions in some other states in the form of a table.

### Chhattisgarh

Chhattisgarh is one of the attractive states for investing in biodiesel is Chhattisgarh as it has been successful in creating the right conditions that favour investment in the biofuels sector especially biodiesel. Initiatives Facilitating Investment in Biofuels: To facilitate the development of industry in general through infrastructure development, the state of Chhattisgarh has drawn up an Infrastructure Development Action Plan. The State has also been offering a number of incentives and subsidies to promote investments in general and investment in Biofuels in particular. Some of these subsidies have been highlighted below:

- Interest subsidy of Rs 2 million annually for 5 years and a capital subsidy of up to 35 percent of the capital costs
- Exemption from electricity duty for 15 years and exemption from stamp duty, land registration charges and loan documentation charges.

The State government has also provided substantial funds for the promotion of biodiesel plantations which includes raising of about 380 Million seedlings, which have been planted in unused, waste and marginal lands.Constitution of the CBDA: The state has also constituted the Chhattisgarh Biodiesel Development Authority (CBDA) to focus exclusively on the development of bio fuels in the state. Through the CBDA the state government is also encouraging the leasing of fallow land for Jatropha plantations with a lease period of 20 years and setting up of plantation through a joint venture. It has entered into joint venture with Indian Oil Corporation Ltd and Hindustan Petroleum Corporation for taking up large scale plantation in the state. To provide the much needed pull to the biodiesel sector, the state government has also announced a minimum support price for Jatropha and Karanja seeds and oil. Besides these interventions the state government is also in the process of setting up a number of seed procurement centres in the state.

Every farmer is being given 500 free seedlings and for 5000 seedlings at a nominal price of Rs 0.50 per seedling is charged. A minimum purchase price of Rs 6.50 per kg for Jatropha seeds and Rs 6 per kg for Pongamia and non-edible oil price of Rs 18 per litre has been announced.

**Uttarakhand**

Uttarakhand is another state that is encouraging the development of the biodiesel industry with the twin objectives of employment generation and encouraging investment in the state. The state has undertaken an ambitious scheme for the planting of almost 200,000 hectares of land through public private partnership through the Uttarakhand Biofuels Board. This target of 200,000 hectares has been divided into 2 phases with the first phase targeting the planting of 100,000 hectares by 2010-2011 and the rest 100,000 starting 2011-2012. The state till 2008-09 has planted 20,239 hectares of Jatropha across 10 districts.

The state has used the concept of Van Panchayats (Forestland managed by community committees) to promote the planting of trees in degraded forests across various districts of the state. The state is focusing predominantly on Jatropha as the feedstock for biodiesel production. The seeds or the saplings are financed by the state government from its own funds and from programmes such as the Village Energy Security Programme, NOVOD Board programmes and SGSY. In addition to funds from the National Rural Employment Guarantee Scheme have also been used for funding this programme.

The state government is using Jatropha plantations as a means of social and economic empowerment of the poor and down trodden. Only Below Poverty Line Families (BPL) or SC/ ST families are eligible for taking up the plantation under the van panchayats. The funding for the programme comes from the state and central government programmes. The state government has entered into an agreement with the Uttarakhand Biofuels Limited (UBL, a private company) for setting up a biodiesel plant. All seeds collected at the van panchayat level would be sold and transported to UBL for processing.

The Uttarakhand Forest Development Corporation will bel responsible for purchasing of Jatropha seeds from growers at the rate of Rs3/- kg, could be amended as per the rate of Bio-fuel in the market and Uttarakhand Bio-Fuel Ltd. shall responsible to set up a Tranesterification unit for oil extraction and purchasing of entire quantity of seeds at the rate of Rs3500/MT up to six years of plantation. 20% of price adjustment formula shall be applicable from sixth to tenth year. From eleventh year the purchase price will be calculated as per following formula

(Y/X) x Rs3500/-

Where;

X =Basic rate of Diesel as on date of plantation

Y= Basic rate of Diesel after 10 years of plantation

In case of any dispute and differences of opinion among the parties regarding any condition under the agreement the same shall be referred to the Arbitration & Conciliation Act 1996. Green cover to the barren hills, protection of soil erosion and improvement in the environment, besides providing energy security by means of extracting green fuel from Jatropha seeds are some of the primary objectives of Uttarakhand Biofuel Board.'

**Andhra Pradesh**

The state has been focusing on the promotion of Pongamia and more recently Simaruba, as both these species use less water than Jatropha. The state uses a dual organisational structure for promoting bio-diesel. The Rain Shadow Areas Development Department makes policy, monitors and promotes entrepreneurship, the Department for Panchayati Raj and Rural Development implements the programme. The state encourages private sector engagement and allots areas for private enterprises to promote plantation. The state also extends full NREGA scheme support to all small and marginal farmers who enter into buy-back agreements with these enterprises. These enterprises are required to set up expelling and trans-esterification units in the area of operation. The Forest Department also promotes plantations on forest land using Joint Forest Management.

**Karnataka**

In Karnataka, Pongamia has been planted by farmers for centuries and as a result a fully functioning oil-expelling industry is already present. As a result a functioning Pongamia oil-expelling industry is already present in the state.. There is good demand of Pongamia oil in the state prices were in the range of Rs 45 to 50 Rs./litre

The government of Karnataka has set up Biofuel Taskforce to coordinate the efforts in the area of Biofuels.The Government has brought out a drafr Policy on biofuels which Policy states[1] that the state government will set up the Karnataka Bio-fuel Development Authority (KBDA), which will be incharge of fine tuning and overseeing the implementation of the Policy and the programme at the state level.

The state's approach in biofuels development varies from that of other states because its emphasis on a multi-species approach and also encourages the use of SVOs from various sources. The state of Karnataka has over 20 TBO species available for bio-fuel production, with the main ones being Pongamia, Neem, Simarouba, Mahua, Jatropha, etc. Promoting different

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[1] See http://rdpr.kar.nic.in/MGIRED.pdf

TBOs will allow farmers to choose the right crop for the varying climate and soil conditions within the state. The state proposes a 5% blend for Bio-fuels in the state.

The Karnataka Task Force on Bio-fuels has as a part of its bio-fuel policy developed a model for decentralized growth and consumption of feedstock, oil and bio-fuel. The feedstock, to be grown in the rural areas would be expelled at the village or cluster level. The oil would either be consumed locally or sold to a trans-esterification unit. Development of bio-fuel from non-edible oil seeds will be a completely decentralized process located in rural areas developed with the objective of increasing the income of rural population.

The Bio-fuels policy would use KVK's (Kissan Vikas Kendra's) as centers for the promotion of bio-fuels on lines with the AMUL model for milk procurement, processing and distribution. The state is planning to use the supply chain and the institutional mechanism available through the agri and milk cooperative network to develop the bio-fuel supply chain and encourage bio-fuel feedstock cultivation.

**Tamil Nadu**

The state government has been advocating two approaches for supporting Jatropha cultivation in the state., mostly on private land. First, through the distribution of free seedlings to farmers and Panchayats and second through the distribution of subsidized seedlings and provision of loans for contract farming.

The first Jatropha programme was launched in 2004 when the state government financed Jatropha nurseries from which 30 million Jatropha seedlings were to be distributed. The basic lacunae in this programme was that, although nurseries had an incentive to distribute seedlings only, but not toensure that the seedlings were actually planted and maintained.Asca consequence, seedlings were distributed to farmers without any technical back up and support and only 20–30 % for the seedlings distributed survived.

A second programme was launched in 2006 with the focus on providing subsidy of Rs 1.5 per/seedling to the nurseries managed by SHGs, NGOs and the Tamil Nadu Agricultural University. With farmers also having to make a financial contribution, it was hoped that the programme would fare better. To provide back up support and technical handlholding, the government cooperates with private companies like D1 Mohan Bio Oils Ltd.. The Agriculture Department encourages farmers to cultivate Jatropha and then links them up with D1 Mohan Bio Oils Ltd. D1 in turn signs a buy-back arrangement and provides extension services.

In 2008, the state government allocated 400 million Rs. to Primary Agriculture Cooperative Banks for subsidised loans for encouraging Jatropha cultivation (over 20,000 hectares). Since a buy-back agreement is a precondition for the cooperative banks to gain access to loans, and D1 is the only significant seed purchaser at the moment, the company will have a monopoly until other companies step in.

The Government of Tamil Nadu has exempted Jatropha seeds from the purchase tax and SVO from the VAT.

**Table21. 1[2]: State Policy & Other Initiatives**

| Key Initiative | Andhra Pradesh | Chhattisgarh | Karnataka | Madhya Pradesh | Rajasthan | Tamil Nadu | Uttarakhand | Uttar Pradesh |
|---|---|---|---|---|---|---|---|---|
| **General policy issues** | | | | | | | | |
| Formal State bio-diesel policy | Does Not Exist | Does Not Exist | Yes | Does Not Exist | Does Not Exist | Does Not Exist | Does Not Exist | Does Not Exist |
| State bio-diesel strategy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| State coordination body | Rainshadow Areas Development Department | Chhattisgarh Biofuel Development Authority | Karnataka Biofuel Development Authority – Under formation | Minor Forest Products Corporation and Industrial Development Corporation | Biofuel Authority of Rajasthan | No nodal agency: Dept. of Agriculture is responsible for oil bearing trees | Uttarakhand Biodiesel Board | Horticulture department |
| Feedstock explicitly favored | Pongamia | Jatropha, Pongamia | Multi species | Jatropha | Jatropha, Karanj and other oil seed plants | Jatropha, Pongamia | Jatropha | Jatropha |
| **Supply side measures** | | | | | | | | |
| Allocation of government land for TBO plantation | Forestland managed by community committees | Forestland under the forest department, land under revenue | On community land (in pilot project in Hassan district). On | Forest degraded land under state forest department. And, private | Wasteland allotted to government undertakings, companies | No significant cultivation on government land (after | Forestland managed by community committees | Wasteland |

[2] Source: Biodiesel policies for rural development in India , DIE and other govt websites and stakeholder consultation

| Key Initiative | Andhra Pradesh | Chhattisgarh | Karnataka | Madhya Pradesh | Rajasthan | Tamil Nadu | Uttarakhand | Uttar Pradesh |
|---|---|---|---|---|---|---|---|---|
| | | department and community land<br>JV for lease of land | forestland, Pongamia used for afforestation | farm sector. Allotment of land on leasehold basis. | and societies on the leasehold basis | failed project of cultivation on community land) | | |
| Input subsidies/ distribution of input | On forestland, seedlings provided by government. Free seedlings distributed to small and marginal farmers. | 500 seedlings distributed free of cost to private farmers. The balance (upto 5000) will cost Rs 0.50 per seedling | Free seedlings are distributed (in pilot project in Hassan District) | No subsidy | Land Resource dept., Govt of India, funded for 75 lakhs of seedlings in 2006-07 and for 174 lakhs of seedlings in 2007-08. | 50% government subsidy for Jatropha seedlings | Seedlings financed by the government | No subsidy |
| Government funding sources | On forestland: NABARD RIDF – loan NAP (NREGS use planned). On private land: NREGS | On all public lands: NREGS State government | In Hassan district: State govt. (NREGS use planned) | Data not available | Data not available | Subsidized loans of Primary Agriculture Cooperative Banks to farmers for Jatropha plantation | SGSY, VESP, NOVOD Board and state government | Govt. is promoting P4 model – Public Private Panchayat Partnership |

| Key Initiative | Andhra Pradesh | Chhattisgarh | Karnataka | Madhya Pradesh | Rajasthan | Tamil Nadu | Uttarakhand | Uttar Pradesh |
|---|---|---|---|---|---|---|---|---|
| Provision and funding of extension services | Training provided through CRIDA (before through APARD) | Agriculture Department provides free services | Agriculture University provides services in Hassan District. | Facilitation cell to train farmers in the cultivating and harvesting techniques. | Data not available | Agriculture Department provides free services | Forest Department, UBB staff and funding of NGOs | Horticulture dept. is undertaking awareness generation and field demonstration activities |
| Subsidies for government provision of processing facilities | No | Govt. installed 10 oil extraction units. Financial support given for setting up private processing units | Funding of processing units for demonstration purposes planned in Hassan district | Govt. has proposed to open a facilitation cell to train farmers in cultivating and harvesting techniques | Free allotment of land to a few categories on Gair Khateidari basis | No | No | No |
| **Demand side measures** | | | | | | | | |
| Minimum support price | Pongamia seeds: 10 Rs./kg, adjusted soon Jatropha seeds: 6 Rs./kg | Jatropha seeds: 6.5 Rs./kg SVO: 18 Rs./kg | State govt. will constitute a Price fixation committee that will meet periodically to fix the minimum | Guaranteed buy-back agreements with minimum prices for the harvesting period of 50 years | Minimum support price for Jatropha is 7 Rs/Kg | No | Jatropha seeds: currently 3 Rs./kg<br><br>SVO: 18 Rs./kg. | Govt.'s special cell will retain the buyer status for next 15 years and extend above for next 15 years to Joint Venture Partners |

| Key Initiative | Andhra Pradesh | Chhattisgarh | Karnataka | Madhya Pradesh | Rajasthan | Tamil Nadu | Uttarakhand | Uttar Pradesh |
|---|---|---|---|---|---|---|---|---|
| | | | support price. | | | | | |
| Blending requirement and encouraging state owned enterprises to consume biodiesel | No blending requirement. AP State Road Transport Corporation planned to run 10% of its fleet with 5% blending | Blending requirement of 5% if biodiesel is available at 25 Rs/litre. No data on state owned companies. | No blending requirement KA State Road Transport Corporation and Southern Railways use blending | Data not available | Data not available | No blending requirement Southern Railways uses blending | No blending requirement No data on state owned companies | Data not available |
| Tax exemptions | Reduced VAT of 4% on biodiesel | No data available | Draft policy envisages to exempt bio-diesel from VAT | Data not available | Jatropha, crude bio-diesel and B100 bio-diesel exempted from VAT | Exemption of Jatropha seeds from purchase tax and Jatropha SVO from VAT | Tax exemption of bio-diesel from VAT | Data not available |
| Promotion of local use of SVO and biodiesel | Local consumption not explicitly targeted | Decentralized value addition and local consumption part of the state approach | Decentralized value addition and local consumption | Data not available | Data not available | No promotion of local use of SVO or biodiesel | Small rural electrification programme under VESP | Data not available |

## Appendix 3

# Overview of Rural Biomass Energy Use in India

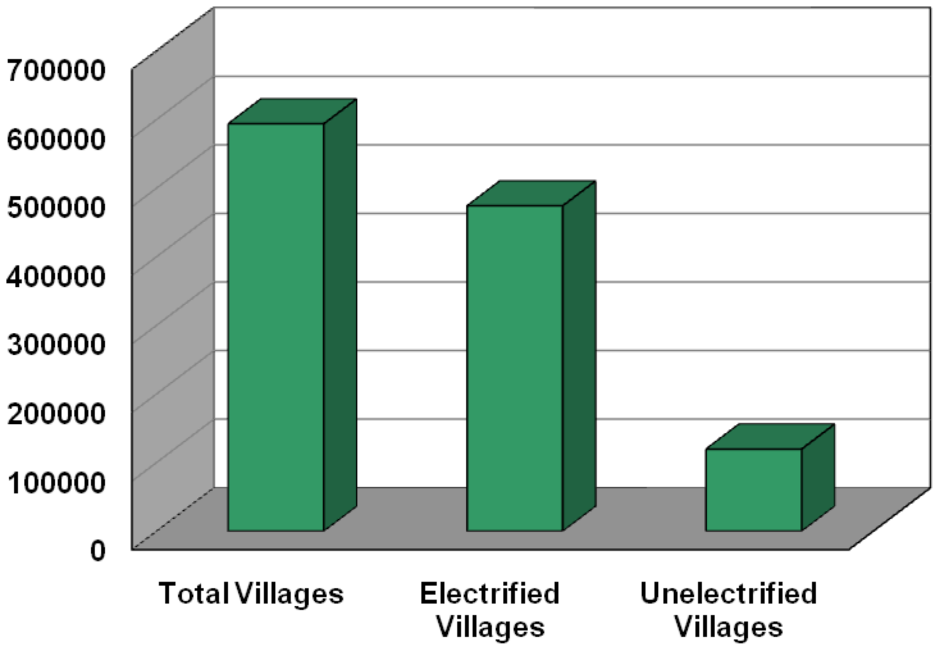
Rural energy sources and consumption patterns differ widely across India for catering to a variety of tasks such as cooking, lighting, agricultural activities, pumping water for irrigation, rural transport, etc thereby satisfying several economic, technical as well as social objectives or goals. Large number of Indian rural population (about 700 million people) which does not have access to modern energy services is dependent on biomass, animal waste and kerosene for meeting their cooking and lighting requirements. As per 2001 Census nearly 56.5 per cent of the rural households do not have electric connections. In 2001-2002, the consumption of traditional fuels was estimated at 140 million tonnes of oil equivalent. It is estimated that currently the share of traditional fuels is around 28% of the total consumption. In terms of cooking fuel about 625 million people do not have access to modern cooking fuels (Parikh. J, 2007).

Energy Demand Screening Group - EDSG (1986) has assessed the rural energy requirements in India and it has estimated that the level of requirement for 2004-2005 as 520 kcal/capita/day. More recent studies have shown that at an estimated rate of 1.22 kg/per capita per day the total energy demand as per 2001 census it is estimated that annually about 215 million tonnes of biomass is used in rural areas for meeting the energy demand (about 65% rural households continue to be dependent of biomass resources for meeting their energy requirements in India). According to the Integrated Energy Policy (IEP) Report of the Expert Committee, prepared by the Planning Commission, the household demand for non-commercial energy will increase from around 109 Mtoe in 2000 to 131 Mtoe in 2031. The expectation is that the additional requirement will be met from agricultural residues and increased livestock activity that can be expected with 8-9 % growth rates.

- It proposes establishing neighbourhood fuelwood plantations within one kilometre of each habitation to ease the burden and reduce the time taken in gathering and transporting wood.
- To create energy secure villages, it suggests financing a large-scale socioeconomic experiment to operate community-sized biogas plants and also for women’s groups to form cooperatives to develop and manage fuelwood or oilseed plantations requiring the same effort as they currently put into searching for and gathering fuelwood.
- It also suggests improving the efficiency of domestic chulhas (stoves) and lanterns for any who may have to continue using fuelwood, and the generation of electricity through wood gasifiers or by burning surplus biogas from community biogas plants.

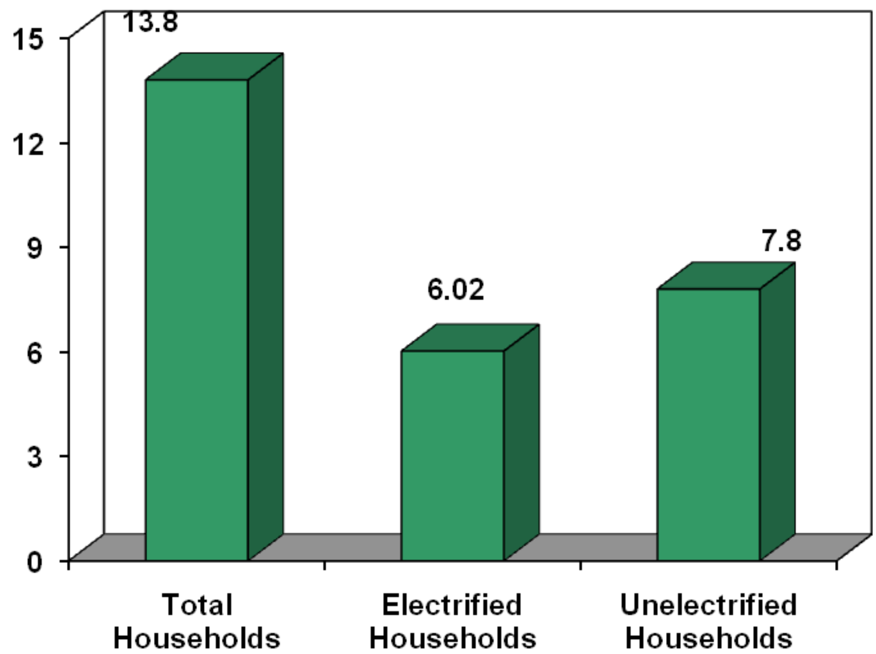
Biomass such as crop residues, animal dung and fuelwood are widely used in rural India. Each year, the equivalent of nearly three billion person-days are spent gathering fuels, and a further 700 million in processing them (chopping, drying, turning, storing, stacking and handling). About 800 million days are of potentially productive work are lost due to diseases related to indoor air pollution. Women are also exposed to a variety of health hazards from cooking over poorly ventilated indoors fires, resulting in respiratory infections, cancers and eye diseases. Smoke from indoor fires accounts for between 410,000 and 570,000 premature deaths each year in India.

**Figure 3A. 1: Village Electrification Scenario in India - 2005**




***Source:*** *Ministry of Power, Government of India*

**Figure 3A. 2: Extent of Electrification at Household Level in India as on 2005 in Crores**




***Source:*** *Ministry of Power, Government of India*

According to IEP while the current usage of biomass in rural areas is around 140 Mtoe/year and the total potential is about 600 Mtoe/year using 60 million hectares of waste land yielding 20 metric tonnes/ha/year. Similarly it projects potential generation of 10 Mtoe of ethanol per annum by utilizing 1.2 Mha of intensive cultivation land. IEP aims for

- Electrification of all households
- Provision of clean cooking energy (LPG, NG, biogas, kerosene) for all within 10 years
- Provision of fuelwood plantations within 1 km of all habitations
- Formation of women's groups to run oilseed plantations and tree-growing cooperatives to produce biofuels and fuelwood.
- Provision of financial assistance through self-help groups to transform women from today's energy gatherers into tomorrow's energy management micro-entrepreneurs.

The Rural Electrification Policy (REP) 2006 aims at:

- Provision of access to electricity to all households by year 2009 – ensuring access to all.
- Quality and reliable power supply at reasonable rates – USO there but quantification has to be undertaken and benchmarks have to be developed
- Minimum lifeline consumption of 1 unit per household per day as a merit good by year 2012 – USO related to actual consumption of service.

- The RE Policy also states that in places where local distribution has been handed over to users' association, co-operative society, panchayat Institutions or non-Government organization, the universal service obligation for the area would rest with that institution and the supply obligation of the licensee, if any, in that area, would be residual

The Ministry of Power's Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) electrification scheme aims to electrify the 125,000 non-electrified villages, connect all the estimated 23.4 million non-electrified households below the poverty line and augment the backbone network in all 462,000 currently electrified villages by 2010. It is targeting complete village level electrification by 2009 and complete household electrification by 2012. This apart, it is focusing on development of a Rural Electricity Distribution Backbone (REDB) with a 33/11 KV (or 66/11 KV) sub-station in every block and distribution transformers of appropriate capacity in villages/habitations so as to ensure a minimum per capita energy usage of at least one unit. If these targets are achieved, the rural biomass energy uses will gradually decline in India. Therefore, the potential conflict between land use for biodiesel and firewood may not be very serious in the future. In any case, a proper land allocation scheme that prevents the lands currently used by communities for rural biomass energy purposes being taken for oil seed plantations is necessary to ensure avoiding land use conflicts.

## Appendix 4

# Bundling of Small Scale CDM Projects & Programmatic CDM

In the following a brief overview of the salient features of bundling of small scale CDM projects as well as PoA of CDM are presented.

**Bundling of Small Scale CDM projects**

UNFCCC provides an opportunity to bundle small scale project activities into a single CDM project activity. The salient features of the bundle include:

- Project activities wishing to be bundled shall indicate this when making the request for registration;
- Once a project activity becomes part of a bundle for a project cycle stage, it shall not be de-bundled for this stage. The Board may consider debundling in exceptional situations;
- The composition of bundles shall not change over time (i.e. the submission of project activities to be used in a bundle shall be made at the same time. A project activity shall not be taken out of a bundle nor shall a project activity be added to the bundle after registration).
- All project activities in the bundle shall have the same crediting period (i.e. the same length and same starting date of the crediting period);
- It should be demonstrated that the bundle will remain under the limit for the type every year during the crediting period. The total emission reduction estimated for the crediting period must be included in the draft CDM-PDD and further monitored;
- If a bundle goes beyond the limits for the selected small-scale CDM project activities type, the emission reduction that can be claimed for this particular year will be capped at the maximum emission reduction level estimated for the bundle by the project participants in the "Bundle" form for that year during the crediting period.
- Project activities may use the same baseline under some conditions (details on these conditions will be further elaborated);

- A common monitoring plan can be utilized for the bundle with the submission of one monitoring report, under conditions to be specified (e.g. conditions for sampling);
- Each small-scale CDM project in the bundle should comply with the simplified modalities and procedures for small-scale CDM project activities and use an approved simplified baseline and monitoring methodology included in Appendix B of the simplified modalities and procedures for small-scale CDM project activities.

State governments can use this window of opportunity given by UNFCCC for taking up large number of small scale projects as bundled CDM project activity so as to reduce the transaction costs. Similarly in recent times a more useful opportunity for similar project activities spread across spatially (geographically distinct regions) and temporally (activities taken up during different time periods) can also be considered under single CDM project which is termed as Programatic CDM. In the following a brief description of the same is presented.

**Programme of Activities**

While a local/regional/national policy or standard cannot be considered as a clean development mechanism project activity, but the project activities arising out of a policy or a standard under a programme of activities can be registered as a single clean development mechanism project activity provided that approved baseline and monitoring methodologies are used that, inter alia, define the appropriate boundary, avoid double counting and account for leakage, ensuring that the net anthropogenic removals by sinks and emission reductions are real, measurable and verifiable, and additional to any that would occur in the absence of the project activity.

The PoA was established as a new type of CDM projects in 2007 with the same objective as for bundling of small scale project, to enable economy of scale to overcome transaction costs by aggregating several small projects. The key difference between a Programmatic CDM and the bundling of individual activities is the fact that in bundling, the project proponent knows and defines in advance the number of project activities to bundle. In CDM PoA activities, the entity running the PoA does not know in advance the number of individuals/entities that will respond to the programme (because response to such a programme is by definition, voluntary). Another difference is that the activities under such a program can have different crediting period, while project activities under a bundled SSC CDM project must have the same crediting period.

## Appendix 5

# Details of Financial Analysis

With the objective of the financial analyses to determine the realistic cost of biofuel production, the financial analysis has been undertaken based on certain assumptions based on primary data collection, stakeholders' consultation and literature survey available in public domain.

The financial analysis for biodiesel is based on a three step process as follows:

1. Financial analysis of crops (Pongamia and Jatropha) for producing Biodiesel
2. Financial analysis of extraction unit for producing biodiesel
3. Financial analysis of transesterfication unit

Similarly, the financial analysis for bioethanol has been done in two step process:

1. Financial analysis of crops (Sugarcane, Sweet Sorghum and Tropical Sugar beet)
2. Financial analysis of producing ethanol from four different alternatives i.e.
    - Ethanol from molasses
    - Ethanol from direct sugarcane
    - Ethanol from sweet sorghum
    - Ethanol from tropical sugar beet

In a nutshell, the pricing of the biodiesel and bioethanol is determined while making certain that each of the stakeholders should be endowed with sufficient and acceptable returns so as to get the adequate profitability. In general, In Indian scenario, the pricing of government regulated commodities is determined while considering an acceptable range of IRR. For instance, Central Electricity Regulatory Commission (CERC) decides the tariff of power projects while considering the returns of ~19%. Considering the prevailing acceptable range of return of 16-18%, the financial analysis would determine biofuel price which would ensures adequate profitability to each and every stakeholder across the value chain.

**Table 5A.1: Illustration of Key assumptions and Details of the Financial Analysis of Plantation of Crops for Biodiesel Production**

| Particulars of Key Assumption ( In INR Per Hectare) | Jatropha | | Pongamia | |
|---|---|---|---|---|
| | North | South | North | South |
| Ownership Pattern | 100% | 100% | 100% | 100% |
| **Fixed Cost Calculation** | | | | |
| Total Area under Plantation | 1 | 1 | 1 | 1 |
| Total Saplings required Per Hectare | 2000 | 2000 | 220 | 200 |
| Plants per Hectare | 2000 | 2000 | 220 | 200 |
| Survival rate | 80% | 80% | 80% | 80% |
| Escalation Value | 2% | 2% | 2% | 2% |
| Man days for Land Development per hectare | 5 | 5 | 5 | 5 |
| Man Days for Planting and filling | 88 | 88 | 20 | 20 |
| **Variable Cost Calculation** | | | | |
| Man Days for Weeding/ Plant Protection/Pruning | 30 | 30 | 15 | 15 |
| Man Power for Harvesting/ Decortication | 25 | 25 | 125 | 125 |
| Man days for Land Development per hectare | 5 | 5 | 5 | 5 |
| Man Days for Planting and filling | 88 | 88 | 20 | 20 |
| Man Days for Weeding/ Plant Protection/Pruning | 30 | 30 | 15 | 15 |

| **Particulars of Key Assumption ( In INR Per Hectare)** | **Jatropha** | | **Pongamia** | |
|---|---|---|---|---|
| | North | South | North | South |
| Man Power for Harvesting/ Decortication | 25 | 25 | 125 | 125 |
| Land Development Expense on Equipments | 2500 | 2500 | 2500 | 2500 |
| Cost of land lease | 1000 | 1000 | 1000 | 1000 |
| Landed Cost of Sapling | 3 | 3 | 3 | 3 |
| Cost of Fertilizers | 1500 | 1500 | 2250 | 2250 |
| Cost of labor - Skilled | 150 | 150 | 150 | 150 |
| Cost of labor - Unskilled | 100 | 100 | 100 | 100 |
| Insurance Premium @1% | 0 | 0 | 0 | 0 |
| Contingency @5% | 5% | 5% | 5% | 5% |
| Cost of Water/ Irrigation | 1100 | 1100 | 1500 | 1300 |
| Seed Production per Hectare in tonnes | | | | |
| Year 1 | 0 | 0 | 0 | 0 |
| Year2 | 0 | 0 | 0 | 0 |
| Year3 | 0.25 | 0.25 | 0 | 0 |
| Year4 | 0.75 | 0.5 | 0.25 | 0.25 |
| Year5 | 1.0 | 1 | 0.5 | 0.5 |
| Year 6 | 1.2 | 1.3 | 1 | 1 |

| Particulars of Key Assumption ( In INR Per Hectare) | Jatropha | | Pongamia | |
|---|---|---|---|---|
| | North | South | North | South |
| Year7 | 1.2 | 1.5 | 1 | 1 |
| Year8 | 1.2 | 1.5 | 2 | 2 |
| Year9 | 1.2 | 1.5 | 2 | 2 |
| Year10 | 1.2 | 1.5 | 2 | 2 |
| Year11 | 1.2 | 1.5 | 2.2 | 2.5 |
| Market Price of Seed Rs per Ton | 7500 | 7500 | 7500 | 7500 |
| Escalation in Seed Price | 5% | 5% | 5% | 5% |
| Losses during Transport and Storing | 2% | 2% | 2% | 2% |
| Transportation Cost Rs per Ton | 1000 | | | |
| Final Output Cost Rs Per Ton | 8500 | | | |

## Table 5A.2: Financial Analysis of Planting Pongamia in India (In Rs per Hectare)

| Financial Analysis - for Unit Model | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Cost | 20570 | 8904 | 8946 | 8819 | 7785 | 6167 | 6256 | 6346 | 6438 | 6533 | 6629 | 6727 | 6826 | 6928 | 7032 | 7138 | 7247 | 7357 | 7469 | 7584 | 7701 | 7821 | 7942 | 8067 | 8193 | 8323 |
| Cost of Land on Lease | 1000 | 1020 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Capital Expense | 6180 | 1022 | 204 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cost of Skilled Labor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unskilled Labor Cost | 10417 | 3828 | 4648 | 6388 | 6515 | 4892 | 4975 | 5060 | 5147 | 5235 | 5325 | 5417 | 5511 | 5607 | 5704 | 5804 | 5905 | 6009 | 6114 | 6222 | 6332 | 6444 | 6558 | 6674 | 6793 | 6915 |
| Cost of Fertilizers | 1625 | 1658 | 1691 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cost of Irrigation | 1100 | 1122 | 1144 | 1167 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other Development Cost | 249 | 254 | 259 | 264 | 269 | 275 | 280 | 286 | 291 | 297 | 303 | 309 | 315 | 322 | 328 | 335 | 341 | 348 | 355 | 362 | 370 | 377 | 385 | 392 | 400 | 408 |
| Revenue | 0 | 0 | 0 | 2171 | 4558 | 9572 | 10051 | 15830 | 22162 | 25597 | 28709 | 30145 | 28060 | 29463 | 30936 | 32483 | 34107 | 35813 | 37603 | 39484 | 41458 | 43531 | 45707 | 47993 | 50392 | 52912 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue from Sale of Seed | 0 | 0 | 0 | 2171 | 4558 | 9572 | 10051 | 15830 | 22162 | 25597 | 28709 | 30145 | 28060 | 29463 | 30936 | 32483 | 34107 | 35813 | 37603 | 39484 | 41458 | 43531 | 45707 | 47993 | 50392 | 52912 |
| Net Benefit | -10538 | -6970 | -12242 | -13273 | -9658 | -3792 | -3551 | 1985 | 8070 | 11252 | 14107 | 15280 | 12927 | 14057 | 15251 | 16514 | 17848 | 19257 | 20746 | 22318 | 23979 | 25731 | 27581 | 29533 | 31593 | 33766 |
| IRR | 14.44% | | | | | | | | | | | | | | | | | | | | | | | | | |
| NPV | 11263 | | | | | | | | | | | | | | | | | | | | | | | | | |

## Table 5A.3: Financial Analysis of Planting Jatropha in India (In Rs per Hectare)

| **Financial Analysis - for Unit Model** | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Cost (in Rs per hectare) | 22655 | 9351 | 8257 | 7350 | 6358 | 4517 | 4571 | 4627 | 4683 | 4740 | 4799 | 4859 | 4920 | 4982 | 5045 | 5110 | 5176 | 5243 | 5312 | 5382 | 5453 | 5526 | 5600 | 5676 | 5753 | 5832 |
| Cost of Land on Lease | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Capital Expense | 7070 | 1200 | 240 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cost of Skilled Labor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unskilled Labor Cost | 11800 | 4310 | 4120 | 4986 | 5086 | 3239 | 3288 | 3337 | 3388 | 3440 | 3492 | 3546 | 3600 | 3656 | 3713 | 3771 | 3830 | 3891 | 3952 | 4015 | 4079 | 4144 | 4211 | 4279 | 4348 | 4419 |
| Cost of Fertilizers | 1500 | 1530 | 1561 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Appendix 5*

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost of Irrigation | 1033 | 1054 | 1075 | 1097 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other Cost | 252 | 257 | 262 | 267 | 272 | 278 | 283 | 289 | 295 | 301 | 307 | 313 | 319 | 326 | 332 | 339 | 345 | 352 | 359 | 367 | 374 | 381 | 389 | 397 | 405 | 413 |
| Revenue | 0 | 0 | 2067 | 5426 | 9116 | 11726 | 13568 | 14247 | 14959 | 15707 | 16493 | 17317 | 18183 | 19092 | 20047 | 21049 | 22102 | 23207 | 24367 | 25585 | 26865 | 28208 | 29618 | 31099 | 32654 | 34287 |
| Revenue from Sale of Seed | 0 | 0 | 2067 | 5426 | 9116 | 11726 | 13568 | 14247 | 14959 | 15707 | 16493 | 17317 | 18183 | 19092 | 20047 | 21049 | 22102 | 23207 | 24367 | 25585 | 26865 | 28208 | 29618 | 31099 | 32654 | 34287 |
| Net Benefit | -22655 | 9351 | -6190 | -1924 | 2758 | 7209 | 8997 | 9620 | 10276 | 10967 | 11694 | 12459 | 13263 | 14110 | 15002 | 15939 | 16926 | 17964 | 19055 | 20204 | 21412 | 22682 | 24018 | 25423 | 26901 | 28455 |
| IRR | 17.91% | | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 5A.4: Illustration of Key Assumptions and Details of the Financial Analysis of 'Extraction Unit' for Biodiesel Production**

| Assumption | 5TPD | 10TPD |
|---|---|---|
| | | |
| Crushing Capacity in Tones Per day | 5 | 10 |
| Operating Days | 250 | 250 |
| CJ Oil Recovery from Seeds | 30% | 30% |
| Recovery of Oil Cake | 70% | 70% |
| Capex - Rs Capex | 2800000 | 4000000 |
| Escalation | 2% | 2% |
| | | |
| Requirement of Power in kWh/ tones | 55 | 55 |
| Requirement of Steam in Tones per TPD | 0.4 | 0.4 |
| General and Operating cost | 80000 | 130000 |
| O&M Cost | 3% | 3% |
| Cost of Steam  Rs per tones | 1000 | 1000 |
| Cost of Power Rs per kWh | 5 | 5 |
| Cost of Chemical in Rs per tones | 0 | 0 |
| Cost of seeds Rs Per tones | 8500 | 8500 |

| | | |
|---|---|---|
| Transportation cost per Tones of Oil | 1000 | 1000 |
| Fixed cost - For year | | |
| Skilled Staff in RS | 234000 | 234000 |
| Unskilled labor in Rs | 150000 | 240000 |
| | | |
| Annual output of SVO in Tones | 375 | 750 |
| Annual Output of SVO/ CJO in KL | 417 | 833 |
| Rate of SVO/CJO Rs per KL | 29000 | 29000 |
| Annual Output of Oil Cake in tones | 875 | 1750 |
| | | |
| Rate of Oil Cake Rs per Tones | 2000 | 2000 |
| Increase in CJO Price | 5% | 5% |
| Increase in Oil Cake Price | 5% | 5% |
| | | |
| Debt Component | 70% | 70% |
| Term loan interest | 13% | 13% |
| Working capital interest | 13% | 13% |
| Depreciation rate | 5% | 5% |
| Tax Rate | 33% | 33% |

**Table 5A.5: Financial Cost Benefit Analysis of Extraction unit (5 TPD) of Straight Vegetable Oil Production (in Rs Million)**

| For Capacity of 5 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Expense (in Rs) | 15.17 | 13.14 | 13.51 | 13.90 | 14.31 | 14.73 | 15.17 | 15.63 | 16.10 | 16.60 | 17.11 | 17.65 | 18.23 | 18.84 | 19.47 | 20.12 | 20.80 | 21.51 | 22.24 | 23010357 | 23808045 |
| Capital Cost | 2.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Labour Cost | 0.38 | 0.39 | 0.40 | 0.41 | 0.42 | 0.42 | 0.43 | 0.44 | 0.45 | 0.46 | 0.47 | 0.48 | 0.49 | 0.50 | 0.51 | 0.52 | 0.53 | 0.54 | 0.55 | 0.55 | 0.56 |
| Fuel Cost | 0.84 | 0.86 | 0.88 | 0.90 | 0.91 | 0.93 | 0.95 | 0.97 | 0.99 | 1.01 | 1.03 | 1.05 | 1.07 | 1.09 | 1.11 | 1.14 | 1.16 | 1.18 | 1.21 | 1.24 | 1.27 |
| Others | 0.51 | 1.05 | 1.18 | 1.33 | 1.48 | 1.65 | 1.82 | 2.01 | 2.22 | 2.43 | 2.67 | 2.91 | 3.20 | 3.50 | 3.83 | 4.17 | 4.53 | 4.91 | 5.32 | 5.65 | 5.89 |
| Feed Stock Cost | 10.63 | 10.84 | 11.05 | 11.28 | 11.50 | 11.73 | 11.97 | 12.20 | 12.45 | 12.70 | 12.95 | 13.21 | 13.48 | 13.74 | 14.02 | 14.30 | 14.59 | 14.88 | 15.18 | 15.76 | 16.01 |
| Revenue (in Rs) | 0.00 | 13.83 | 14.53 | 15.25 | 16.01 | 16.81 | 17.66 | 18.54 | 19.46 | 20.44 | 21.46 | 22.53 | 23.66 | 24.84 | 26.08 | 27.39 | 28.76 | 30.20 | 31.71 | 32.78 | 33.43 |
| Revenue | 0.00 | 13.83 | 14.53 | 15.25 | 16.01 | 16.81 | 17.66 | 18.54 | 19.46 | 20.44 | 21.46 | 22.53 | 23.66 | 24.84 | 26.08 | 27.39 | 28.76 | 30.20 | 31.71 | 32.24 | 33.41 |
| Net Cash Flow (in Rs) | -15.17 | 0.70 | 1.01 | 1.35 | 1.70 | 2.08 | 2.48 | 2.91 | 3.36 | 3.84 | 4.35 | 4.88 | 5.43 | 6.01 | 6.62 | 7.27 | 7.96 | 8.69 | 9.46 | 10.14 | 11.21 |
| **IRR** | **17.24%** | | | | | | | | | | | | | | | | | | | | |
| **NPV** | **7.12** | | | | | | | | | | | | | | | | | | | | |

**Table 5A.6: Financial Cost Benefit Analysis of Extraction unit (10TPD) of Straight Vegetable Oil Production (in Rs Million)**

| For Capacity of 10 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Expense (in Rs) | 28.16 | 25.91 | 26.67 | 27.46 | 28.28 | 29.14 | 30.02 | 30.94 | 31.90 | 32.90 | 33.94 | 35.02 | 36.17 | 37.38 | 38.63 | 39.93 | 41.28 | 42.69 | 44.16 | 45.68 | 47.27 |
| Capital Cost | 4.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Labor Cost | 0.47 | 0.48 | 0.49 | 0.50 | 0.51 | 0.52 | 0.53 | 0.54 | 0.56 | 0.57 | 0.58 | 0.59 | 0.60 | 0.61 | 0.63 | 0.64 | 0.65 | 0.66 | 0.68 | 0.69 | 0.70 |
| Fuel Cost | 1.69 | 1.72 | 1.76 | 1.79 | 1.83 | 1.86 | 1.90 | 1.94 | 1.98 | 2.02 | 2.06 | 2.10 | 2.14 | 2.18 | 2.23 | 2.27 | 2.32 | 2.36 | 2.41 | 2.46 | 2.51 |
| Others | 0.75 | 2.03 | 2.32 | 2.62 | 2.94 | 3.29 | 3.66 | 4.05 | 4.47 | 4.92 | 5.40 | 5.91 | 6.48 | 7.09 | 7.74 | 8.42 | 9.14 | 9.91 | 10.72 | 11.58 | 12.48 |
| Feedstock Cost | 21.25 | 21.68 | 22.11 | 22.55 | 23.00 | 23.46 | 23.93 | 24.41 | 24.90 | 25.40 | 25.90 | 26.42 | 26.95 | 27.49 | 28.04 | 28.60 | 29.17 | 29.76 | 30.35 | 30.96 | 31.58 |
| Revenue (in Rs) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Revenue | 0.00 | 27.67 | 29.05 | 30.50 | 32.03 | 33.63 | 35.31 | 37.08 | 38.93 | 40.88 | 42.92 | 45.07 | 47.32 | 49.69 | 52.17 | 54.78 | 57.52 | 60.39 | 63.41 | 66.58 | 69.91 |
| Net Cash Flow (in Rs) | 0.00 | 27.67 | 29.05 | 30.50 | 32.03 | 33.63 | 35.31 | 37.08 | 38.93 | 40.88 | 42.92 | 45.07 | 47.32 | 49.69 | 52.17 | 54.78 | 57.52 | 60.39 | 63.41 | 66.58 | 69.91 |
| **IRR** | **18.94%** | | | | | | | | | | | | | | | | | | | | |
| **NOV** | **18.52** | | | | | | | | | | | | | | | | | | | | |

**Table 5A.7: Illustration of Key Assumptions and Details of the Financial Analysis of Trans-esterification of Crops for Biodiesel Production**

| Assumption | 30 TPD | 100TPD | 300TPD |
|---|---|---|---|
| Base Assumption | | | |
| Trans-esterification Capacity in Tones Per day | 30 | 100 | 300 |
| Intake of SVO Tones per day **in TOTAL** | 31.5 | 105 | 315 |
| Operating Days | 300 | 200 | 200 |
| % Biodiesel Oil Recovery from SVO | 95% | 95% | 95% |
| % of Glycerol | 12% | 12% | 12% |
| Capex - Rs Capex | 280000000 | 422000000 | 1322000000 |
| Requirement of Methanol in **TOTAL** | 3 | 10 | 30 |
| General Escalation | 2% | 2% | 2% |
| Fixed Cost | | | |
| Utilities/ tones | 2000 | 2000 | 2000 |
| Transportation Cost per tone | 80 | 80 | 80 |
| Marketing cost and other Overheads **in TOTAL** | 100000 | 300000 | 500000 |
| General and Administration cost **in TOTAL** | 100000 | 300000 | 500000 |
| O&M Cost | 3% | 3% | 3% |
| Variable Costs | | | |

| Assumption | 30 TPD | 100TPD | 300TPD |
|---|---|---|---|
| Cost of Methanol in Rs per tones | 14740 | 14740 | 14740 |
| Cost of Chemical and Consumables in Rs per tones | 1400 | 1400 | 1400 |
| Skilled Labor Cost | 1008000 | 1400000 | 2000000 |
| Unskilled Labor Cost | 300000 | 500000 | 800000 |
| Assumed Market Price of SVO Rs per KL | 29000 | 29000 | 29000 |
| **Output** | | | |
| Assumed Rate of Biodiesel Rs per KL | 37000 | 37000 | 37000 |
| Rate of Glycerol Rs per Tones | 27000 | 27000 | 27000 |
| Growth in Price of Biodiesel | 3% | 3% | 3% |
| Growth in Price of Glycerin | 1% | 1% | 1% |
| **Financing** | | | |
| Debt Component | 70% | 70% | 70% |
| Term loan interest | 12.5% | 12.5% | 12.5% |
| Working capital interest | 12.5% | 12.5% | 12.5% |
| Depreciation rate | 5% | 5% | 5% |
| Tax Rate | 33% | 33% | 33% |

**Table 5A.8: Financial Cost Benefit Analysis of Transesterification unit (30 TPD) of Biodiesel Production (in Rs Million)**

| For Capacity of 30 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Expense (in Rs) | 315.0 | 369.4 | 375.1 | 381.0 | 387.2 | 393.5 | 400.1 | 406.9 | 413.9 | 421.1 | 428.6 | 436.3 | 446.5 | 457.1 | 467.9 | 479.0 | 490.3 | 501.9 | 513.8 | 526.0 | 538.5 |
| Capital Cost | 280.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Labor Cost | 0.0 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 | 1.7 | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 | 1.9 | 1.9 |
| Fuel Cost | 0.0 | 18.0 | 18.4 | 18.7 | 19.1 | 19.5 | 19.9 | 20.3 | 20.7 | 21.1 | 21.5 | 21.9 | 22.4 | 22.8 | 23.3 | 23.8 | 24.2 | 24.7 | 25.2 | 25.7 | 26.2 |
| Others | 35.0 | 76.0 | 75.9 | 75.8 | 75.9 | 76.0 | 76.2 | 76.5 | 76.9 | 77.4 | 78.0 | 78.7 | 81.8 | 85.0 | 88.4 | 91.9 | 95.5 | 99.2 | 103.0 | 107.0 | 111.2 |
| Feedstcok Cost | 0.0 | 274.1 | 279.5 | 285.1 | 290.8 | 296.6 | 302.6 | 308.6 | 314.8 | 321.1 | 327.5 | 334.1 | 340.7 | 347.6 | 354.5 | 361.6 | 368.8 | 376.2 | 383.7 | 391.4 | 399.2 |
| Revenue (in Rs) | 0.0 | 381.1 | 392.0 | 403.1 | 414.6 | 426.4 | 438.5 | 451.0 | 463.9 | 477.2 | 490.8 | 504.9 | 519.4 | 534.3 | 549.6 | 565.4 | 581.7 | 598.4 | 615.6 | 633.4 | 651.6 |
| Net Cash Flow (in Rs) | -315.0 | 11.8 | 16.9 | 22.1 | 27.4 | 32.8 | 38.4 | 44.2 | 50.1 | 56.1 | 62.3 | 68.6 | 72.8 | 77.2 | 81.7 | 86.4 | 91.4 | 96.5 | 101.8 | 107.4 | 113.1 |
| **IRR** | **12.54%** | | | | | | | | | | | | | | | | | | | | |
| **NOV** | 0.94 | | | | | | | | | | | | | | | | | | | | |

**Table 5A.9: Financial Cost Benefit Analysis of Transesterification Unit (100 TPD) of Biodiesel Production (in Rs Million)**

| For Capacity of 100 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Expense (in Rs) | 474.8 | 802.7 | 817.1 | 831.8 | 847.1 | 862.7 | 878.9 | 895.5 | 912.7 | 930.3 | 948.4 | 967.1 | 989.9 | 1013.2 | 1037.1 | 1061.5 | 1086.6 | 1112.3 | 1138.6 | 1165.6 | 1193.3 |
| Capital Cost | 422.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Labor Cost | 0.0 | 1.9 | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.3 | 2.4 | 2.4 | 2.5 | 2.5 | 2.6 | 2.6 | 2.7 | 2.7 | 2.8 |
| Fuel Cost | 0.0 | 40.0 | 40.8 | 41.6 | 42.4 | 43.3 | 44.2 | 45.0 | 45.9 | 46.9 | 47.8 | 48.8 | 49.7 | 50.7 | 51.7 | 52.8 | 53.8 | 54.9 | 56.0 | 57.1 | 58.3 |
| Others | 52.8 | 151.8 | 153.1 | 154.6 | 156.3 | 158.2 | 160.3 | 162.5 | 165.0 | 167.6 | 170.5 | 173.7 | 180.5 | 187.7 | 195.1 | 202.7 | 210.6 | 218.8 | 227.2 | 236.0 | 245.0 |
| Feedstcok Cost | 0.0 | 609.0 | 621.2 | 633.6 | 646.3 | 659.2 | 672.4 | 685.8 | 699.5 | 713.5 | 727.8 | 742.4 | 757.2 | 772.4 | 787.8 | 803.6 | 819.6 | 836.0 | 852.7 | 869.8 | 887.2 |
| Revenue (in Rs) | 0.0 | 847.0 | 871.0 | 895.8 | 921.3 | 947.5 | 974.5 | 1002.3 | 1031.0 | 1060.4 | 1090.8 | 1122.0 | 1154.2 | 1187.3 | 1221.3 | 1256.4 | 1292.6 | 1329.8 | 1368.1 | 1407.5 | 1448.1 |
| Net Cash Flow (in Rs) | 0.0 | 847.0 | 871.0 | 895.8 | 921.3 | 947.5 | 974.5 | 1002.3 | 1031.0 | 1060.4 | 1090.8 | 1122.0 | 1154.2 | 1187.3 | 1221.3 | 1256.4 | 1292.6 | 1329.8 | 1368.1 | 1407.5 | 1448.1 |
| **IRR** | **19.02%** | | | | | | | | | | | | | | | | | | | | |
| **NOV** | 267.99 | | | | | | | | | | | | | | | | | | | | |

**Table 5A.10: Financial Cost Benefit Analysis of Transesterification Unit (300 TPD) of Biodiesel Production (in Rs Million)**

| For Capacity of 100 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Expense (in Rs) | 1487.3 | 2410.5 | 2453.1 | 2496.9 | 2542.1 | 2588.7 | 2636.6 | 2686.0 | 2736.9 | 2789.3 | 2843.2 | 2898.8 | 2967.0 | 3036.9 | 3108.5 | 3181.9 | 3257.1 | 3334.2 | 3413.1 | 3494.0 | 3576.9 |
| Capital Cost | 1322.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Labor Cost | 0.0 | 2.8 | 2.9 | 2.9 | 3.0 | 3.0 | 3.1 | 3.2 | 3.2 | 3.3 | 3.3 | 3.4 | 3.5 | 3.6 | 3.6 | 3.7 | 3.8 | 3.8 | 3.9 | 4.0 | 4.1 |
| Fuel Cost | 0.0 | 120.0 | 122.4 | 124.8 | 127.3 | 129.9 | 132.5 | 135.1 | 137.8 | 140.6 | 143.4 | 146.3 | 149.2 | 152.2 | 155.2 | 158.3 | 161.5 | 164.7 | 168.0 | 171.4 | 174.8 |
| Others | 165.3 | 460.7 | 464.3 | 468.4 | 473.0 | 478.2 | 483.9 | 490.2 | 497.2 | 504.8 | 513.0 | 522.0 | 542.7 | 564.1 | 586.3 | 609.2 | 632.9 | 657.5 | 682.9 | 709.2 | 736.4 |
| Feedstock Cost | 0.0 | 1827.0 | 1863.5 | 1900.8 | 1938.8 | 1977.6 | 2017.2 | 2057.5 | 2098.6 | 2140.6 | 2183.4 | 2227.1 | 2271.6 | 2317.1 | 2363.4 | 2410.7 | 2458.9 | 2508.1 | 2558.2 | 2609.4 | 2661.6 |
| Revenue (in Rs) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Net Cash Flow (in Rs) | 0.0 | 2541.0 | 2613.1 | 2687.4 | 2763.8 | 2842.5 | 2923.6 | 3007.0 | 3092.9 | 3181.3 | 3272.3 | 3366.0 | 3462.5 | 3561.8 | 3664.0 | 3769.3 | 3877.7 | 3989.3 | 4104.2 | 4222.5 | 4344.3 |
| **IRR** | 18.36% | | | | | | | | | | | | | | | | | | | | |
| **NOV** | 748.80 | | | | | | | | | | | | | | | | | | | | |

**Table 5A.11: Illustration of Key Assumptions and Details of the Financial Analysis of Plantation of Crops for Bioethanol Production**

| Particulars of Key Assumptions ( In INR Per Hectare) | Sugar Cane | | | | Sweet Sorghum | | Tropical Sugar Beat |
|---|---|---|---|---|---|---|---|
| | North | South | West | East | North | South | |
| **Fixed Cost Calculation** | | | | | | | |
| Seeds Requirement ( for Sugarcane % of total production and for SS & TSB Kg per hectare) | 12% | 9% | 8% | 9% | 180 | 180 | 3 |
| Man Days Requirement - **Total** | | | | | | | |
| Land Development Mandays | 10 | 10 | 10 | 5 | 10 | 10 | 5 |
| Labor Mandays for Cultivation - per hectare | 75 | 75 | 75 | 6 | 100 | 100 | 75 |
| Labor Req. for Routine Operation | 110 | 110 | 110 | 60 | 90 | 90 | 30 |
| Labor for Harvesting & Drying - Man days/ Hectare | 60 | 90 | 100 | 40 | 80 | 80 | 45 |
| **Cost Factors** | | | | | | | |
| Cost of Land on lease Per Hectare | 35000 | 55000 | 55000 | 60000 | 15000 | 16000 | 20000 |
| Land Development Expense - On Equipment | 11000 | 12000 | 11000 | 7200 | 8500 | 8000 | 5000 |
| **Variable Cost Calculation** | | | | | | | |
| Cost of Manure Per Hectare | 2500 | 3000 | 3000 | 900 | 1500 | 1500 | 2500 |

| Particulars of Key Assumptions ( In INR Per Hectare) | Sugar Cane | | | | Sweet Sorghum | | Tropical Sugar Beat |
|---|---|---|---|---|---|---|---|
| | North | South | West | East | North | South | |
| Cost of Fertilizers Per Hectare (Mainly 14-14-14) | 7500 | 9000 | 9000 | 8000 | 3800 | 3800 | 5000 |
| Cost of Insecticide/ Herbides Per Hectare | 2500 | 3000 | 3000 | 8000 | 2200 | 2200 | 5000 |
| Total Cost of Fertilizers Per Hectare | 12500 | 15000 | 15000 | 16900 | 7500 | 7500 | 12500 |
| Cost of Planting Material per Kg (for SS & TSB) (per Ton for SC) | 1800 | 1800 | 1800 | 2500 | 20 | 20 | 1850 |
| Cost of Skilled Labor | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| Cost of Unskilled Labor | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Transportation Cost per Tons | 80 | 80 | 80 | 300 | 80 | 80 | 80 |
| Cost of Irrigation - Rs per hectare | 8000 | 9000 | 25000 | 2260 | 2300 | 2500 | 4000 |
| Other Expenses | | | | | | | |
| Contingency Charges | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| Cost of Supervisory work (% of total labor) | 10% | 10% | 10% | 10% | | | |
| Sugar Cane Crops Output (Tons per Hect) | 65 | 85 | 100 | 70 | | | |
| Sweet Sorghum Grain Output (Tons per Hectare) - Rainy | | | | | 1 | 1 | |
| Sweet Sorghum Grain Output (Tons per Hectare) Post Rainy | | | | | 2 | 2 | |

| Particulars of Key Assumptions ( In INR Per Hectare) | Sugar Cane | | | | Sweet Sorghum | | Tropical Sugar Beat |
|---|---|---|---|---|---|---|---|
| | North | South | West | East | North | South | |
| Sweet Sorghum Cane Output (Tons/Hectare) - Rainy | | | | | 15 | 15 | |
| Sweet Sorghum Cane Output (Tons per Hectare) - Post Rainy | | | | | 25 | 25 | |
| Output of Beet in Tons per Hectare | | | | | | | 65 |
| Output Data | | | | | | | |
| Sale Price of cane Rs per Tons | 2250 | 2100 | 2200 | 2500 | 1400 | 1400 | |
| Sale Price of Grain | | | | | 9000 | 9000 | |
| Sale price of TSB | | | | | | | 1250 |
| Financing and Taxing | | | | | | | |
| Working Capital (% of Total Investment) | 40% | 40% | 40% | 40% | 40% | 40% | 40% |
| Working capital interest | 13% | 13% | 13% | 13% | 13% | 13% | 13% |

**Table 5A.12: Illustration of Key Assumptions and Details of the Financial Analysis of Bioethanol Production from Alternative Feedstock**

| **Particulars of Key Assumption**<br>**( In INR Per Hectare)** | Only Through Molasses<br>Sugar Cane<br>100 KLPD | Sugar Cane sum Molasses<br>Through SC<br>100 KLPD | **Sweet Sorghum**<br>SS<br>100 KLPD | Tropical Sugar Beet<br>TSB<br>100 KLPD |
|---|---|---|---|---|
| Distillery Capacity in KLPD | 100 | 100 | 100 | 100 |
| Operating Days | 250 | 135 | 250 | 180 |
| Recovery (Mol/ feedstock - Ethanol) | 22% | 7% | 7% | 8% |
| Capex - Rs Capex | 440000000 | 300000000 | 480000000 | 480000000 |
| Requirement of Molasses or other Feedstock in Tones per KL | 5 | | 15 | 13 |
| Requirement of Power in kWh/ KL | 325 | 640 | 600 | 500 |
| Requirement of Steam TPKL | 3 | 3.5 | 3.5 | 3.5 |
| Operating cost of ETP/ RO per KL | 750 | 750 | 500 | 500 |
| General cost | 2500000 | 3000000 | 3000000 | 3000000 |
| O&M Cost | 1% | 1% | 1% | 1% |
| General Inflation | 3% | 3% | 3% | 3% |
| Cost of Steam Rs per Ton | 900 | 1000 | 1000 | 900 |
| Cost of Power Rs per kWh | 5 | 5 | 5 | 5 |

| **Particulars of Key Assumption**<br><br>**( In INR Per Hectare)** | Only Through Molasses<br><br>Sugar Cane<br><br>100 KLPD | Sugar Cane sum Molasses<br><br>Through SC<br><br>100 KLPD | **Sweet Sorghum**<br><br>SS<br><br>100 KLPD | Tropical Sugar Beet<br><br>TSB<br><br>100 KLPD |
|---|---|---|---|---|
| Cost of Chemical in Rs per KL | 250 | 350 | 350 | 250 |
| Landed Cost of Molasses or other Feedstock Rs Per ton | 3250 | 1350 | 1500 | 1500 |
| Skilled labor in RS | 4000000 | 5000000 | 10000000 | 4000000 |
| Unskilled labor in Rs | 3500000 | 3000000 | 6000000 | 3500000 |
| Marketing and Other Expense per KL | 1000 | 1000 | 1000 | 1000 |
| Output | | | | |
| Output of Ethanol | 25000 | 13500 | 25000 | 18000 |
| Rate of Ethanol Rs per KL | 27500 | 27500 | 31000 | 34000 |
| Escalation in Sale Price of Ethanol | 3% | 3% | 3% | 3% |
| Total Recovery of Bagasse | 0% | 30% | 25% | 7% |
| Market Price of Bagasse(Rs per Ton)/ Beet Pulp | 0% | 2000 | 2000 | 2000 |
| Financing | | | | |
| Debt Component | 70% | 50% | 70% | 70% |
| Term loan interest | 13% | 13% | 13% | 13% |

| **Particulars of Key Assumption**<br>**( In INR Per Hectare)** | Only Through Molasses<br>Sugar Cane<br>100 KLPD | Sugar Cane sum Molasses<br>Through SC<br>100 KLPD | **Sweet Sorghum**<br>SS<br>100 KLPD | Tropical Sugar Beet<br>TSB<br>100 KLPD |
|---|---|---|---|---|
| Working capital interest | 13% | 13% | 13% | 13% |
| Depreciation rate | 5% | 5% | 5% | 5% |
| Tax Rate | 33% | 33% | 33% | 33% |
| Repayment Years | 10 | 10 | 10 | 10 |

## Table 5A.13: Financial Cost Benefit Analysis of Producing Bioethanol from Molasses (in Rs Million)

| For Capacity of 100 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Expense (in Rs) | 478.5 | 620.3 | 633.4 | 649.4 | 665.9 | 683.0 | 700.6 | 718.9 | 737.8 | 757.3 | 777.5 | 798.4 | 822.6 | 847.5 | 873.1 | 899.5 | 926.7 | 954.8 | 983.6 | 1013.3 | 1044.0 |
| Capital Cost | 440.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Labor Cost | 0.0 | 7.5 | 7.7 | 8.0 | 8.2 | 8.4 | 8.7 | 9.0 | 9.2 | 9.5 | 9.8 | 10.1 | 10.4 | 10.7 | 11.0 | 11.3 | 11.7 | 12.0 | 12.4 | 12.8 | 13.2 |
| Fuel Cost | 0.0 | 108.1 | 111.4 | 114.7 | 118.2 | 121.7 | 125.3 | 129.1 | 133.0 | 137.0 | 141.1 | 145.3 | 149.7 | 154.2 | 158.8 | 163.5 | 168.5 | 173.5 | 178.7 | 184.1 | 189.6 |
| Others | 38.5 | 135.3 | 133.9 | 134.9 | 136.0 | 137.1 | 138.4 | 139.8 | 141.4 | 143.0 | 144.8 | 146.7 | 151.3 | 156.1 | 161.0 | 166.0 | 171.2 | 176.6 | 182.1 | 187.8 | 193.6 |
| Feedstcok Cost | 0.0 | 369.3 | 380.4 | 391.8 | 403.6 | 415.7 | 428.1 | 441.0 | 454.2 | 467.8 | 481.9 | 496.3 | 511.2 | 526.6 | 542.4 | 558.6 | 575.4 | 592.6 | 610.4 | 628.7 | 647.6 |
| Revenue | 0.0 | 687.5 | 708.1 | 729.4 | 751.2 | 773.8 | 797.0 | 820.9 | 845.5 | 870.9 | 897.0 | 923.9 | 951.7 | 980.2 | 1009.6 | 1039.9 | 1071.1 | 1103.2 | 1136.3 | 1170.4 | 1205.5 |
| Net Cash Flow (in Rs) | -478.5 | 67.2 | 74.7 | 80.0 | 85.4 | 90.8 | 96.4 | 102.0 | 107.8 | 113.6 | 119.5 | 125.5 | 129.1 | 132.7 | 136.5 | 140.4 | 144.4 | 148.5 | 152.7 | 157.1 | 161.6 |
| **IRR** | **19.13%** | | | | | | | | | | | | | | | | | | | | |

## Table 5A.14: Financial Cost Benefit Analysis of Producing Bioethanol from Sweet Sorghum (in Rs Million)

| For Capacity of 100 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Expense (in Rs) | 522.0 | 895.5 | 921.8 | 946.1 | 971.2 | 997.2 | 1024.0 | 1051.8 | 1080.4 | 1110.0 | 1140.5 | 1172.1 | 1207.5 | 1244.0 | 1281.5 | 1320.2 | 1360.0 | 1401.1 | 1443.4 | 1486.9 | 1531.7 |
| Capital Cost | 480.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Labor Cost | 0.0 | 16.0 | 16.5 | 17.0 | 17.5 | 18.0 | 18.5 | 19.1 | 19.7 | 20.3 | 20.9 | 21.5 | 22.1 | 22.8 | 23.5 | 24.2 | 24.9 | 25.7 | 26.4 | 27.2 | 28.1 |
| Fuel Cost | 0.0 | 162.5 | 167.4 | 172.4 | 177.6 | 182.9 | 188.4 | 194.0 | 199.9 | 205.9 | 212.0 | 218.4 | 224.9 | 231.7 | 238.6 | 245.8 | 253.2 | 260.8 | 268.6 | 276.6 | 284.9 |
| Others | 42.0 | 140.1 | 143.7 | 144.7 | 145.8 | 147.0 | 148.3 | 149.8 | 151.3 | 153.0 | 154.9 | 156.9 | 161.8 | 166.9 | 172.2 | 177.6 | 183.1 | 188.8 | 194.8 | 200.8 | 207.1 |
| Feedstcok Cost | 0.0 | 576.9 | 594.2 | 612.1 | 630.4 | 649.3 | 668.8 | 688.9 | 709.5 | 730.8 | 752.8 | 775.3 | 798.6 | 822.6 | 847.2 | 872.6 | 898.8 | 925.8 | 953.6 | 982.2 | 1011.6 |
| Revenue | 0.0 | 967.3 | 996.3 | 1026.2 | 1057.0 | 1088.7 | 1121.4 | 1155.0 | 1189.7 | 1225.4 | 1262.1 | 1300.0 | 1339.0 | 1379.1 | 1420.5 | 1463.1 | 1507.0 | 1552.2 | 1598.8 | 1646.8 | 1696.2 |
| Net Cash Flow (in Rs) | -522.0 | 71.8 | 74.5 | 80.1 | 85.8 | 91.5 | 97.3 | 103.3 | 109.3 | 115.4 | 121.6 | 127.9 | 131.5 | 135.2 | 139.0 | 142.9 | 147.0 | 151.2 | 155.5 | 159.9 | 164.4 |
| **IRR** | **17.66%** | | | | | | | | | | | | | | | | | | | | |

## Table 5A.15: Financial Cost Benefit Analysis of Producing Bioethanol from Tropical Sugar Beet (in Rs Million)

| For Capacity of 100 TPD | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Expense (in Rs) | 522.0 | 562.9 | 571.0 | 579.2 | 587.7 | 596.4 | 605.3 | 614.5 | 623.9 | 633.6 | 643.5 | 653.6 | 666.9 | 680.4 | 694.1 | 708.2 | 722.5 | 737.1 | 752.0 | 767.2 | 782.7 |
| Capital Cost | 480.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Labor Cost | 0.0 | 7.5 | 7.7 | 7.8 | 8.0 | 8.1 | 8.3 | 8.4 | 8.6 | 8.8 | 9.0 | 9.1 | 9.3 | 9.5 | 9.7 | 9.9 | 10.1 | 10.3 | 10.5 | 10.7 | 10.9 |
| Fuel Cost | 0.0 | 101.7 | 103.7 | 105.8 | 107.9 | 110.1 | 112.3 | 114.5 | 116.8 | 119.2 | 121.5 | 124.0 | 126.5 | 129.0 | 131.6 | 134.2 | 136.9 | 139.6 | 142.4 | 145.3 | 148.2 |
| Others | 42.0 | 93.7 | 92.4 | 91.1 | 89.8 | 88.5 | 87.3 | 86.1 | 85.0 | 83.8 | 82.7 | 81.7 | 83.5 | 85.3 | 87.2 | 89.1 | 91.0 | 93.0 | 95.0 | 97.1 | 99.2 |
| Feedstcok Cost | 0.0 | 360.0 | 367.2 | 374.5 | 382.0 | 389.7 | 397.5 | 405.4 | 413.5 | 421.8 | 430.2 | 438.8 | 447.6 | 456.6 | 465.7 | 475.0 | 484.5 | 494.2 | 504.1 | 514.2 | 524.5 |
| Revenue | 0.0 | 645.6 | 658.5 | 671.7 | 685.1 | 698.8 | 712.8 | 727.1 | 741.6 | 756.4 | 771.6 | 787.0 | 802.7 | 818.8 | 835.2 | 851.9 | 868.9 | 886.3 | 904.0 | 922.1 | 940.5 |
| Net Cash Flow (in Rs) | -522.0 | 82.7 | 87.5 | 92.5 | 97.4 | 102.4 | 107.5 | 112.5 | 117.7 | 122.9 | 128.1 | 133.3 | 135.9 | 138.4 | 141.0 | 143.7 | 146.4 | 149.2 | 152.0 | 154.9 | 157.8 |
| **IRR** | **19.44%** | | | | | | | | | | | | | | | | | | | | |

## Appendix 6

# Overview of Molasses Based Ethanol Industry

Molasses is a byproduct of sugar industry. The production of sugarcane is related to sugar production which in turn is related to the production of molasses. The production of molasses in the last decade is as follows.

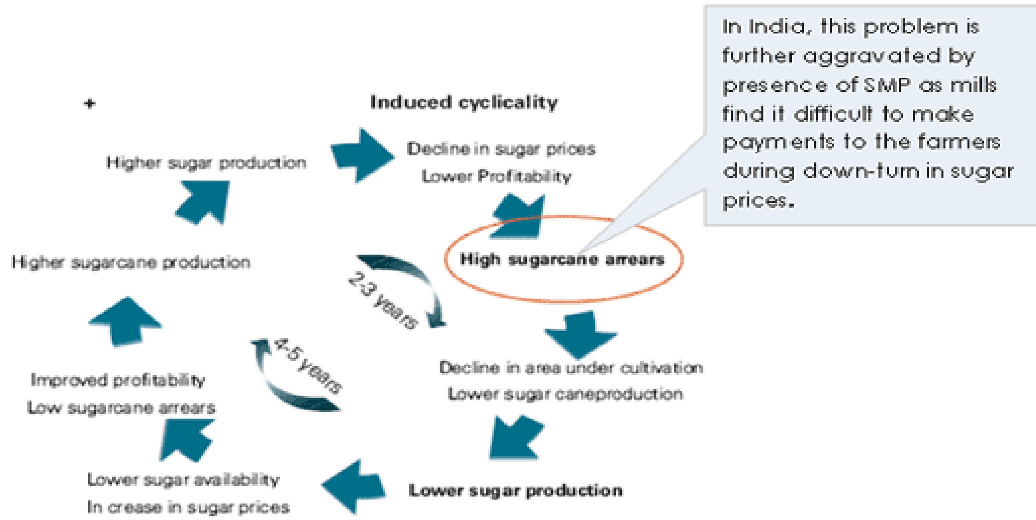
**Table 6A.1: Indian Molasses and Alcohol Production**

| S.No. | Year | Molasses Production (Mill Tonnes) | Estimated Alcohol Production (Mill. Litres) |
|---|---|---|---|
| 1 | 1970-71 | 1.62 | 346 |
| 2 | 1980-81 | 2.13 | 455 |
| 3 | 1990-91 | 5.44 | 1163 |
| 4 | 2000-01 | 7.82 | 1672 |
| 5 | 2001-02 | 8.07 | 1725 |
| 6 | 2002-03 | 8.87 | 1896 |
| 7 | 2003-04 | 5.91 | 1263 |
| 8 | 2004-05 | 5.51 | 1178 |
| 9 | 2005-06 | 8.55 | 1828 |
| 10 | 2006-07 | 13.09 | 2798 |
| 11 | 2007-08 | 11.31 | 2418 |
| 12 | 2008-09 | 6.50 | 1389 |
| 13 | 2009-10 (E) | 8.30 | 1774 |
| 14 | 2010-11 (P) | 11.48 | 2454 |

*Source: Ministry of Agriculture/ISMA*

From the above table it can be seen that the molasses production has fluctuated significantly in the last one decade. This is primarily due to the cyclic nature of the sugar industry which follows of a three to five year cycle. This consists of higher production leading to glut of sugar and molasses followed by a shortage and then by another increase in production (See Figure 6A.1).

**Figure 6A.1: Sugar Cycle**




However, the sugar/molasses production has significantly increased on a long term basis. In India the molasses produced is C heavy from which as much sugar as possible has been extracted. However, B heavy molasses can also be produced which can produce much larger quantity of alcohol per tonne of molasses. In order to facilitate this and to avoid glut in the sugar industry the Ministry of Consumer Affairs, Food And Public Distribution, (Department of Food and Public Distribution) vide its order dated Dec 28, 2007 permitted the use of sugarcane juice and B heavy molasses for producing Ethanol.

**Alcohol Production**

Alcohol can be commercially produced from sugar and starch based feedstocks. While grain and tuber based alcohol is primarily used for producing potable alcohol because of its high cost of production, molasses is the dominant feedstock and is used for potable, industrial and for blending purposes. It has been estimated that about 95% of the molasses produced in India is used for the production of Alcohol. Since the alcohol production is related to molasses production, therefore its production also becomes cyclic. The estimates of alcohol production based molasses are shown in table 6A. 1**.** The production of Khandsari also leads to production of molasses. This source and grain based alcohol also contributes to production of alcohol but is often not taken into account while estimating the total production of alcohol.

While there is a general agreement on estimated production of alcohol based on molasses, estimates of alcohol based on grain as well khandsari molasses is not reflected in estimates by three prime Associations representing various sectors of Industry, which recently made presentation to the committee examining the price of Ethanol for Government of India (Table 6A.2). However, there is no consensus on the utilization of alcohol for various sectors.

**Table 6A.2 : Production and Utilization of Alcohol**

| | 2006-07 | 2007-08 | 2008-09 | 2009-10 (Expected) |
|---|---|---|---|---|
| Sugar Production (100,000 Mt) | 283 | 263 | 147 | 185 |
| Molasses Production (100,000 Mt) | 130 | 113 | 65 | 83 |
| Alcohol Availability (Million ltr) | 2100 | 2200 | 1300 | 1720 |
| Alcohol Consumption (Million ltrs) | | | | |
| Potable Sector | 990 | 1000 | 1000 | 1070 |
| Fuel Blending | 120 | 320 | 120 | - |
| Industrial Sector | 1010 | 960 | 530 | 1000 |
| Balance/Deficit of alcohol (Million ltrs) | (20) | (80) | (350) | (350) |
| Imports of alcohol (Million ltrs) | 20 | 80 | 350 | 350 |

*Source: Indian Chemical Council*

While the All India Alcohol Based Industries Development Association (ABIDA) in its website has shown that total use of alcohol by the Alcohol based industries was 293 mill L in 2006-07 and 326 mill L for 2007-08, Indian Chemical Council has shown 1010 mill L and 960 mill l respectively. Thus there is a very significant variation in statistics by two organizations representing the same industry.

The Alcohol based Industry has been importing significant quantities of alcohol in years which it found that Indian prices were higher than the landed prices of imported of alcohol. The Integrated Energy Policy 2006 has stated that in 2005 411 Mill L of Alcohol was imported into the country. The ICC estimates of imports of Alcohol in subsequent years are 20 mill L, 80 mill L, 350 mill L and 350 mill L for 2009-10. The GAIN Report of USDA has given the following estimates on alcohol availability and use based on Trade sources (Table 6A.3). The Industrial use is also significantly higher than AABIDA. According to this report small quantities of alcohol are exported from the country also.

**Table 6A.3: Availability and Utilizations of Alcohol in India**

| Calendar Year | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|
| Opening Stock | 483 | 747 | 1,396 | 1,673 | 1,243 | 1,145 |
| Production | 1,898 | 2,398 | 2,150 | 1,073 | 1,435 | 1,859 |
| Imports | 29 | 15 | 70 | 280 | 300 | 300 |
| Total Supply | 2,410 | 3,160 | 3,616 | 3,026 | 2,978 | 3,304 |
| Exports | 24 | 14 | 3 | 3 | 3 | 10 |
| Consumption | | | | | | |
| Industrial Use | 619 | 650 | 700 | 700 | 720 | 750 |
| Potable Liquor | 745 | 800 | 850 | 880 | 950 | 1010 |
| Blended petrol | 200 | 200 | 280 | 100 | 50 | 200 |
| Other Use | 75 | 100 | 110 | 100 | 110 | 110 |
| Total Consumption | 1639 | 1750 | 1940 | 1780 | 1830 | 1970 |
| Ending Stocks | 747 | 1,396 | 1,673 | 1,243 | 1,145 | 1,224 |

From the above table it can be seen that the estimates of Alcohol production for 2010 and 2011 are much lower than estimates of the Industry Associations. It appears that the production statistics of the industry associations are more accurate because the 2010 estimates have been jacked up considerably based on real time data and significantly higher molasses projections have been made by the ISMA for 2011 because excellent monsoon and feedback from the industry.

From the above it can be seen that the data available is contradictory. However, another indicator of the availability is the price of the commodity. However, alcohol is not a commodity that is traded on the commodity exchange. The availability and price of alcohol have to be verified by undertaking a detailed study which should include extensive consultation, data collection and field visits. It is based on this study a reasonably accurate estimate can be made on the availability of alcohol and price of alcohol and would lead to more reliable conclusions but this is beyond the scope of this report.

**Table 6A.4: Predicted Alcohol Demand and Supply by Indian Chemical Council**

| Alcohol Requirement (Million ltrs) | 2010-11 | 2011-12 | 2012-13 | 2013-14 | 2014-15 |
|---|---|---|---|---|---|
| 5%Fuel Blending | 1040* | 1090 | 1150 | 1200 | 1260 |
| Industrial sector | 1050 | 1100 | 1160 | 1210 | 1280 |
| Potable Sector | 1450 | 1550 | 1660 | 1780 | 1900 |
| Total (Million ltrs) | 3540 | 3740 | 3970 | 4190 | 4440 |
| Highest expected Alcohol availability (Million ltrs) | 2400 | 2400 | 2400 | 2400 | 2400 |
| Deficit Million ltrs) | (114.00) | (134.00) | (157.00) | (179.00) | (204.00) |

**Following growth rates on the basis of past trends were assumed: Potable Sector: 7%; Industrial sector: 5%; Fuel Demand: 5%*

Table 6A.4 shows the predicted demand for alcohol in different sectors together with the predicted supply. The data presented in the above table is obtained from Indian Chemical Council. Naturally industrial and potable sectors now compete with transport for ethanol and this competition may increase the Molasses price and erode profits of some sectors. Therefore, independent sources of data are required to properly assess the Ethanol sector and availability of alcohol for transport. Despite the possibility of ICC data being biases it clearly show one thing; there is a significant opportunity cost for ethanol blending if diversion takes place from industrial or potable sector to meet the targets of ethanol blending in transport sector.

## Appendix 7

# Details of the Economic Analysis of Biofuels

**Table 7A.1. Financial Cost of Ethanol Production from Molasses and Sugarcane**

| Item | Molasses Ethanol (Rs/L) | Sugarcane Ethanol (Rs/L) |
|---|---|---|
| Cost of Feedstock | 12.55 | 16.73 |
| Steam | 3.00 | 3.50 |
| Electricity | 1.63 | 3.25 |
| Chemicals | 0.25 | 0.35 |
| ETP/RO operating cost | 0.75 | 0.75 |
| Manpower cost | 0.44 | 0.59 |
| Admin and overheads | 0.19 | 0.22 |
| Repair & Maintenance | 0.15 | 0.22 |
| Marketing and other expenses | 1.00 | 1.00 |
| Total | 19.96 | 26.61 |

**Table 7A.2: Cost Benefit Stream of Molasses Based Ethanol Base Case, in millions**

| Year | Quantity of Molasses tones | Quantity of Ethanol KL | Cost of production, Rs. | Gross benefits, Rs. | Net Benefits Rs. |
|---|---|---|---|---|---|
| 1 | 8.40 | 1.85 | 32857.44 | 35235.56 | 2378.12 |
| 2 | 9.07 | 2.00 | 35483.80 | 38052.01 | 2568.21 |
| 3 | 9.74 | 2.14 | 38110.16 | 40868.46 | 2758.29 |
| 4 | 10.41 | 2.29 | 40736.53 | 43684.91 | 2948.38 |
| 5 | 11.09 | 2.44 | 43362.89 | 46501.35 | 3138.47 |
| 6 | 11.76 | 2.59 | 45989.25 | 49317.80 | 3328.56 |
| 7 | 12.43 | 2.73 | 48615.61 | 52134.25 | 3518.64 |
| 8 | 13.10 | 2.88 | 51241.96 | 54950.69 | 3708.73 |
| 9 | 13.10 | 2.88 | 51241.96 | 54950.69 | 3708.73 |
| | | | | | |
| | | | | | |
| 24 | 13.10 | 2.88 | 51241.96 | 54950.69 | 3708.73 |
| 25 | 13.10 | 2.88 | 51241.96 | 54950.69 | 3708.73 |

**Table: 7A.3: Cost Benefit Streams of Without Project Sugar cum Ethanol Production, in millions**

| Year | Quantity of Sugar tonnes | Quantity of Ethanol KL | Cost of Sugar, $C_s$ Rs. | Benefit $B_s$ Rs. | Quantity of ethanol KL | Cost of Ethanol $C_{me}$ Rs. | Benefit $B_{me}$, Rs. | $NB_{1.}$ Rs. |
|---|---|---|---|---|---|---|---|---|
| 4 | 3.27 | 2.29 | 68173.95 | 91318.42 | 0.46 | 8147.31 | 10653.82 | 25650.98 |
| 5 | 3.48 | 2.44 | 72569.25 | 97205.89 | 0.49 | 8672.58 | 11340.69 | 27304.75 |
| 6 | 3.70 | 2.59 | 76964.56 | 103093.37 | 0.52 | 9197.85 | 12027.56 | 28958.52 |
| 7 | 3.91 | 2.73 | 81359.86 | 108980.84 | 0.55 | 9723.12 | 12714.43 | 30612.29 |
| 8 | 4.12 | 2.88 | 85755.15 | 114868.29 | 0.58 | 10248.39 | 13401.30 | 32266.05 |
| 9 | 4.12 | 2.88 | 85755.15 | 114868.29 | 0.58 | 10248.39 | 13401.30 | 32266.05 |
| | | | | | | | | |
| 24 | 4.12 | 2.88 | 85755.15 | 114868.29 | 0.58 | 10248.39 | 13401.30 | 32266.05 |
| 25 | 4.12 | 2.88 | 85755.15 | 114868.29 | 0.58 | 10248.39 | 13401.30 | 32266.05 |

**Table 7A.4: Benefit Cost Stream for Ethanol Production from Cane Juice, in millions**

| Year | Quantity of Ethanol KL | Cost, $C_e$ Rs | Benefit, $B_e$ Rs. | Net Benefits $NB_2$, Rs. | Incremental Benefit $NB_{INC}$ Rs. |
|---|---|---|---|---|---|
| 4 | 2.29 | 54300.09 | 43684.91 | -10615.19 | -36266.17 |
| 5 | 2.44 | 57800.92 | 46501.35 | -11299.57 | -38604.32 |
| 6 | 2.59 | 61301.75 | 49317.80 | -11983.95 | -40942.47 |
| 7 | 2.73 | 64802.58 | 52134.25 | -12668.33 | -43280.62 |
| 8 | 2.88 | 68303.40 | 54950.69 | -13352.71 | -45618.76 |
| 9 | 2.88 | 68303.40 | 54950.69 | -13352.71 | -45618.76 |
| | | | | | |
| | | | | | |
| 24 | 2.88 | 68303.40 | 54950.69 | -13352.71 | -45618.76 |
| 25 | 2.88 | 68303.40 | 54950.69 | -13352.71 | -45618.76 |

**Table 7A.5: Cost Benefit Stream of Jatropha Subproject**

| Year | Quantity bio-diesel million KL | Total cost, Rs. million | Benefits, Rs. million | Net Benefit, Rs million |
|---|---|---|---|---|
| 1 | 0.0 | 42755.7 | 0.0 | -42755.7 |
| 2 | 0.0 | 78438.0 | 0.0 | -78438.0 |
| 3 | 0.0 | 103287.5 | 0.0 | -103287.5 |
| 4 | 1.2 | 135998.2 | 34473.6 | -101524.6 |
| 5 | 2.3 | 165735.8 | 66074.4 | -99661.4 |
| 6 | 4.2 | 200360.9 | 120657.6 | -79703.3 |
| 7 | 6.0 | 189681.0 | 172368.0 | -17313.0 |
| 8 | 8.0 | 203589.3 | 229824.0 | 26234.7 |
| 9 | 10.6 | 234285.1 | 303746.9 | 69461.8 |
| 10 | 11.7 | 228602.3 | 335097.2 | 106494.9 |
| 11 | 12.8 | 251055.1 | 367971.2 | 116916.1 |
| 12 | 12.8 | 198967.5 | 367971.2 | 169003.7 |
| 13 | 12.8 | 201683.8 | 367971.2 | 166287.5 |
| 14 | 12.8 | 204454.3 | 367971.2 | 163516.9 |
| 15 | 12.8 | 207280.3 | 367971.2 | 160690.9 |
| 16 | 12.8 | 210162.8 | 367971.2 | 157808.4 |

| Year | Quantity bio-diesel million KL | Total cost, Rs. million | Benefits, Rs. million | Net Benefit, Rs million |
|---|---|---|---|---|
| 17 | 12.8 | 213103.0 | 367971.2 | 154868.2 |
| 18 | 12.8 | 216102.0 | 367971.2 | 151869.2 |
| 19 | 12.8 | 219160.9 | 367971.2 | 148810.3 |
| 20 | 12.8 | 222281.0 | 367971.2 | 145690.2 |
| 21 | 12.8 | 222281.0 | 368005.7 | 145724.7 |
| 22 | 12.8 | 222281.0 | 368005.7 | 145724.7 |
| 23 | 12.8 | 222281.0 | 368005.7 | 145724.7 |
| 24 | 12.8 | 222281.0 | 368005.7 | 145724.7 |
| 25 | 12.8 | 222281.0 | 368005.7 | 145724.7 |

**Table 7A.6: Cost Benefit Stream of Pongamia Subproject**

| Year | Quantity bio-diesel million KL | Total cost, Rs. million | Benefits, Rs. million | Net Benefit |
|---|---|---|---|---|
| 1 | 0.0 | 9661.4 | 0.0 | -9661.4 |
| 2 | 0.0 | 18940.2 | 0.0 | -18940.2 |
| 3 | 0.0 | 26581.3 | 0.0 | -26581.3 |
| 4 | 0.0 | 46666.0 | 0.0 | -46666.0 |
| 5 | 1.0 | 66348.5 | 28728.0 | -37620.5 |

| Year | Quantity bio-diesel million KL | Total cost, Rs. million | Benefits, Rs. million | Net Benefit |
|---|---|---|---|---|
| 6 | 2.0 | 88394.5 | 57456.0 | -30938.5 |
| 7 | 3.0 | 105139.9 | 86184.0 | -18955.9 |
| 8 | 4.0 | 139718.1 | 114912.0 | -24806.1 |
| 9 | 5.5 | 160783.9 | 158004.0 | -2779.9 |
| 10 | 7.8 | 156883.9 | 223398.1 | 66514.2 |
| 11 | 8.5 | 172292.7 | 245314.1 | 73021.4 |
| 12 | 8.5 | 136546.3 | 245314.1 | 108767.8 |
| 13 | 8.5 | 138410.4 | 245314.1 | 106903.7 |
| 14 | 8.5 | 140311.8 | 245314.1 | 105002.3 |
| 15 | 8.5 | 213376.8 | 245314.1 | 31937.3 |
| 16 | 8.5 | 144229.4 | 245314.1 | 101084.7 |
| 17 | 8.5 | 146247.2 | 245314.1 | 99067.0 |
| 18 | 8.5 | 148305.3 | 245314.1 | 97008.9 |
| 19 | 8.5 | 150404.5 | 245314.1 | 94909.6 |
| 20 | 8.5 | 152545.8 | 245314.1 | 92768.3 |
| 21 | 8.5 | 152545.8 | 245337.1 | 92791.3 |
| 22 | 8.5 | 152545.8 | 245337.1 | 92791.3 |

| Year | Quantity bio-diesel million KL | Total cost, Rs. million | Benefits, Rs. million | Net Benefit |
|---|---|---|---|---|
| 23 | 8.5 | 152545.8 | 245337.1 | 92791.3 |
| 24 | 8.5 | 152545.8 | 245337.1 | 92791.3 |
| 25 | 8.5 | 152545.8 | 245337.1 | 92791.3 |

## Appendix 8

# Details of the Computable General Equilibrium Models

### 1. Main Feature of the India CGE Model

India CGE model is multi-sectoral CGE model with four factors of productions namely land, unskilled labor, and skilled labor. The model consists of 30 commodities/activities, consisting of 9 agricultural related sectors, 7 service sectors and 14 manufacturing sectors. Within the existing structure and subject to budget constraint, producers (enterprises) in the model maximize profits under constants returns to scale, with the choice between factors governed by constant elasticity of substitution (CES) function. Factors are then combined with fixed-share intermediates using a Leontief specification. Under profit maximization, factors receive income where marginal revenue equals marginal cost based on endogenous relative prices. For households, the initial factor endowments are fixed. They therefore supply factors inelastically. Their commodity-wise demands are expressed for given income and market prices, through constant difference elasticity demand function in the tradition of the GTAP model. Also households save and pay taxes to the government. The government receives income from imposing economic activity, indirect taxes, direct taxes and export/import tariffs and then make transfers to household, enterprises (in the form of subsidies) and the rest of the world. The government also purchases commodities in the form of government consumption expenditure and the remaining income of government is saved. All savings from households, enterprises, government are the rest of the worlds (foreign savings) are collected in a saving poll from which investment is financed.

The rest of the world supplies goods which are imperfect substitutes for domestic output to the Indian economy provides transfer payments and demand exports. The standard small-country assumption is made implying that India is a price-taker in import markets and can import as much as it wants. However, because imported goods are differentiated from the domestically produced goods, the two varieties are aggregated using Armington type CES function. As a result, the imports of a given good depend on the relation between the prices of the imported and the domestically produced varieties of that good. By contrast, India faces a perfectly elastic world demand curve at fixed world price under the small country assumption. On the supply side, constant elasticity of transformation (CET) function is used to define the output of a given sector as revenue –maximization aggregate of goods for the domestic market and goods for the foreign markets. This implies that the response of the domestic supply of goods in favor or against exports depends upon the price of those goods in the foreign markets vis-à-vis their prices in the domestic markets, given the elasticity of transformation between goods for the two types of markets.

The model is Walrasian in character. Markets for all commodities clear through adjustment in prices. In our models, we assume all factors are mobile except land, which is assumed to be a sluggish factor in tune with CGE model.[1] We further assume that the economy face a fixed supply of endowment of factors (land, unskilled labor, skilled labor, capital). Thus equilibrium is attained in capital, and skilled labor though adjustment in factor prices. So movement of factors between sectors occur still aggregate demand and supply of factors attains equilibrium and the economy would realize a single rate of return for factors like capital and skilled labor across sectors. Since land is a sluggish factor, rate of return would differ across sectors. Though, unskilled labor is mobile between sectors in reality, we follow a different equilibrating mechanism.  In a country like India, we can assume that there is a perfectly elastic supply of unskilled labor at a fixed real price of labor. So, we assume unskilled labor adjust to meet the required demand of labor at a given real wage. Since our model is typically neoclassical in nature, we have assumed a saving-driven closure in which foreign savings is exogenously fixed and investment is endogenous.

The CGE model is calibrated to 2006-07 Social Accounting Matrix (SAM) of India shown in Table 8A.1 in Appendix. This table is constructed from National Accounts statistics of India, latest Input-Output Table of India and from the SAM constructed by Pal, Ojha, Pohit and Roy (2009). We have chosen year 2006-07 as the base year of the model since detailed national accounts data for subsequent years are not available. In must be noted that neither jatropha plantation nor biodiesel processing sectors are accounted in national accounts statistics.  Our accounting of these sectors is based on primary survey in selected states contributing most to the growth of these sectors. To that extent, our results should be taken with caution.   The model is calibrated so that the initial equilibrium reproduces the base-year values from the SAM.

Our model requires estimates of various types of elasticity measures, viz. demand elasticities of exports and imports and elasticities of substitution between factors of production and between varieties of goods. Similar to other CGE models, most of our estimates are based on the published literature and are drawn primarily for the study by Ojha, Pohit, Pal (2009) and Chadha, Pohit, Deardorff and Stern (1998).

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[1] See Hetel, T, 1998, Global trade analysis: Modeling and applications, Cambridge University Press.

**Table 8A.1: Social Accounting Matrix of India for 2006-07 in US $ Millions**

| | Sectors | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 8383 | 132 | 692 | 1 | 0 | 106 | 0 |
| 2 | Wheat | 147 | 6287 | 877 | 0 | 0 | 32 | 0 |
| 3 | Other cereals | 125 | 298 | 4218 | 0 | 0 | 5943 | 0 |
| 4 | Cash crops | 9 | 34 | 111 | 1841 | 0 | 3 | 0 |
| 5 | Jatropha | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Animal husbandry | 1365 | 189 | 2219 | 1521 | 0 | 61 | 0 |
| 7 | Forestry | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 8 | Fishing | 1 | 1 | 3 | 0 | 0 | 0 | 0 |
| 9 | Coal | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | Oil | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| 11 | Gas | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 12 | Food & Beverages | 105 | 15 | 44 | 0 | 0 | 635 | 0 |
| 13 | Textiles & Leather Products | 49 | 50 | 36 | 8 | 0 | 6 | 1 |
| 14 | Wood | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 15 | Minerals n.e.c | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 16 | Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Sectors | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 17 | Diesel & other Petroleum Products | 1025 | 459 | 996 | 465 | 0 | 3 | 8 |
| 18 | Chemicals | 7 | 8 | 14 | 5 | 0 | 45 | 2 |
| 19 | Paper & Paper Products | 2 | 2 | 4 | 1 | 0 | 1 | 0 |
| 20 | Fertilizer | 3609 | 3144 | 3565 | 2212 | 0 | 0 | 0 |
| 21 | Other Manufacturing | 31 | 20 | 20 | 9 | 0 | 12 | 7 |
| 22 | Machinery | 147 | 173 | 190 | 30 | 0 | 16 | 1 |
| 23 | Electricity | 856 | 825 | 437 | 132 | 0 | 3 | 0 |
| 24 | Biomass | 145 | 21 | 252 | 158 | 0 | 32 | 2 |
| 25 | Water distribution | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | Construction | 696 | 433 | 562 | 221 | 0 | 11 | 8 |
| 27 | Land Transport including Railways | 1506 | 788 | 1074 | 532 | 0 | 1049 | 26 |
| 28 | Air Transport | 73 | 47 | 34 | 17 | 0 | 5 | 0 |
| 29 | Sea Transport | 2 | 3 | 7 | 1 | 0 | 68 | 0 |
| 30 | All Other Services | 2062 | 1275 | 2078 | 851 | 0 | 4816 | 23 |
| | Labour | 9483 | 6798 | 33652 | 12809 | 0 | 20427 | 399 |
| | Capital | 1698 | 1217 | 5711 | 2039 | 0 | 16230 | 348 |

| | Sectors | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| | Land | 5919 | 4243 | 21294 | 8126 | 0 | 0 | 0 |
| | Household | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Private | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Public | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Government | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Indirect tax less subsidies | -3512 | -4934 | -3432 | -2621 | 0 | 79 | 12 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ROW | 0 | 72 | 1889 | 644 | 0 | 79 | 1424 |

**Table 8A.1: Social Accounting Matrix of India for 2006-07 in US $ Millions (contd.)**

| | Sectors | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 1 | 0 | 0 | 0 | 1116 | 0 | 0 |
| 2 | Wheat | 0 | 0 | 0 | 0 | 2130 | 0 | 0 |
| 3 | Other cereals | 0 | 0 | 0 | 0 | 7095 | 17 | 1 |
| 4 | Cash crops | 0 | 0 | 0 | 0 | 12621 | 4782 | 1 |
| 5 | Jatropha | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Animal husbandry | 0 | 0 | 0 | 0 | 3725 | 866 | 1 |
| 7 | Forestry | 0 | 0 | 0 | 0 | 45 | 1 | 128 |

| | Sectors | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|
| 8 | Fishing | 572 | 0 | 0 | 0 | 1067 | 0 | 0 |
| 9 | Coal | 0 | 26 | 0 | 2 | 68 | 64 | 13 |
| 10 | Oil | 0 | 0 | 115 | 3 | 0 | 0 | 1 |
| 11 | Gas | 0 | 0 | 0 | 0 | 7 | 85 | 0 |
| 12 | Food & Beverages | 27 | 0 | 0 | 0 | 10001 | 39 | 1 |
| 13 | Textiles & Leather Products | 326 | 0 | 0 | 0 | 248 | 12794 | 4 |
| 14 | Wood | 16 | 70 | 0 | 5 | 397 | 183 | 34 |
| 15 | Minerals n.e.c | 0 | 0 | 0 | 0 | 10 | 16 | 4 |
| 16 | Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Diesel & other Petroleum Products | 371 | 98 | 202 | 26 | 945 | 948 | 17 |
| 18 | Chemicals | 23 | 710 | 143 | 67 | 2887 | 5021 | 89 |
| 19 | Paper & Paper Products | 0 | 10 | 0 | 1 | 1029 | 372 | 45 |
| 20 | Fertilizer | 1 | 0 | 0 | 0 | 142 | 5 | 16 |
| 21 | Other Manufacturing | 263 | 256 | 372 | 46 | 128 | 525 | 72 |
| 22 | Machinery | 0 | 484 | 450 | 60 | 641 | 1300 | 18 |
| 23 | Electricity | 0 | 299 | 81 | 43 | 617 | 1740 | 38 |

| | **Sectors** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
|---|---|---|---|---|---|---|---|---|
| 24 | Biomass | 0 | 0 | 0 | 0 | 219 | 4 | 432 |
| 25 | Water distribution | 0 | 4 | 0 | 0 | 16 | 8 | 0 |
| 26 | Construction | 0 | 71 | 627 | 42 | 775 | 958 | 6 |
| 27 | Land Transport including Railways | 140 | 349 | 129 | 44 | 3772 | 4505 | 104 |
| 28 | Air Transport | 5 | 2 | 3 | 0 | 229 | 16 | 8 |
| 29 | Sea Transport | 0 | 2 | 1 | 0 | 41 | 78 | 1 |
| 30 | All Other Services | 142 | 428 | 455 | 66 | 14265 | 11266 | 305 |
| | Labour | 4811 | 2443 | 2032 | 1085 | 6341 | 8851 | 761 |
| | Capital | 3110 | 5320 | 4565 | 880 | 7821 | 7110 | 429 |
| | Land | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Household | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Private | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Public | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Government | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Indirect tax less subsidies | -154 | 254 | 4584 | 135 | 1444 | 1224 | 129 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Sectors | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|
| | ROW | 34 | 2406 | 30930 | 1706 | 6100 | 2988 | 155 |

**Table 8A.1: Social Accounting Matrix of India for 2006-07 in US $ Millions (contd.)**

| | Sectors | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 0 | 0 | 0 | 47 | 4 | 1 | 4 |
| 2 | Wheat | 0 | 0 | 0 | 86 | 0 | 2 | 7 |
| 3 | Other cereals | 0 | 0 | 2 | 717 | 46 | 10 | 40 |
| 4 | Cash crops | 0 | 0 | 4 | 1695 | 10 | 20 | 84 |
| 5 | Jatropha | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Animal husbandry | 0 | 0 | 1 | 366 | 2 | 5 | 113 |
| 7 | Forestry | 0 | 0 | 1 | 37 | 118 | 0 | 84 |
| 8 | Fishing | 0 | 0 | 0 | 46 | 0 | 1 | 4 |
| 9 | Coal | 56 | 0 | 587 | 324 | 124 | 76 | 7708 |
| 10 | Oil | 0 | 0 | 43426 | 493 | 1 | 0 | 264 |
| 11 | Gas | 3 | 0 | 2 | 762 | 5 | 887 | 1049 |
| 12 | Food & Beverages | 1 | 0 | 2 | 1115 | 27 | 26 | 63 |
| 13 | Textiles & Leather Products | 9 | 0 | 10 | 856 | 27 | 22 | 479 |
| 14 | Wood | 6 | 0 | 23 | 624 | 157 | 58 | 518 |

| | **Sectors** | **15** | **16** | **17** | **18** | **19** | **20** | **21** |
|---|---|---|---|---|---|---|---|---|
| 15 | Minerals n.e.c | 61 | 0 | 6 | 450 | 11 | 377 | 6214 |
| 16 | Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Diesel & other Petroleum Products | 148 | 0 | 2374 | 2749 | 196 | 1841 | 4347 |
| 18 | Chemicals | 282 | 0 | 1271 | 35510 | 981 | 2966 | 6270 |
| 19 | Paper & Paper Products | 4 | 0 | 34 | 2239 | 1437 | 20 | 591 |
| 20 | Fertilizer | 0 | 0 | 8 | 524 | 1 | 1343 | 29 |
| 21 | Other Manufacturing | 295 | 0 | 90 | 2358 | 78 | 41 | 52547 |
| 22 | Machinery | 78 | 0 | 96 | 1127 | 36 | 55 | 7746 |
| 23 | Electricity | 174 | 0 | 830 | 2227 | 276 | 224 | 6849 |
| 24 | Biomass | 0 | 0 | 2 | 139 | 402 | 1 | 285 |
| 25 | Water distribution | 1 | 0 | 0 | 28 | 0 | 4 | 50 |
| 26 | Construction | 135 | 0 | 447 | 765 | 23 | 116 | 2420 |
| 27 | Land Transport including Railways | 134 | 0 | 1529 | 3981 | 468 | 641 | 8849 |
| 28 | Air Transport | 3 | 0 | 35 | 67 | 12 | 28 | 263 |
| 29 | Sea Transport | 1 | 0 | 9 | 112 | 11 | 3 | 84 |
| 30 | All Other Services | 405 | 0 | 2321 | 10020 | 804 | 1435 | 23543 |

| | Sectors | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|
| | Labour | 2141 | 0 | 786 | 9176 | 661 | 1093 | 20012 |
| | Capital | 4662 | 0 | 10639 | 16160 | 928 | 2318 | 27447 |
| | Land | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Household | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Private | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Public | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Government | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Indirect tax less subsidies | 498 | 0 | 12332 | 12263 | 1592 | -1391 | 17958 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ROW | 18222 | 0 | 8185 | 19839 | 1398 | 2827 | 91510 |

**Table 8A.1: Social Accounting Matrix of India for 2006-07 in US $ Millions (contd.)**

| | Sectors | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|
| 1 | Paddy | 1 | 3 | 12 | 0 | 0 | 0 | 0 |
| 2 | Wheat | 1 | 5 | 7 | 0 | 0 | 3 | 0 |
| 3 | Other cereals | 9 | 25 | 497 | 1 | 2468 | 2217 | 2 |
| 4 | Cash crops | 22 | 39 | 7 | 1 | 2 | 0 | 0 |
| 5 | Jatropha | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | Sectors | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|
| 6 | Animal husbandry | 29 | 11 | 16 | 0 | 1399 | 0 | 0 |
| 7 | Forestry | 6 | 2 | 4 | 0 | 194 | 0 | 0 |
| 8 | Fishing | 1 | 3 | 1 | 0 | 0 | 0 | 0 |
| 9 | Coal | 265 | 3937 | 0 | 0 | 5 | 10 | 0 |
| 10 | Oil | 11 | 95 | 0 | 1 | 0 | 0 | 0 |
| 11 | Gas | 83 | 757 | 0 | 0 | 1 | 0 | 0 |
| 12 | Food & Beverages | 14 | 29 | 56 | 1 | 1 | 44 | 2 |
| 13 | Textiles & Leather Products | 456 | 17 | 8 | 0 | 217 | 187 | 2 |
| 14 | Wood | 529 | 5 | 1 | 0 | 2138 | 2 | 0 |
| 15 | Minerals n.e.c | 496 | 14 | 0 | 0 | 8672 | 0 | 0 |
| 16 | Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Diesel & other Petroleum Products | 1213 | 3849 | 66 | 5 | 7803 | 28901 | 101 |
| 18 | Chemicals | 6153 | 278 | 25 | 15 | 2655 | 5149 | 405 |
| 19 | Paper & Paper Products | 578 | 81 | 7 | 4 | 85 | 281 | 1 |
| 20 | Fertilizer | 14 | 8 | 15 | 3 | 26 | 1 | 0 |
| 21 | Other Manufacturing | 34546 | 980 | 54 | 17 | 52634 | 7802 | 240 |

| | Sectors | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|
| 22 | Machinery | 29417 | 1976 | 13 | 10 | 5504 | 2233 | 29 |
| 23 | Electricity | 1704 | 12090 | 4 | 63 | 2527 | 1809 | 13 |
| 24 | Biomass | 20 | 6 | 18 | 0 | 664 | 9 | 0 |
| 25 | Water distribution | 4 | 51 | 0 | 329 | 412 | 37 | 43 |
| 26 | Construction | 2417 | 885 | 60 | 272 | 8815 | 3282 | 80 |
| 27 | Land Transport including Railways | 3270 | 2132 | 283 | 17 | 11013 | 7182 | 151 |
| 28 | Air Transport | 27 | 121 | 1 | 0 | 200 | 326 | 1 |
| 29 | Sea Transport | 73 | 13 | 6 | 0 | 56 | 84 | 0 |
| 30 | All Other Services | 18158 | 5403 | 569 | 209 | 23190 | 18713 | 385 |
| | Labour | 9453 | 4817 | 4832 | 839 | 57836 | 29260 | 1381 |
| | Capital | 10586 | 8795 | 3859 | 766 | 16492 | 17293 | 827 |
| | Land | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Household | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Private | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Public | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Government | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Indirect tax less | 6003 | -5219 | 0 | 4 | 298 | -1132 | 6 |

| | Sectors | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|
| | subsidies | | | | | | | |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ROW | 26830 | 0 | 0 | 0 | 0 | 1088 | 0 |

**Table 8A.1: Social Accounting Matrix of India for 2006-07 in US $ Millions (contd.)**

| | Sectors | 29 | 30 | LAB | CAP | LAN | Household |
|---|---|---|---|---|---|---|---|
| 1 | Paddy | 0 | 1680 | 0 | 0 | 0 | 19947 |
| 2 | Wheat | 0 | 935 | 0 | 0 | 0 | 10041 |
| 3 | Other cereals | 0 | 5478 | 0 | 0 | 0 | 43956 |
| 4 | Cash crops | 0 | 341 | 0 | 0 | 0 | 5403 |
| 5 | Jatropha | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Animal husbandry | 0 | 3013 | 0 | 0 | 0 | 32454 |
| 7 | Forestry | 0 | 7 | 0 | 0 | 0 | 1131 |
| 8 | Fishing | 0 | 40 | 0 | 0 | 0 | 6410 |
| 9 | Coal | 0 | 48 | 0 | 0 | 0 | 68 |
| 10 | Oil | 0 | 31 | 0 | 0 | 0 | 0 |
| 11 | Gas | 0 | 16 | 0 | 0 | 0 | 292 |
| 12 | Food & Beverages | 0 | 5739 | 0 | 0 | 0 | 58085 |
| 13 | Textiles & Leather | 0 | 397 | 0 | 0 | 0 | 28027 |

| | Sectors | 29 | 30 | LAB | CAP | LAN | Household |
|---|---|---|---|---|---|---|---|
| | Products | | | | | | |
| 14 | Wood | 0 | 57 | 0 | 0 | 0 | 279 |
| 15 | Minerals n.e.c | 0 | 63 | 0 | 0 | 0 | 0 |
| 16 | Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Diesel & other Petroleum Products | 227 | 2472 | 0 | 0 | 0 | 22543 |
| 18 | Chemicals | 300 | 8521 | 0 | 0 | 0 | 18738 |
| 19 | Paper & Paper Products | 2 | 789 | 0 | 0 | 0 | 1323 |
| 20 | Fertilizer | 0 | 33 | 0 | 0 | 0 | 0 |
| 21 | Other Manufacturing | 213 | 7013 | 0 | 0 | 0 | 8236 |
| 22 | Machinery | 12 | 5341 | 0 | 0 | 0 | 5457 |
| 23 | Electricity | 6 | 2105 | 0 | 0 | 0 | 4245 |
| 24 | Biomass | 0 | 47 | 0 | 0 | 0 | 7565 |
| 25 | Water distribution | 2 | 256 | 0 | 0 | 0 | 325 |
| 26 | Construction | 79 | 8873 | 0 | 0 | 0 | 5057 |
| 27 | Land Transport including Railways | 119 | 10643 | 0 | 0 | 0 | 44378 |
| 28 | Air Transport | 3 | 134 | 0 | 0 | 0 | 1677 |
| 29 | Sea Transport | 1 | 339 | 0 | 0 | 0 | 485 |

| | Sectors | 29 | 30 | LAB | CAP | LAN | Household |
|---|---|---|---|---|---|---|---|
| 30 | All Other Services | 245 | 49239 | 0 | 0 | 0 | 209635 |
| | Labour | 628 | 198763 | 0 | 0 | 0 | 0 |
| | Capital | 376 | 212338 | 0 | 0 | 0 | 0 |
| | Land | 0 | 0 | 0 | 0 | 0 | 0 |
| | Household | 0 | 0 | 451004 | 230803 | 39582 | 0 |
| | Private | 0 | 0 | 0 | 30438 | 0 | 0 |
| | Public | 0 | 0 | 0 | 19825 | 0 | 0 |
| | Government | 0 | 0 | 0 | 17816 | 0 | 29115 |
| | Indirect tax less subsidies | 6 | -169 | 0 | 0 | 0 | 22510 |
| | CAC | 0 | 0 | 0 | 84750 | 0 | 163330 |
| | ROW | 0 | 17907.7 | 0 | 0 | 0 | 0 |

**Table 8A.1: Social Accounting Matrix of India for 2006-07 in US $ Millions (contd.)**

| | Sectors | PVT | PUB | GOV | ITX | CAC | ROW |
|---|---|---|---|---|---|---|---|
| 1 | Paddy | 0 | 0 | 170 | 0 | 256 | 1376 |
| 2 | Wheat | 0 | 0 | 77 | 0 | -270 | 1234 |
| 3 | Other cereals | 0 | 0 | 320 | 0 | 1343 | 1719 |
| 4 | Cash crops | 0 | 0 | 0 | 0 | 1713 | 260 |

| | Sectors | PVT | PUB | GOV | ITX | CAC | ROW |
|---|---|---|---|---|---|---|---|
| 5 | Jatropha | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | Animal husbandry | 0 | 0 | 591 | 0 | 1063 | 660 |
| 7 | Forestry | 0 | 0 | 0 | 0 | 14 | 489 |
| 8 | Fishing | 0 | 0 | 0 | 0 | 24 | 1515 |
| 9 | Coal | 0 | 0 | 11 | 0 | -198 | 38 |
| 10 | Oil | 0 | 0 | 0 | 0 | -16 | 257 |
| 11 | Gas | 0 | 0 | 62 | 0 | 27 | 174 |
| 12 | Food & Beverages | 0 | 0 | 683 | 0 | 3418 | 5769 |
| 13 | Textiles & Leather Products | 0 | 0 | 571 | 0 | 1592 | 19367 |
| 14 | Wood | 0 | 0 | 0 | 0 | -2422 | 129 |
| 15 | Minerals n.e.c | 0 | 0 | 0 | 0 | -248 | 11171 |
| 16 | Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Diesel & other Petroleum Products | 0 | 0 | 1177 | 0 | -6958 | 6434 |
| 18 | Chemicals | 0 | 0 | 2123 | 0 | 12137 | 14106 |
| 19 | Paper & Paper Products | 0 | 0 | 209 | 0 | 228 | 457 |
| 20 | Fertilizer | 0 | 0 | 0 | 0 | -138 | 486 |

| | Sectors | PVT | PUB | GOV | ITX | CAC | ROW |
|---|---|---|---|---|---|---|---|
| 21 | Other Manufacturing | 0 | 0 | 793 | 0 | 58073 | 59660 |
| 22 | Machinery | 0 | 0 | 484 | 0 | 74275 | 14988 |
| 23 | Electricity | 0 | 0 | 989 | 0 | 0 | 0 |
| 24 | Biomass | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | Water distribution | 0 | 0 | 985 | 0 | 0 | 0 |
| 26 | Construction | 0 | 0 | 1276 | 0 | 165899 | 0 |
| 27 | Land Transport including Railways | 0 | 0 | 1361 | 0 | 4266 | 10344 |
| 28 | Air Transport | 0 | 0 | 32 | 0 | 74 | 230 |
| 29 | Sea Transport | 0 | 0 | 65 | 0 | 430 | 243 |
| 30 | All Other Services | 0 | 0 | 64996 | 0 | 11936 | 63251 |
| | Labour | 0 | 0 | 0 | 0 | 0 | -568 |
| | Capital | 0 | 0 | 0 | 0 | 0 | -6331 |
| | Land | 0 | 0 | 0 | 0 | 0 | 0 |
| | Household | 0 | 0 | 0 | 0 | 0 | 29326 |
| | Private | 0 | 0 | 0 | 0 | 0 | 0 |
| | Public | 0 | 0 | 0 | 0 | 0 | 0 |
| | Government | 22009 | 0 | 0 | 81346 | 0 | -53425 |

| | Sectors | PVT | PUB | GOV | ITX | CAC | ROW |
|---|---|---|---|---|---|---|---|
| | Indirect tax less subsidies | 0 | 0 | 3760 | 0 | 18752 | 65 |
| | CAC | 8429 | 19825 | 16126 | 0 | 0 | 52813 |
| | ROW | 0 | 0 | 0 | 0 | 0 | 0 |

## 2. Main Feature of the Global CGE Model

This paper uses a version of the World Bank's Linkage Model, a global, multiregion, multisector, dynamic applied general equilibrium model. The base data set—GTAP Version 7.0—is defined across 118 country and/or region groupings, and 57 economic sectors. For this paper, the model has been defined for an aggregation of 13 country and/or regions and 10 sectors, including sectors of importance to the poorer developing countries—grains, textiles, and apparel. The remainder of this section outlines briefly the main characteristics of supply, demand, and the policy instruments of the model.

### 2.1 Production

All sectors are assumed to operate under constant returns to scale and perfect competition. Production in each sector is modeled by a series of nested CES production functions that are intended to represent the different substitution and complementarity relations across the various inputs in each sector. There are material inputs that generate the input/output table, as well as factor inputs representing value added.

Three different production archetypes are defined in the model—crops, livestock, and all other goods and services. The CES nests of the three archetypes are graphically depicted in Figures 8A.1 through 8A.3. Within each production archetype, sectors will be differentiated by different input combinations (share parameters) and different substitution elasticities. Share structures are largely determined by base year data, and the elasticities are given values by the modeler.

The key feature of the crop production structure is the substitution between intensive cropping versus extensive cropping, i.e., between fertilizer and land (Figure 8A.1). Livestock production captures the important role played by feed versus land, i.e., between ranch- versus range-fed production (Figure 8A.2). Production in the other sectors more closely matches the traditional role of capital/labor substitution, with energy introduced as an additional factor of production (Figure 8A.3).

In each period, the supply of primary factors—capital, labor, and land—is usually predetermined. However, the supply of land is assumed to be sensitive to the contemporaneous price of land. Land is assumed to be partially mobile across agricultural sectors. Given the comparative static nature of the simulations that assume a longer-term horizon, both labor and capital are assumed to be perfectly mobile across sectors (though not internationally).

Model current specification has an innovation in the treatment of labor resources. The GTAP data set identifies two types of labor skills—skilled and unskilled. Under the standard specification, both types of labor are combined together in a CES bundle to form aggregate sectoral labor demand, i.e., the two types of labor skills are directly substitutable. In the new specification, a new factor of production has been inserted, which we call human capital. It is combined with capital to form a physical cum human capital bundle, with an assumption that they are complements. On input, the user can specify the percentage of the skilled labor factor to allocate to the human capital factor. Once the optimal combination of inputs is determined, sectoral output prices are calculated assuming competitive supply (zero-profit) conditions in all markets.

### 2.2 Consumption and Closure Rules

All income generated by economic activity is assumed to be distributed to a single representative household. The single consumer allocates optimally its disposable income among the consumer goods and saving. The consumption/saving decision is completely static: saving is treated as a “good” and its amount is determined simultaneously with the demands for the other goods, the price of saving being set arbitrarily equal to the average price of consumer goods.

Government collects income taxes, indirect taxes on intermediate and final consumption, taxes on production, tariffs, and export taxes and/or subsidies. Aggregate government expenditures are linked to changes in real GDP. The real government deficit is exogenous. Closure therefore implies that some fiscal instrument is endogenous in order to achieve a given government deficit. The standard fiscal closure rule is that the marginal income tax rate adjusts to maintain a given government fiscal stance. For example, a reduction or elimination of tariff rates is compensated by an increase in household direct taxation, ceteris paribus.

Each region runs a current-account surplus (deficit) that is fixed (in terms of the model numéraire). The counterpart of these imbalances is a net outflow (inflow) of capital, subtracted from (added to) the domestic flow of saving. In each period, the model equates gross investment to net saving (equal to the sum of saving by households, the net budget position of the government, and foreign capital inflows). This particular closure rule implies that investment is driven by saving. The fixed-trade balance implies an endogenous real exchange rate. For example, removal of tariffs, which induces increased demand for imports, is compensated by increasing exports—which is achieved through a real depreciation.

### 2.3. Foreign Trade

The world trade block is based on a set of regional bilateral flows. The basic assumption in Linkage is that imports originating in different regions are imperfect substitutes (Figure 8A.4). Therefore in each region, total import demand for each good is allocated across trading partners according to the relationship between their export prices. This specification of imports—commonly referred to as the Armington specification—implies that each region faces a downward-sloping demand curve for its exports. The Armington specification is implemented using two CES nests. At the top nest, domestic agents choose the optimal combination of the domestic good and an aggregate import good consistent with the agent's preference function. At the second nest, agents optimally allocate demand for the aggregate import good across the range of trading partners.

The bilateral supply of exports is specified in parallel fashion using a nesting of constant-elasticity-of-transformation (CET) functions. At the top level, domestic suppliers optimally allocate aggregate supply across the domestic market and the aggregate export market. At the second level, aggregate export supply is optimally allocated across each trading region as a function of relative prices.

Trade variables are fully bilateral and include both export and import taxes and/or subsidies. Trade and transport margins are also included; therefore world prices reflect the difference between FOB and CIF pricing.

### 2.4 Prices

The Linkage model is fully homogeneous in prices, i.e., only relative prices are identified in the equilibrium solution. The price of a single good, or of a basket of goods, is arbitrarily chosen as the anchor to the price system. The price (index) of the Organisation for Economic Co-operation and Development (OECD) manufacturing exports has been chosen as the numéraire, and is set to 1.

### 2.5 Elasticities

Production elasticities are relatively standard and are available from the authors. Aggregate labor and capital supplies are fixed, and within each economy they are perfectly mobile across sectors.

### 2.6 Equivalent Variation Aggregate National Income

Aggregate income gains and/or losses summarize the extent to which trade distortions are hindering growth prospects and the ability of economies to use the gains to help those whose income could potentially decline. Real income is summarized by Hicksian equivalent variation (EV). This represents the income consumers would be willing to forego to achieve post-reform well-being (up) compared to baseline well-being (ub) at baseline prices (pb):

$$EV = E\left(p^b, u^p\right) - E\left(p^b, u^b\right)$$

where E represents the expenditure function to achieve utility level u given a vector of prices p (the b superscript represents baseline levels, and p the post-reform levels). The model uses the extended linear expenditure system (ELES), which incorporates savings in the consumer's utility function. The discounted real income uses the following formula:

$$CEV = \sum_{t=2005}^{2015} \beta^{(t-2004)} EV_t^a \,/\, \sum_{t=2005}^{2015} \beta^{(t-2004)} Y_t^d$$

where CEV is the cumulative measure of real income (as a percent of baseline income), β is the discount factor (equal to 1/(1+r) where r is the subjective discount rate), $Y^d$ is real disposable income, and $EV^a$ is adjusted equivalent variation. The adjustment to EV extracts the component measuring the contribution of household saving, since this represents future consumption. Without the adjustment, the EV measure would be double counting. The saving component is included in the EV evaluation for the terminal year. Similar to the OECD, a subjective discount rate of 1.5% is assumed in the cumulative expressions.

### 2.7 Specification of Endogenous Productivity Growth

Productivity in manufacturing and services is the sum of three components:

- a uniform factor used as an instrument to target gross domestic product growth in the baseline simulation
- a sector-specific fixed shifter which allows for relative differentials across sectors (for example, manufacturing productivity two percentage points higher than productivity in the services sectors)

- a component linked to sectoral openness as measured by the export-to-output ratio

  The openness component takes the following functional form:

$$\gamma_i^e = \chi_i^0 \left( \frac{E_i}{X_i} \right)^{\eta} \qquad (1)$$

where $\gamma$e is the growth in sectoral productivity due to the change in openness, $\gamma^0$ is a calibrated parameter, E and X represent respectively sectoral export and output, and η is the elasticity. The parameter ⍰0 has been calibrated so that (on average) openness determines roughly 40% of productivity growth in the baseline simulation, and the elasticity has been set to 1.

In agriculture, productivity is fixed in the baseline, set to 2.5% per annum in most developing countries. However, a share of the fixed productivity is attributed to openness, using equation (1).

In the baseline, GDP growth is given. Agricultural productivity is similarly given, and equation (1) is simply used to calibrate the shift parameter, ⍰0, so that a share of agricultural productivity is determined by sectoral openness. Average productivity in the manufacturing and services sectors is endogenous and is calibrated in the baseline to achieve the given GDP growth target. The economy-wide (excluding agriculture) productivity parameter is endogenous. Equation (1) is used to calibrate the same ⍰0 parameter, under the assumption that some share of sectoral productivity is determined by openness, for example 40%.

In policy simulations, the economy-wide productivity factor, along with other exogenous productivity factors (sector-specific shifters) are held fixed, but the openness-related part of productivity is endogenous and responds to changes in the sectoral export-to-output ratio. In the manufacturing and services sectors, the elasticity is set at 1. In the agricultural sectors it is set to 0.5.

Say sectoral productivity is 2.5%, and that 40% of it can be explained by openness, i.e., 1.0%, with the residual 1.5% explained by other factors. Assume sectoral openness increases by 10%. If the elasticity is 1, this implies that the openness-related productivity component will increase to 1.1% and total sectoral productivity will increase to 2.6% (implying that the total sectoral productivity increases by 4% with respect to the 10% increase in sectoral openness).

## Figure 8A.1: Production Function for Crops

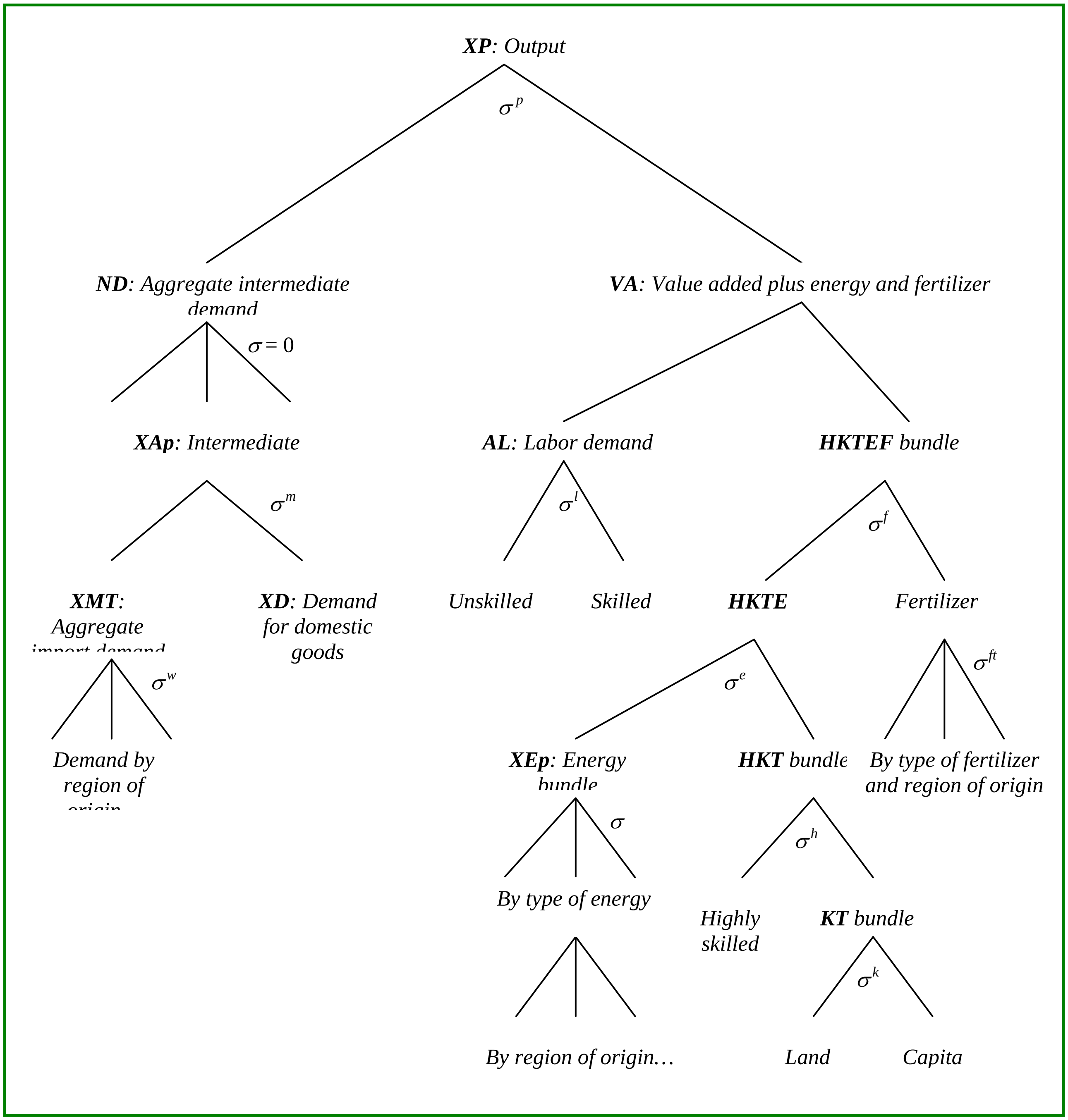

**Figure 8A.2: Production Function for Livestock**

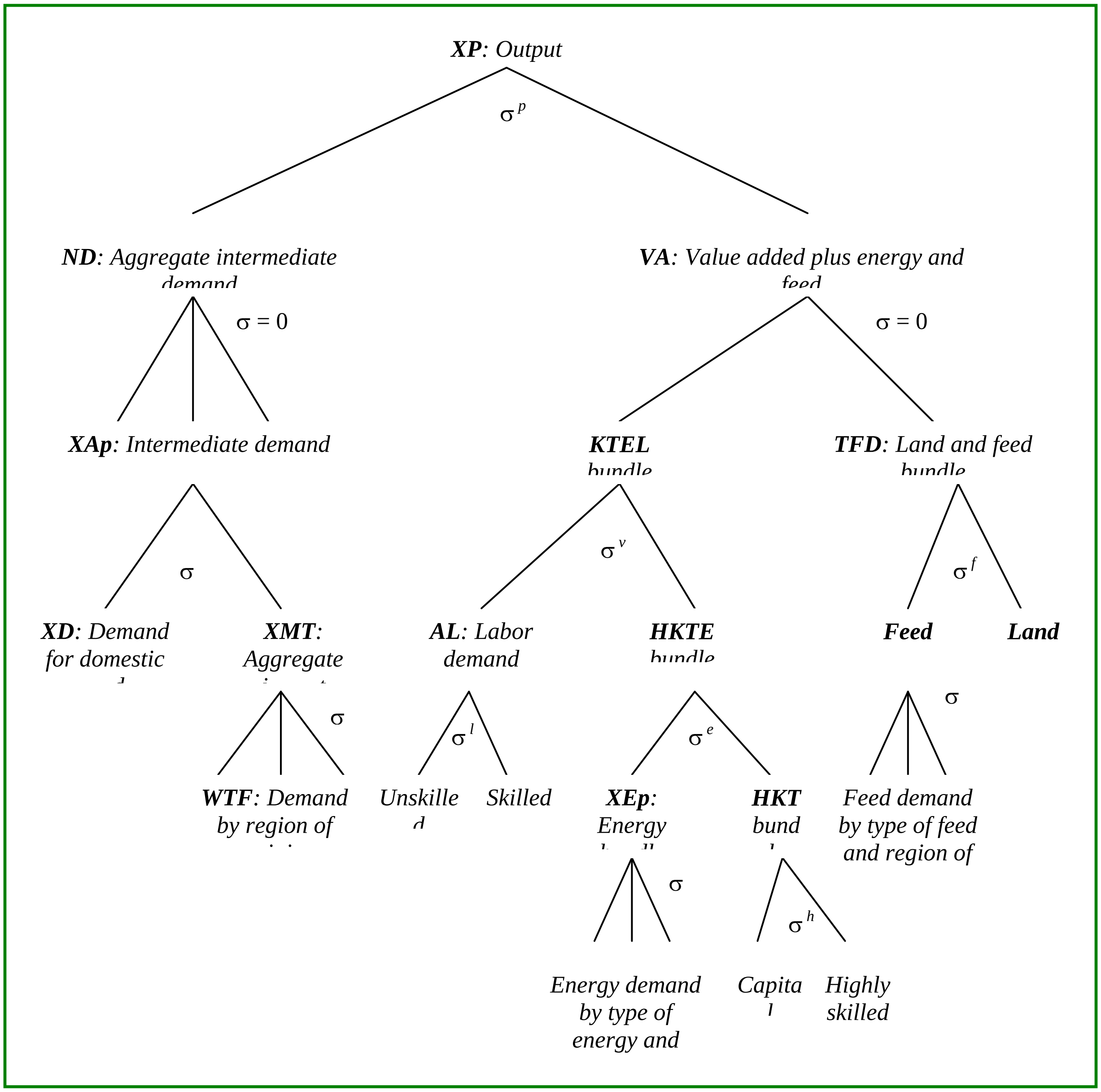

**Figure 8A.3: Production Function for Non-agriculture**

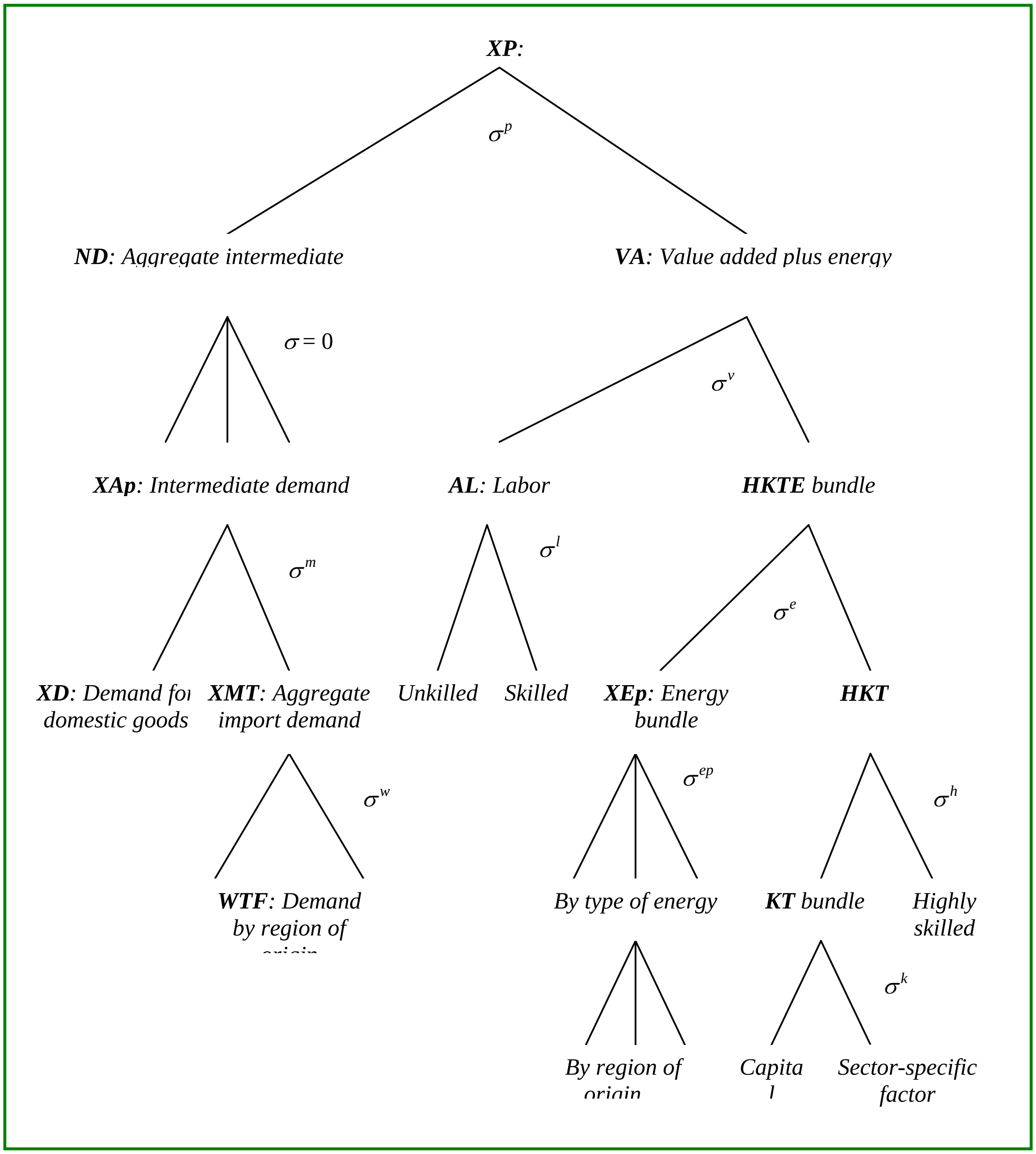

**Figure 8A.4: Trade Aggregation**