Chapter 2
Importance of *Jatropha curcas* for Indian Economy

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Introduction

Energy is a vital commodity as it is commonly recognized that access to energy is closely linked with economic development (DFID 2005). India is targeting gross domestic product (GDP) growth rate of 8–9% in coming years. It is likely to have a significant consumption of energy resources in future for meeting the targeted growth rate and fulfilling the energy needs of its increasing population. It lacks sufficient domestic resources to meet its growing crude oil requirements. In India, it has been projected that there is a need to increase the primary energy supply by at least three to four times from their 2003–04 levels by 2031–32 in order to maintain 8% growth rate. Maximum contribution of renewable energy in an optimistic scenario will be around 5–6% by 2031–32 with an import dependence on crude oil expected to be in the range of 90% in the next decade making energy security a concern (Planning Commission 2006). On account of high targeted economic growth rate and with over 15% of the world's population, India is likely to have a significant consumption of energy resources. India ranks fifth in terms of primary energy consumption and accounts for less than 4% of the global commercial energy demand as it is still in developing phase. With GDP of $4.469 trillion (WEO 2011), India is the third largest economy in purchasing parity terms. However because of its large population, per capita energy consumption is extremely low. On 2011 census basis,

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the per capita energy consumption is estimated to be 451 *kg oil equivalent* (kgoe) whereas for developed countries it is around 5,000 kgoe. Despite a global slowdown in economy, India's energy demand has shown an increasing trend. In terms of end-use, increase in energy demand in the transport sector is expected to be particularly high.

Crude oil is the largest consumed fossil fuel after coal in India. Worldwide known crude oil reserves are estimated to be depleted in less than 50 years at the present rate of consumption (Sheehan et al. 1998). Many countries lacking crude oil resources are facing foreign exchange crisis and high inflation rate mainly due to import of crude oil (Demirbas 2005). For oil deficit countries, renewable energy is to be looked as possible resource for meeting energy demand challenges and for fulfilling the targeted growth.

Dependence on imported crude oil, environmental issues and employment in rural areas are reasons for replacement of fossil fuels by biofuels (Senthilkjumar and Gunasekaran 2005). Biofuels can be viable substitutes in transport sector for petroleum products, which account for one third of India's total imports. Researchers have put forward that the need for wide spread usage of renewable energy to meet the energy demand in India may compete with the use of land and water resources, which could have an adverse impact on food security (Rajagopal et al. 2007). Self-sustainable energy sources are likely to hold the key to economic development of India in future. India cannot depend on certain group of countries to meet its ever growing energy needs, but it is mandatory to seriously implement bioenergy development programs as a part of environmental sustainability in the form of clean development mechanism (CDM) (Kumar et al. 2010).

Brundtland Report introduced environmental protection by defining sustainable development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED 1987). Global initiatives related to mitigating climate change, like Kyoto Protocol and Asia Pacific Partnership on Clean Development and Climate Change to which India is also a party, could give a thrust to biofuel based energy technologies, which are still in the infancy stage in India.

The *clean development mechanism* (CDM), established by the Kyoto Protocol, promotes the industrialized nations to provide resources to developing countries in order to support their sustainable development, while at the same time reducing the global green house gases (GHGs).

High speed diesel (HSD) is the largest consumed petro-product in India on account of better mileage, power and lower price rate compared to petrol (gasoline) (Kumar et al. 2008a). Among various alternatives to diesel, Planning Commission of India has identified *Jatropha curcas* L. (Jatropha), a non-edible oilseed tree whose oil can be easily converted into biodiesel with properties very similar to diesel (Planning Commission 2003). Jatropha is a drought-resistant, perennial plant living up to 50 years and has the capability to grow on marginal soils. It requires little irrigation and grows in all types of soils, thus making Jatropha a more sustainable choice than other vegetable oils (NOVOD 2007, 2008; Altenburg et al. 2009; Reubens et al. 2011). Jatropha biodiesel can be used for decentralized micro-grid electricity generation at village or taluka (suburb) level and as a replacement for diesel fuel in irrigation pump sets, diesel generators and also as an alternative to kerosene. Thus, Jatropha biodiesel has to be seen not in isolation, but as part of a total management system of environmental and energy resources.

Prevailing Energy Scenario in Transport Sector of India

India is emerging as one of the fastest growing economies in the world with a GDP growth ranging between 6 and 8% consistently for the past few years and this trend is expected to continue in the future. Because energy is the key driver of this growth, its easy and cheap availability is of prime importance to sustain the continuous economic growth of the India. The available future projections show that the energy demand is expected to be more than three to four times of the current level in the next 25 years. With this pace of growth, India is expected to face formidable challenges in meeting out its energy needs in a sustainable manner at reasonable cost. Critical analysis of the current energy scenario as well as future plans suggests that India still has a long way to go in ensuring energy security to its people. Some of the following summarized statistics clearly helps in establishing this fact:

- Data from 2012 (April 1st) indicate that India has total reserves (proved and inferred) of 1,201 *million metric tons* (MMT) of crude oil and 1,437 billion cubic meters of natural gas.
- Net petro-products import was 121,897 MMT during the year 2010–11.
- Crude oil production during 2010–11 at 37.68 MMT is almost stagnant.
- The consumption of petroleum products during 2010–11 was 141.78 MMT (including sales through private imports) among which diesel accounted for 59.99 MMT.
- In the year 2010–11, the increase in diesel consumption in absolute terms was nearly three times larger than the increase in petrol consumption.

National Autofuel Policy envisages technologies for producing biofuels from renewable sources by providing *research and development* (R&D) as well as other support. It seeks to ensure sustainable, safe, affordable and uninterrupted supplies of auto fuels of high quality to support social and economic development. One of the key factors for meeting this policy objective is to diversify the sources and reduce dependence on any single source of supply (National Autofuel Policy 2003). This policy, lends support and encouragement for biofuels.

Rationale Behind Usage of Bioenergy

Mass utilization of diesel in India imposes a threat to meeting the future energy needs, if the unexpected volatilities in the price of petroleum persists in future and government of India enforces oil marketing companies to sell diesel at uncapped

Table 2.1 Categorization of waste-land in India (Planning Commission 2003)

Type of land	Area (Mha)
Forest area	3
Boundary plantations	3
Agro forestry	2
Cultivable fallow lands	2.4
Waste lands under integrated watershed development	2
Strip land like: railway, road & canal	1
Total	13.4

Table 2.2 Some key socio-economic indicators of India (TERI India)

	1990s	2020s	2050s
Population projections (million)	846	1354	1888
GDP projections (Rs Crore)	886,933	5,094,093	14,298,068
Demand for food grains (million tons)	176	295	450
Required food grain productivity (tons/ha)	1.7	2.3	3.5
Demand for electricity by urban households (mtoe)	3.9	23.4	69.4

price (Kumar et al. 2008b). Its demand is expected to raise up to 100 MMT with an assumption of 6% per annum growth rate on a very conservative basis by 2020. With an approximate import dependency of 90%, energy security favours the adoption of 20% diesel blending with Jatropha biodiesel (B20). Table 2.1 shows that in India 13.4 Mha of waste land can be used for Jatropha plantations (Planning Commission 2003).

The key macro-indicators of India: population, GDP, energy requirement and food grain demand are shown in Table 2.2. The data clearly shows that with the growth of population, the per capita food intake and energy requirement also increased since the 90s. Additional population increase may result in competition between food and biofuels. Further studies are required to estimate the possible usage of waste land in sustainable harmony with flora, fauna and environment.

Social education is needed for the production and usage of proper biofuel crops according to local constraints. Concerns have been raised that cultivators may willingly opt for alternative crops with higher rate of return on biofuel production in the short term. Farming is an energy intensive activity requiring power for irrigation, ploughing and processing. The *Indian government* (GoI) initiative to promote the plantations of Jatropha saplings under National Rural Employment Guarantee Scheme (NREGS) is a sincere move towards the integration of Jatropha to energy production. In India, researchers have observed that Jatropha biodiesel and its blends with diesel can be used in existing diesel engines without any modifications (Banapurmath et al. 2008; Sahoo and Das 2009; Sahoo et al. 2009; Kumar et al. 2012a). In the longer run, the economic sustainability of Jatropha biodiesel will definitely prove to be the best bet for India as far as the economic viability of biodiesel with respect to diesel is concerned (Kumar et al. 2008c).

Table 2.3 Employment generation potential from Jatropha biodiesel production in Man Days/hectare (Adholeya and Dadhich 2008)

Stage	First year[a]	Second year
Nursery	68	0
Plantation	122	29
Post-harvesting	0	56
Oil extraction	0	15
Transesterification	0	14
Total	190	114

[a]The values in the table are given per hectare

With rapid increase in population in Asia, arable land area is decreasing and it is already only 0.1 hectare per person, on average, in several densely populated countries, which means that it cannot be used for biofuel plantations. Establishing biofuel plantations like Jatropha on degraded soils can be a win-win strategy provided that these soils are adequately restored and specific problems (e.g., nutrient and water imbalance, loss of top soil, shallow rooting depth, drought stress, salinization, compaction, crusting) alleviated.

Considering households, the average energy requirements per capita is 20% less in rural areas compared to urban areas (Pachauri 2004). It is obvious that a significant rise in energy consumption is expected from the improvement of living condition standards and population increase (Parikh and Lior 2009). Rural bioenergy is still the predominant form of energy used by people in less developed countries such as India. Thus, meeting income generation and irrigation management through renewable sources provide a large potential for sustainable development.

In rural areas, particularly in remote locations, the distribution of energy generated from fossil fuels can be difficult and expensive. Renewable energy can facilitate economic and social development in communities if projects of sustainable development are intelligently designed and carefully executed with local inputs and cooperation. In poor areas, the renewable energy projects would absorb a significant part of participants' small incomes. Investigations in this direction have been based on the following concepts namely: renewable energy sources can be replenished in a short period of time and it is clean, i.e., it produces lower or negligible levels of greenhouse gases and other pollutants when compared with the conventional energy sources they replace (Demirbas and Demirbas 2007).

One of the major synergic effects on the economic return of a state investment in biodiesel would be the availability of facilities for power generation in close proximity to the area of biomass production. Such structural investments can result in manifold increase in employment opportunities. As observed from Table 2.3 it is evident that 190 man days of employment in the first year and 114 man days in the second year per hectare for poor people living in rural areas may prove to be a potential source of income generation.

Considering the average man days for first and second year from Table 2.3 for 150 days employability in a year, Jatropha cultivation on 13.4 Mha of wasteland will result in 300 days/year employment for roughly 6.5 million people through social schemes of GoI, such as National Rural Employment Guarantee Schemes

(NREGS) for people of rural areas. Because of the uneven distribution of wealth and the large population size, India is passing through social unrest in many parts of the country leading to large scale violence in many forms. The creation and development of such local opportunities in poor rural areas would also help in relaxing social unrest due to poverty.

CDM is a potential tool for climate change mitigation that allows the compensation of an excess in an industrial country by a mitigation project to be conducted in a developing country. The fees of CDM could be paid back to the stake holders to invest in local power generation powered by Jatropha biodiesel or its blend with fossil diesel. Actually, direct use of Jatropha oil, pure or in blends with fossil diesel, would be preferable to biodiesel since it would save a huge quantity of energy by avoiding the transesterification process that is needed to transform Jatropha's oil into biodiesel. Under the CDM system, industrialized countries are committed to contribute by financing, technology transfer and other supports necessary to the success of target projects. The increased flow of these resources to developing countries is intended in principle to support their sustainable development, while at the same time reducing the global GHGs emissions since it is becoming practically impossible to achieve this commitment in the developed countries (Akorede et al. 2010). Energy production using Jatropha biodiesel could be a viable project that Annex I parties (which have ratified the Kyoto Protocol) could embark upon to assist most developing countries since it is glaringly evident that convulsive electric power supply has always been the bane of development in these countries. However, recent studies have revealed that CDM has not been able to achieve its purpose as mandated by Kyoto Protocol since its inception in 1997 due to certain factors such as delay in ratification and absence of binding targets for developing nations (Olsen 2007). On the other hand, it is widely believed that widespread adoption of localized power generation systems based on eco-friendly fuels can play a key role in creating a clean, reliable energy with substantial benefits including environmental ones.

Shifting to Sustainable Renewable Energy Regime in India

Fossil fuels will continue to play a dominant role in the energy scenario in India in the next few decades. However, conventional or fossil fuel resources are limited, non-renewable, polluting and, therefore, need to be used prudently. On the other hand, renewable energy resources are indigenous, non-polluting and virtually inexhaustible. India is endowed with abundant renewable energy resources. Therefore, their use should be encouraged in every possible way. India's energy security would remain vulnerable until the partial or total replacement of petroleum based fuels by alternative fuels developed from indigenously produced renewable feedstocks. Considering biofuels, the country has a ray of possible alternatives to warrant energy security. Biofuels are environment friendly fuels and their utilization would address global concerns about the control of carbon emissions. The transportation sector has been identified as a major polluting sector. Use of biofuels has, therefore, become

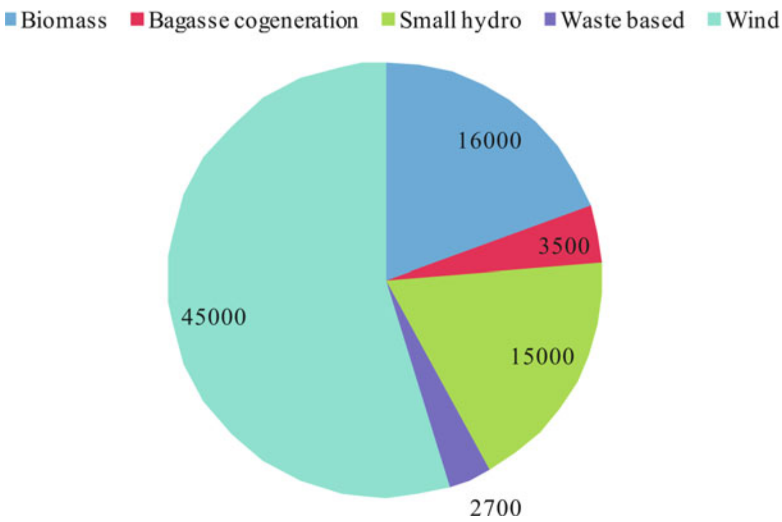

Fig. 2.1 India's technical potential of renewable power in MW (ABPS 2009)

compelling in view of the tightening automotive vehicle emission standards to curb air pollution (National Biofuel Policy 2008).

Figure 2.1 shows the huge potential capacity for renewable energy in India. Biofuels have great potential in remote areas with non-uniform topography where it is not economically sustainable to build power plants or to transport fuels. It is critical to note that India met its 50% of edible oil consumption requirements through imports to warrant a total domestic consumption of around 16.91 MMT in 2010–11 (ADM Investor Services 2011). Even with this large import dependence for edible oil, it hardly reaches an average consumption rate around 14 kg per capita, which is much lower compared to that of developed countries (44–48 kg per capita). Due to heavy dependency on import of edible oil, the production of biodiesel from edible oil as feedstock in India is neither feasible nor affordable. Therefore, it is necessary to explore non-edible oilseeds, such as Jatropha for sustainable biodiesel production as indicated by the policy statement of the Government of India (GoI) (Planning Commission 2003).

India has a total geographical area of 328 Mha out of which around 142 Mha are used for agriculture. By 2030 Indian population is expected to rise up to 1.5 billion from around 1.21 billion presently. To feed this large population it will require around 185 Mha of agricultural land even with very conservative estimates and with the assumption of constant land productivity. The promotion of biofuels at the cost of food products would have catastrophic consequences on the Indian social equity and peace. Thus, the promotion of biodiesel needs to incorporate measures and regulations to ensure the role of the agricultural industry and the first and foremost is to achieve food security for its population. National Biofuel Policy needs to focus on the increased use of waste land to promote environment friendly biofuels.

Economics of Jatropha Biodiesel and Fossil Diesel

Cost vulnerability of petroleum imports is a serious issue for the policy makers as drastic fluctuations in prices of crude oil in international market during last few years has drawn serious attention on the need to decrease the nation's dependency on fossil fuels by using all possible means and resources.

The *oil marketing companies* (OMCs) are currently rating their products from the refineries on import parity basis, i.e., a price charged for a domestically produced good that is set equal to the domestic price of an equivalent imported good. The difference between the cost price and the realized price represents the under-recoveries of OMCs. At prevailing current crude oil price level (Indian basket rules at US $ 122.95 per barrel on the basis of 06.3.2012 quotation) the under recoveries may go up to 140,000 (Exchange rate Rs./$ 50.03) crores (1 crore is ten million) for 2011–12.

Value of crude oil import, is almost 30% of total import value in India. The overall share of transport sector in the total package of petroleum, oil and lubricants (POL) demand is estimated to be 37% (Sethi 2009).

According to statistics, petro-diesel consumption was around 59.99 MMT in 2010–11 and its consumption is continuously growing in India (PPAC 2012). This requires sufficient quantity of Jatropha biodiesel for blending in required proportion at an affordable price to meet the targets of National Biodiesel Mission Phase-II and National Biofuel Policy. GoI has failed in providing the 10% ethanol blended petrol planed under its earlier directive. Important aspect of this failure seems to be non-congruence of opinion between Indian OMCs and ethanol producers related to pricing of ethanol. Availability of sufficient quantity of Jatropha biodiesel for blending with petro-diesel at an affordable price holds the key to successful adoption of bioenergy program in India. One of most important aspect to ensure timely implementation of National Biofuel Policy that should enter in application by 2017 is the economic parity of Jatropha biodiesel with petro-diesel. Table 2.4 below indicates that the expected sale prices of Jatropha biodiesel in India may be around Rs 46–50 per liter. The variation in the cost may depend on the procurement cost of Jatropha seeds.

This indicative price of locally generated biodiesel is about Rs 46.45 per liter without any taxation, is just comparable to *retail selling price* (RSP) of petro-diesel in India (Rs 40.91 per liter at Delhi as on 09-03-2012), though this prices may vary

Table 2.4 Tentative cost of biodiesel production in Indian Rupees (Rs)

Cost component	Rate (Rs/kg)	Quantity (kg)	Cost (Rs)
Seed	16	3.28	52.48
Cost of collection and oil extraction	2.36	1.05	2.478
Less cake produced	1	2.23	–2.23
Transesterification cost	6.67	1	6.67
Less cost of glycerol produced	50	0.095	–4.75
Cost of biodiesel per kg	—	—	54.65
Cost of biodiesel per liter (specific gravity of 0.85 at 15 ^{0}C)	—		46.45

Table 2.5 Central excise and customs Tariff—updated from 2011 June 25 (PPAC 2011)

	Customs			Central excise	
Particulars	Basic customs duty	Additional customs duty (CVD)	Additional customs duty	Basic cenvat duty	Additional excise duty
HSD	2.5%	NIL	Rs 2.00/liter	Nil	Rs 2.00/l
HSD (branded)	—	—	—	Rs 3.75/l	Rs 2.00/l

Table 2.6 Sales tax rate on diesel in Indian states w.e.f. 2011 Dec 01 (PPAC 2011)

State	Rate (%)
Chhattisgarh	25.00
Gujarat	24.63
Madhya Pradesh	24.23
Maharashtra	24.00
Kerala	22.83
Andhra Pradesh	22.25
Tamil Nadu	21.43
Uttaranchal	19.24
West Bengal	18.97
Goa	18.00
Delhi	12.24

from state to state and from producer to producer. Capped and subsidized pricing leads to under recoveries for OMCs. Present petro-diesel costing results in about Rs 10.94 under recovery for OMCs at US $ 120.99 per barrel crude oil pricing for Indian basket (Fortnight, 2012 Feb 16–29). The tax component includes Rs 7.59 comprising customs duty as Rs 1.07 per liter, (specific excise duty as Rs 2.06 per liter and value added tax (VAT) as Rs 4.46 per liter (PPAC 2012). At same rate of taxation, biodiesel costs around Rs 54 per liter. Hence, if under-recovery is also added in present petro-diesel pricing, actual selling price of petro-diesel comes about Rs 52–53 per liter, which is well comparable with computed price of biodiesel.

As clearly evident in Table 2.5, the GoI has levied basic customs duty at the rate of 2.5% at cost and freight price plus import charges along with additional customs duty of Rs 2.00/liter. Excise duty at the rate of Rs. 2.00/l is also applicable in overall price buildup of diesel. Table 2.6 shows state sales tax (VAT) charged by certain states in India. Data clearly reveals that overall taxes/duties are in order of 40–45% of the total selling price.

Petrol is being sold at market-based pricing and diesel is still being sold at capped pricing, this issue may itself be a serious hindrance in production of Jatropha biodiesel and its economics in India. Considering the fact that Indian economy is heavily dependent on crude oil import bill, the National Policy on Biofuels was formulated by GoI to achieve 20% blending of biofuel in both petrol and petro-diesel by 2017. The policy has suggested removal of all the central taxes levied on biodiesel and accorded 'declared goods' status, which will ensure a uniform 4% VAT on the products across the country. Moreover, the policy envisages having certification following the norms of *Bureau of Industrial Standards* (BIS) for blending of biofuel in both petrol and diesel.

Economics of Blended Diesel with Jatropha Biodiesel

Even after the declaration of Biodiesel Purchase policy by the government (MoPNG 2005), there is a lot of confusion among farmers, industrial companies, NGOs, etc. concerning a possible higher economic returns from Jatropha plantations.

OMCs have the largest network for selling of liquid fuels and they would be the natural choice for providing the marketing support for biodiesel. The BIS specifications, BIS 15607:2005 for pure biodiesel (B100) is already available considering all the important properties of biodiesel.

R&D efforts carried out in the transportation sector have already established that 20% biodiesel blended with petro-diesel requires no modification in engine specifications when used as fuel.

Fig. 2.2 reveals that government of India is receiving huge amount of revenue from petroleum sector in the form of royalty, oil development cess, custom and excise duties and sales tax. Moreover the taxes on petrol are more than that on diesel at present. Taxation policy of GoI is itself biased towards diesel. Thus, the GoI may feel that loss in revenue may be one of the reasons to delay introduction of biodiesel blended diesel in Indian market. One of most important aspect is that introduction of biodiesel will indeed help to reduce the import bill burden. It is sure that government is going to lose around 20% of revenue on account of selling the diesel blended with 20% Jatropha biodiesel when Jatropha biodiesel pricing is pegged with petro-diesel selling price under zero duty regime. GoI in its Biofuel policy unveiled in September 2008 has decided to set 2017 as deadline to sell B20 blend in the country. But the presented data itself tells the reasons for the delay in the announcement of that policy.

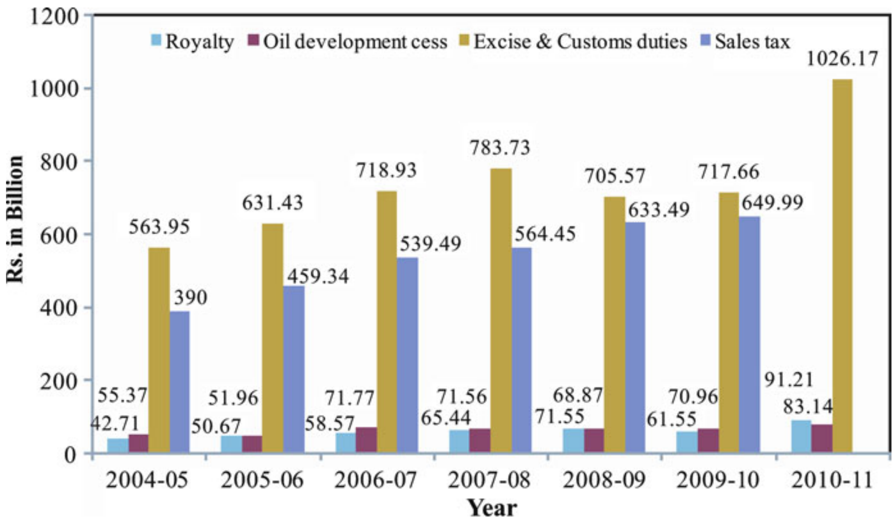

Fig. 2.2 Contribution of oil sector to centre/state government resources (MoPNG 2011)

Impact of Petroleum on Indian Economy

Petroleum is the largest consumer of foreign exchange reserves in India as all the payment for the yearly petroleum bill is made in US dollars. Table 2.7 presents substantial yearly increase in import of crude oil.

The fact that crude oil prices rose to US $ 147 per barrel in July 2008 and that crude oil is currently being traded in the range of US $ 95–115 per barrel (Fig. 2.3), shows the volatile nature of the crude oil pricing in the international market. Moreover the import of crude oil is made by payment in US dollars. In July 2008 it was priced at approximately Rs. 40 but now it is priced at around Rs 52–53. On account of these factors OMCs in India are reporting huge under-recoveries. Impact on inflation is also visible due to rise in price of Indian crude basket. It is clearly evident that economic health of a developing country like India is severely influenced by price of crude oil and its products.

Cost volatility of petroleum imports is a serious issue for the policy makers as drastic fluctuations in prices of crude petroleum oil in international market during the last 2 years has drawn serious attention on meeting nation's energy needs by using all possible sources.

Table. 2.7 Import bill for crude oil in India in crores (PPAC 2011)

Year	2003–04	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11
Crude oil	83,528	117,003	171,702	219,029	272,699	348,304	375,277	455,276

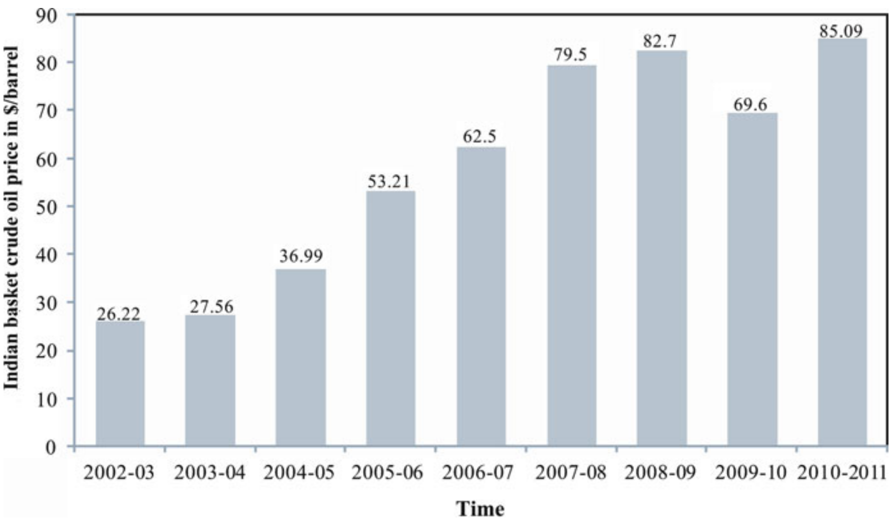

Fig. 2.3 Average Indian basket crude oil price in US $/barrel (PPAC 2011)

Table 2.8 Sector-wise consumption of diesel in India (Sethi 2009)

Sector	Consumption (%)
Agriculture	13.8
Power generation (Gen sets)	9.7
Passenger vehicles	18.9
Commercial vehicles	50.4
Industry	7.2

Table 2.9 Biodiesel emissions compared to petro-diesel (Planning Commission 2003)

Emissions	B100 (%)	B20 (%)
Total unburned hydrocarbons	–93	–30
Carbon monoxide	–50	–20
Particulate matter	–30	–22
NOx	13	2
Carbon dioxide	–80	—

Diesel consumption stands at almost forty percent of total petroleum products consumed and its sector wise consumption is shown in the Table 2.8 below. Diesel consumption in India as per the available statistics stands at 59.99 MMT in 2010–11(PPAC 2012).

At the rate of 8% increase, the diesel consumption may reach a figure of 95.6 MMT by the year 2016–17. Available data states total number of vehicles on road will be around 372.7 millions by 2035, which will require 371 million ton of oil equivalent (mtoe) of fuel to power India (ADB 2006).

Impact of Biodiesel on CDM

GHGs like CO_2 are reduced when using biodiesel or diesel blended with biodiesel as shown in Table 2.9. The CDM could be used to support investment in Jatropha-based fuel production. The CDM is a provision of the UN Climate Change Convention that allows industrialized nations to offset their emissions of GHG by investing in non-polluting projects in developing countries. Through this strategy, one can earn carbon credits that are in turn saleable in the form of CERs. Tradable CERs can be an important parameter for price fixation of biodiesel.

Before pushing Jatropha biodiesel as a reliable source of energy through incentives or policy changes, a detailed analysis of the impact of CDM towards the usage of this particular biofuel needs to be worked out.

Afforestation refers to the planting of trees on areas that were not covered with forests. Reforestation refers to the re-planting of trees on areas that were once covered with forests. Article 3.3 of the Kyoto Protocol and Marrakech Accords in the United Nations Framework Convention on Climate Change (UNFCCC) include

Table 2.10 CO_2 sequestration by Jatropha plantations

Year	First	Second	Third	Fourth	Fifth
Growth of tree (%)	20	40	60	80	100
25 kg CO_2 sequestration/plant at maturity level	5	10	15	20	25
Total CO_2 sequestered in kg for 1,600 plants/hectare	8,000	16,000	24,000	32,000	40,000
Total CO_2 sequestered in ton for 1,600 plants/hectare	8	16	24	32	40
Amount accrued from CER[a] in US$ at $10.47/CER	83.76	167.52	251.28	335.04	418.8

[a]price of CER on NCDEX Mumbai, India on 15th Dec 2011

afforestation and reforestation as possible measures to reduce carbon dioxide level in the atmosphere. Afforestation and reforestation (AR) are defined by the UNFCCC as direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources. Afforestation and reforestation differ only in that the activity will be afforestation if the land on which it takes place had not been forested for at least 50 years, whereas reforestation refers to land that did not contain forest before 1990 for reforestation project activities. The first phase of CDM till the year 2012 is open to reforestation and afforestation projects in developing countries like India. The main features of a possible CDM project state that it should sequester up to 8,000 tons of carbon annually and low-income communities should implement the project.

Jatropha plantations projects are entitled for trade of CER for CO_2 sequestration. Assuming a density of 1,600 plants per hectare, Jatropha will produce, 5 years after plantation, about 200 kg of biomass, including roots with a dry matter content of about 25 % , i.e., a biomass of 80 tons dry matter per hectare. About half of that weight is CO_2, i.e., 40 tons (Jatropha plant has a very light wood with a density ranging from 0.33 to 0.37) (Hooda and Rawat 2006). The trade of certified emission certificates pays around US $10.47 (spot traded price of Rs 562 per CER on NCDEX India as on Dec 15th, 2011, at exchange rate of Rs. 53.68 per US $) per ton of CO_2 sequestration at current market price, which is about US $ 679.2 per hectare as shown in Table 2.10 below.

Considering 13.4 million hectares of waste land, one may calculate that US $ 5.61 billion (13.4 million * 418.8) may be earned by virtue of CERs in the context of CDM due to Jatropha plantations and biodiesel production, which is bound to improve the economic viability of Jatropha biodiesel in India.

On one hand, the combustion details of petro-diesel ($C_{16}H_{34}$), assuming a net calorific value of 43.38 GJ/t, are modeled by equation (2.1) (Peterson and Hustrulid 1998):

$$C_{16}H_{34} + 24.5O_2 + 92.12N_2 \rightarrow 16\ CO_2 + 17H_2O\ + 92.12N_2 \tag{2.1}$$

On the other hand, the combustion of biodiesel ($C_{18}H_{34}O_2$) can be represented by the equation (2.2) (Rajesh et al. 2008):

$$C_{18}H_{34}O_2 + 25.5O_2 + 3.76N_2 \rightarrow 18\ CO_2 + 17H_2O\ + 95.88N_2 \tag{2.2}$$

As shown above in (2.1), 3.11 kg of CO_2 is produced for each kg of diesel fuel used, whereas as per (2.2), 2.81 kg of CO_2 is produced for each kg of biodiesel fuel used. Hence, the same amount of CO_2 would be produced for an equivalent energy content of biodiesel as shown in (2.2). Available data indicates that Jatropha biodiesel has a calorific value of 38,000 kJ/kg while diesel has 43,380 kJ/kg. This means that 14.15% more Jatropha biodiesel (mass basis) is necessary to produce the same energy as diesel, whereas the theoretical carbon balance shows that 11.07% more Jatropha biodiesel would produce the same amount of CO_2. The difference is mainly due to the oxygen content associated with biodiesel. Thus, the combustion of biodiesel and petro-diesel emits about the same amount of CO_2 for similar energy output. Reported *life cycle assessment* (LCA) analysis of Jatropha biodiesel shows that CO_2 emissions are reduced by 80–85% as compared to petro-diesel due to its renewable nature.

Net energy ratio (NER) defined as ratio of energy output to energy input can be taken as an indicator of energy efficiency of any fuel. For petro-diesel, reported value of NER is 0.8328 (Sheehan et al. 1998). Whereas for Jatropha biodiesel under rainfed conditions and without allocating primary process energy to co-products (like: glycerine and seed cake) the reported NER is 1.2 (Kumar et al. 2012b). NER may be improved further either with higher seed yield or by reducing process energy requirement for conversion of Jatropha oil into biodiesel. Transesterification process requires 20% of total process energy. Use of Jatropha oil in existing diesel engines requires preheating due to its very high viscosity.

Conclusions

The greatest impediment to overall development in India is the positive rate of urbanization and population growth. It is necessary to define the fraction of farmland, waste land or barren land that could be used for the production of biodiesel in a sustainable manner without conflicting with food security and environmental issues. Biofuel development can provide supplementary incomes for rural people including the eradication of gender disparity. Proper credit mechanism needs to be developed to help small farmers to cultivate and sell crop profitably.

Renewable energy generation in rural areas may be a viable option of climate change mitigation in India under CDM. Governmental policies may need to be adjusted for subsidizing renewable power for the poor rural areas, the so called *rural poor* (http://www.fao.org/worldfoodsummit/english/fsheets/ifad.pdf).

Development of localized biodiesel supply chain may help in providing valuable energy to fulfill the daily needs of rural people. Worldwide extensive research is going on to develop diesel engine that can run efficiently on biodiesel or even pure oil. Design and development of efficient chulhas (cook-stove) for cooking using Jatropha biodiesel may be a turning point in improving the living standards of the rural poor. Thus, after analyzing all the aspects it can be concluded that, production and utilization of Jatropha biodiesel as prospective fuel needs top most priority in India to achieve sustainable energy regime.

It is desired that world agriculture needs to keep up with continuous growth of world population and, moreover, to develop further in order to reduce the number of undernourished people and to promote health and welfare. However, in the use of these advancements the precautionary principle is imperative in order that food safety, as well as environment protection and biodiversity should be ensured. Otherwise, unwise application of technological tools may further deteriorate human health and environmental quality and compromise future development of human societies.

It is worth mentioning that the undernourishment and the food security problems in the world are critical; thus, their relation to the production of biofuels must be studied. Countries with a better climatic and land potential for the development of biofuels have significant possibilities of developing their agricultural regions, which can improve the population's life condition substantially, by rising their income.

The role of governments to elaborate regulatory marks regarding the use and distribution of land is of utmost importance, given that one of the possible disadvantages of biofuel programs may be the concentration of land ownership. Such resource concentration may generate more poverty, monoculture, forest destruction and ultimately aggravate the environmental impacts. The environment destruction itself may worsen the socio-economic network and generate additional poverty entering a vicious circle.

The major constraint in adopting the Jatropha biodiesel is to provide required marginal lands for its production, developing a supply chain and ensuring its price competitiveness with petro-diesel. Another major area of concern is to restrict the expansion of biodiesel production to land normally dedicated to food crops in order to avoid unnecessary food security threats in India. Thus a major challenge is to devise a public policy to promote the cultivation of Jatropha only on marginal and waste lands, but with incentive to facilitate its integration to the socio-economic system. These incentives may count with the creation of seed collection centers, warranty on oil prices and price parity with any other possible alternative energy source so that its production can be made on a competitive and sustainable basis. Present Jatropha biodiesel economics show that:

(a) The local price of biodiesel, around Rs 46.45 per liter without any taxation, is just comparable to that of petroleum diesel in India (Rs 40.91 per liter at Delhi). Present petro-diesel cost is around Rs 10.94 under recovery for oil marketing companies at 120.99 $ per barrel of crude oil for Indian basket.
(b) Present petro-diesel pricing at Delhi includes Rs 7.59 of taxes. At a same rate of taxation, biodiesel costs around Rs 54 per liter. Hence, if under-recovery is also added in present petro-diesel pricing, actual selling price of petro-diesel comes at about Rs 53 per liter, which is well comparable with biodiesel.
(c) For 13.4 Mha of waste land US $ 5.61 billion (13.4 million * 418.8) may be earned by virtue of CERs in the context of CDM due to Jatropha plantations and biodiesel production. CDM is bound to improve the economic viability of Jatropha biodiesel in India.

(d) 13.4 Mha Jatropha cultivation may result in 300 days/year employment for roughly 6.5 million people.
(e) LCA analysis of Jatropha biodiesel shows that CO_2 emissions are reduced by 80–85% as compared to petro-diesel due to its renewable nature.

Considering the importance of energy as the backbone for economic development of a nation like India, it is of paramount importance to look for a sustainable alternative to petro-diesel. Current volatilities in crude price have already worsened the overall economic situation of major OMCs. The need of the hour is to study and implement the biodiesel program, which is already successfully operational in countries like Germany. Economics are strongly in favour of Jatropha biodiesel to be a sustainable alternative to diesel.

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