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Jatropha biodiesel: Key to attainment of sustainable rural bioenergy regime in India

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ABSTRACT

Agriculture provides employment to mass rural population in India. Indian agriculture has typical land holding pattern with dependence on local credit bodies for finances. Indian Government is paying huge amount of subsidy to provide kerosene at cheaper rates to rural poor people thus incurring huge fiscal deficit. Diesel, the largest consumed petro-product in India is also largely used in rural areas for agricultural purposes as well as meeting other energy needs. Cheaply available kerosene is being mixed with diesel and used in place of pure diesel. This is not only causing misuse of subsidized kerosene, damage to plant and machinery using it but also committing unlawful activities. Biofuels generated and used in rural areas may provide employment, energy; lesser dependency on diesel, climate improvement, food security, improvement in living standards and thus stopping migration of people towards urban areas. In India, Jatropha biodiesel may be a potential energy source even for public distribution system but it can result in food vs fuel conflict also. This study shows that meeting rural energy needs with Jatropha biodiesel will ensure overall sustainable development in India.

Keywords: Rural, Biofuel, Jatropha, Sustainable, Urban.

INTRODUCTION

Energy is a vital commodity as it is commonly recognized that access to energy is closely linked with economic development [1,2]. India is targeting economic 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 energy resources to meet its growing energy requirements. In India, it has been projected that there is need to increase the primary energy supply by at least 3-4 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 is expected to be in the range of 90% in next decade making energy security a concern [3].

Crude oil is the largest consumed fossil fuel after coal in India. Known crude oil reserves are estimated to be depleted in less than 50 years at the present rate of consumption [4]. Many countries lacking crude oil resources are facing foreign exchange crisis and high inflation rate mainly due to import of crude oil [5]. It has been advocated to have large scale usage of renewable energy to meet the energy challenges in India [6]. India's energy supply system has failed to meet the growing needs of rural populations and at the same time contributing significantly to the environmental degradation.

It is believed that dependence on imported crude oil, environmental issues and employment in rural areas are reasons for replacement of fossil fuels by biofuels [7]. Biofuels can be viable substitutes in transport for petroleum products, which account for sizable fraction of India's imports. Researchers have put forward the need for wide spread usage of renewable energy to meet the energy demand in India with the concern on competing use of land and water resources by biofuels, which could have an adverse impact on food security [8].

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" [9]. 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.

Self-sustainable energy sources are likely to hold the key to economic development of India in future. India should not look towards a certain group of countries to meet its ever growing 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) [10]. The 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 GHG emissions since it is becoming practically impossible to reduce emissions in their own countries.

The much required green energy revolution would provide India an opportunity to change its standing from a fuel-importing nation to one that generates clean and affordable energy. Among various alternatives to diesel, Planning Commission of India has identified Jatropha, a non-edible oil bearing tree capable of producing oil that is easily convertible in to biodiesel with properties almost similar to diesel [11]. *Jatropha curcas* plant is a drought-resistant, perennial plant living up to 50 years and has the capability to grow on marginal soils. It requires very little irrigation and grows in all types of soils, thus making Jatropha a more sustainable choice than other vegetable oils [12-15]. Jatropha biodiesel can be used for decentralized micro-grid electricity generation at the village/taluka 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 environment/energy management system. This study attempts to show that for India, addressing the rural energy needs will ensure its sustainable development for transition in to a developed economy.

2. Energy scenario of rural India

In India, 70% of people live in rural areas and rural energy is most vital for sustaining their livelihood. 21% of the villages and about 50% of rural households are still not electrified. There is also wide disparity in the per capita energy consumption between rural and urban areas like: 75% of rural households depend on firewood for cooking, 10% on dung-cake and about 5% on

LPG as against 22% of urban households depend on firewood for cooking, another 22% on kerosene and about 44% on LPG. Similarly for home lighting, while 50% of rural households depend on kerosene and another 48% on electricity, 89% of urban households depend on electricity and another 10% on kerosene. Women spend up to four hours of their productive time per day in fetching fuel wood and cooking. Energy occupies the centre stage in almost all the daily activities – cooking, access to clean water, agriculture, education, transportation, employment generation and environmental sustainability. About 80% of the rural energy used is derived from biomass. This puts heavy pressure on the already declining vegetation in villages. Use of inefficient chulhas often increases the drudgery of women and children who are involved in collection of fuel wood. Increased energy conservation, improved energy efficiency and enhanced energy production from renewable sources may definitely help India to become self sustaining in terms of energy availability [16].

3. Rationale behind usage of bioenergy in rural sector

Average per capita household energy requirements are 20% less in rural areas as compared to urban areas [17]. It is obvious that significant increase in energy requirements is expected to meet the improved standard of living of increasing population of India [18]. Rural electrification may drastically improve living conditions in rural areas and help in stopping the migration of people to already overcrowded cities. Even though over 85% of villages are connected to the electricity grid, less than a-third of rural households are electrified and the rest use kerosene for lighting. Rural bioenergy is still the predominant form of energy used by people in the less developed countries like India. Thus, meeting cooking, income generating and irrigation energy requirements through renewable sources provide a large potential for sustainable development.

In rural areas, particularly in remote locations, transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Renewable energy can facilitate economic and social development in communities if the projects are intelligently designed and carefully planned with local inputs and cooperation. In poor rural areas, the costs of renewable energy projects will 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 [19].

4. Important issues concerning rural Indian population

Rural Indian population is grappling with serious issues like: food security, nature of land holdings and rural credit system. These issues are having a critical impact on overall development process of the nation hence they needs to be addressed on top most priority.

4.1 Food security issues

In building up of a prosperous society, food security and poverty eradication are the two major objectives. Successful control of hunger and under nourishment requires the control on population growth in over-populated country such as India. Poverty in rural areas and the lack of funding for agricultural development are the most important causes of nourishment insecurity, terrorism, naxalite problem, corruption and environmental degradation. Considering the expected population growth of India, which by the year 2030 will reach about 1.5 billion inhabitants, the problems regarding hunger and nourishment insecurity may continue or may even increase dramatically, unless some urgent measures are taken. The Food and Agriculture Organization (FAO) of the United Nations reported in 2008-09 that 854 million people were undernourished in the world. Almost one-fifth of India's population is labeled undernourished making it the nation with the greatest number of underfed, most of whom live in rural areas.

The agenda of governments and international organizations, therefore, should include renewed efforts to control demographic growth, support sustainable agriculture programmes in impoverished regions, educate agriculturalists in the use of agrochemicals, prevent soil erosion and degradation of water resources and protect genetic diversity. The success of these efforts has to be achieved at regional level, especially in the most impoverished regions [20].

4.2 Land holdings

In India the average farm size in Bihar and Orissa is about 0.70 hectare, whereas it is 1.25 hectare in Punjab and 1.41 hectare in Haryana. Furthermore, there is an inverse relationship between the poverty rate and the size of land holdings [21]. The overall average holding is less than 2.0 hectare, often fragmented by legal and family disputes. The main crops grown on these farms are rice, bajra, jowar, and maize followed by ragi and small millets. Alternative crops include groundnut, sugarcane, and pulses [22]. To improve agricultural productivity and farm income, following issues must be taken up on priority basis such as- irrigation technology, primary education, social equity, market access, available land and the use of efficient and modern farming practices. In India most of the rural poor own small pieces of land that prevent them from transitioning to high-value agriculture crops using modern technologies.

4.3. Indian rural credit system

Strengthening agriculture is critical for facing the challenges of rural poverty, food insecurity, unemployment and sustainability of natural resources. Agricultural development strategy must address not only farmers but also people involved in trade, processing and agri-business. In this context, efficient marketing and rural credit systems assume added importance. It is assumed that due to poor handling at the farm gate or village level, about 7% of grains, 30% of fruits and vegetables and 10% of seed species are lost before reaching the market. The rural credit system assumes importance because most Indian rural families have inadequate savings to finance farming and other economic activities. This results in forcing the farmers to sell their produce on prevailing prices or sometimes even lower than the market prices in order to realize the much-needed cash to repay the money borrowed from local money-lenders at very high rate of interest. Looking at the scenario there is a need to focus on small/marginal farmers for meeting their credit requirements through institutional financing, marginalizing the role of money-lenders. Banks should take the help of micro-financers and local formal institutions in their credit extending system with a low lending rate with efficient use of prevailing credit pattern.

5. Urbanization and population growth

In 2008, the world reached an astonishing milestone: for the first time in history, more than half of its human population was living in urban areas. By 2030, this is expected to swell to almost 5 billion. Rapid urbanization and population growth are important factor linked to the agricultural productivity and food security. By 2030, 590 million people will live in cities nearly twice the population of US in 2010. 68 cities will have population of more than one million up from 42 presently and in Europe it is 35. 700-900 m^2 of commercial and residential space required to be built equivalent to one Chicago every year [23]. India will be transformed from a nation that lives in villages to one that lives in over-crowded metropolitans.

6. Food vs biofuels

India has total geographical area of 328 million hectares out of which around 142 million hectares is used for agriculture. By 2030 Indian population is expected to rise to 1.5 billion from around 1.1 billion presently. To feed this much number even with very conservative estimates will require around 185 Million hectares of agricultural land with an assumption that the land productivity remains same. Promotion of biofuels at the cost of rise of food products may have catastrophic results on the Indian social equity and peace. FAO of the United Nations, during the 1996 World Food Summit, stated that ''food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'', stressing the needful action by government to achieve food security [24]. The likely Indian Policy for biodiesel needs to incorporate measures and regulations to ensure that the role of the agricultural industry is to, first and foremost, achieve food security for its population. National biofuel policy should focus on the increased use of waste land to promote environment friendly biofuels.

High speed diesel (HSD) is the largest consumed petro-product in India on account of better mileage, power and lower administered price compared to petrol [25]. 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 price [26]. Its demand is expected to raise up to 100 million tonnes with an assumption of 6% per annum growth rate on very conservative basis by 2020. With an approximate import dependency of 90%, energy security favours the adoption of 20% blending by Jatropha biodiesel. Production of 31.4 million tonnes of Jatropha biodiesel i.e. is 20% of total diesel requirement will require about 26 million hectares of land by 2020. In India 13.4 million hectares of waste land can be used for Jatropha plantations [11]. The key macro-indicators of India like- population, GDP, energy requirement and food grain demand are shown in Table 1. The data clearly shows that with the growth in population, per capita food intake and energy requirement has also increased. Increased population may result in food vs fuel conflict. Further studies are required to estimate the possible usage of waste land to a sustainable level of harmony with the flora, fauna and environment.

Table 1: India's key indicators: population, GDP, energy, food-grain demand [27]

Year	Population (Million)	GDP (billion Rs) 1999-2000 prices	Energy (MToE)	Food grain demand (million n)	Income/Person (Rs)	Energy/ Person (KgoE)	Food grain demand/Person (Kg)
1980	689	6261	208	101	9088	302	147
2000	1021	18704	438	168	18318	429	165
2010	1162	33516	595	233.87	28744	510	200.58

Social awareness is needed on production and usage of biofuels as an alternative to petroleum based fuels. Apprehensions have been expressed that the cultivators may willingly opt for such crops, which may be used for producing biofuels and may be more remunerative in shorter terms. Farming process itself is an energy intensive activity requiring power for irrigation, ploughing and processing of farming produce. Initiative of Indian Government to promote the plantations of Jatropha saplings under National Rural Employment Guarantee Scheme (NREGS) is a sincere move. In India, researchers have observed that Jatropha biodiesel and its blends with diesel can be used in existing diesel engines without any modifications [28-31]. In the longer run economic sustainability of Jatropha biodiesel will definitely prove to be the best bet for India as far as economic viability of biodiesel w. r. t. diesel is concerned [32].

7. Rural employment generation

One of the major economic benefits that would accrue to a state from the increased use of biodiesel is the presence of a facility that creates energy from locally generated input that adds value to the state's industrial and income base. On employability parameters, it can result in manifold increase in employment opportunities. As observed from Table 2 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 of man days for first and second year from Table 2 for 150 days employability in a year, 13.4 million hectare Jatropha cultivation will result in employment for roughly 6.5 million people. Thus Jatropha cultivation can be integrated with social schemes of Government of India such as National Rural Employment Guarantee Scheme (NREGS) for rural poor. The uneven distribution of wealth and with a large population base, India is passing through social unrest in many parts of the country leading to large scale of violence in many forms. Creation of such locally developed employment opportunities for rural poor will also help in diluting social unrest generated due to poverty.

Table 2: Employment generation from Jatropha biodiesel production in Man Days/hectare [33]

	Per hectare	
Stage	First year	Second year
Nursery	68	Nil
Plantation	122	29
Post-harvesting	Nil	56
Oil extraction	Nil	15
Trans-esterification	Nil	14
Total	190	114

8. Energy and Environment

The environmental implications of current energy usage such as GHG emissions, deforestation, land degradation, water and air pollution are of serious concern for policy makers. CO_2 is the most important GHG contributing to climate change. In 2005, the CO_2 emissions from non-electrified households in rural India were very low, equaling about 25 million tons CO_2, which is about 350 kg per household, compared to 1148 million tons total CO_2 emissions for the whole Indian economy [34]. CO_2 emissions were primarily from the use of kerosene for lighting, while the use of traditional biomass and renewable energy is considered as CO_2-neutral. CDM is a potential tool for climate change mitigation, resulting from increased usage of energy. The advantages accrued from CDM can be paid back to the stake holders to make localized power generation through Jatropha biodiesel more economical. It is expected that industrialized countries would contribute finances, technology transfer, and other necessary support for these 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 GHG emissions since it is becoming practically impossible to achieve this in the developed countries [35]. Energy production using Jatropha biodiesel could be a viable project that Annex I parties could embark upon to assist most developing countries since it is glaringly evident that epileptic electric power supply has always being 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 birth in 1997 due to certain factors [36]. On the other hand, it is widely believed that widespread adoption of localized power generation systems can play a key role in creating a clean, reliable energy with substantial environmental and other benefits.

9. Why focusing on sustainable development?

Global prosperity requires bridging the gap between developed and developing nations. To achieve this goal, economic growth rate of 5 to 10 per cent per annum is needed for developing nations. To maintain such growth rate, over exploitation of environment and resources cannot be over ruled. It is required to adopt a sincere and practical approach while utilizing the resources available on the earth for the forthcoming generations.

9.1 Sustainability issues for Rural Development

The distribution of population, income and energy consumption between urban areas of developed countries and rural areas of developing countries is uneven. The urban population of developed countries comprises 14% of the world's population, but uses 58% of the commercial energy. In contrast, rural areas of developing countries have 47% of the world's population with only 10% of the world's commercial energy consumption. Extremely rapid economic growth has been accompanied by environmental destruction, depletion of resources that are otherwise renewable, and loss of habitats of endemic species. Rapid urbanization and unequal development in rural areas encourage immigration, add stress to existing physical and social infrastructures, and compound the environmental problems [37].

9.2 Shifting to sustainable renewable energy regime in India

The Electricity Act, 2003 emphasizes that state electricity regularity commission should specify a percentage of total consumption of electricity in the area of distribution licensee for purchase of electricity from renewable sources. The Government of India is promoting the electrification of remote villages through renewable energy sources and trying to generate at least 10% of the additional installed capacity from renewable energy by the year 2012. Rural electrification policy mainly aims at: quality and reliable power supply at reasonable rates and minimum lifeline consumption of 1 unit per household per day by year 2012 [38].

Figure 1 shows the technical installable capacity of renewable energy in India, data clearly indicates that there is huge potential for renewable energy. Biofuels have great potential in remote areas with a non-uniform topography where it is uneconomical to build power plants or to transport fuels. In Brazil, sugarcane production for biofuels has created numerous unskilled jobs in rural areas. Furthermore, most of the production of biofuels has been handed to small farmers who produce around 30 percent of all the sugarcane designated for biofuels. With such widespread availability of jobs, people are not forced to migrate to urban areas in search of jobs.

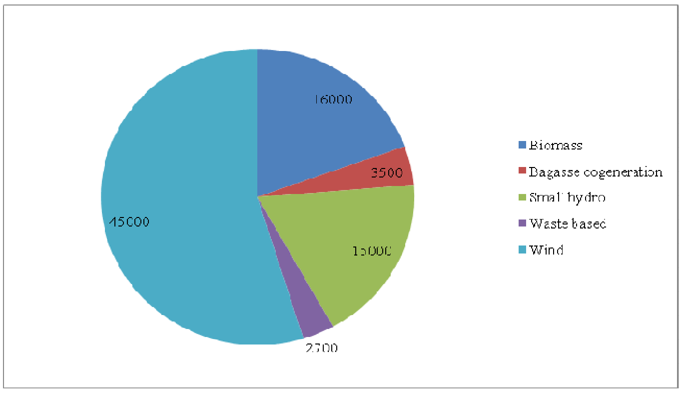

Figure 1: India's Technical Potential of Renewable Power in MW [39]

Brazilian rural energy development model may be adopted in India with required modifications. The income from rural bioenergy development could help in removing a primary impetus for rural exodus and rapid rate of urbanization in India could be decelerated to a certain extent.

9.3 Economics of Jatropha biodiesel and 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 two and a half years has drawn serious attention on meeting a nation's energy needs by using all possible sources. Figure 2 shows the total under recoveries of oil marketing companies (OMCs) at different levels of crude prices on projected demand from 2009-10 to 2030-31 in India.

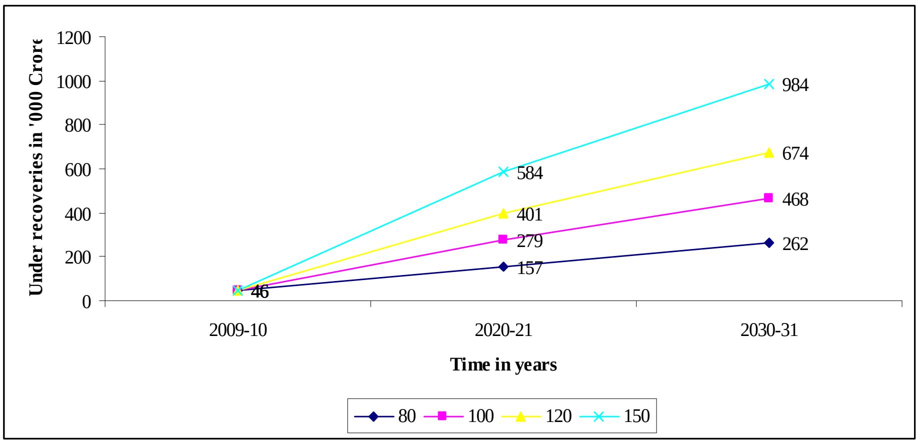

Figure 2: Total under recoveries of oil marketing companies at different levels of crude pricing in US $ per barrel from 2009-10 to 2030-31 [40]

The OMCs are currently sourcing their products from the refineries on import parity basis which then becomes their cost price. The difference between the cost price and the realized price represents the under-recoveries of the OMCs. It is evident that even at current crude oil price level with growing energy needs the under recoveries may go up to 2, 62,000 crores making OMCs either sick or burden on national exchequer. Value of crude oil import, is almost thirty percent of total value of import in India. Overall share of transport sector in total petroleum, oil and lubricants (POL) demand is estimated to be 37% [41].

Table 3: Tentative cost of biodiesel production in Indian Rupee

Cost component	Rate (Rs/kg)	Quantity (kg)	Cost (Rs)
Seed	10	3.28	32.8
Cost of collection and oil extraction	2.36	1.05	2.48
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			34.97
Declared goods tax@4%			1.39
Total cost per kg			36.37
Cost of biodiesel per liter (specific gravity of 0.85)			30.91

Diesel consumption as per the available statistics (Indian ministry of petroleum and natural gas 2010) was around 56.32 million metric tons (MMT) in 2009-10 and its consumption is continuously growing in India. This requires sufficient quantity of Jatropha biodiesel for blending in required proportion at an affordable price to meet the targets of phase-II of national biodiesel mission and national biofuel policy. Indian government has failed in providing 10% ethanol blended petrol as per its earlier directive. Important aspect of 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 that too at an affordable price holds the key to successful adoption of bioenergy program in India. One of most important aspect to ensure timely implantation of National Biofuel policy to be implemented by 2017 is the economic parity of Jatropha biodiesel with petro-diesel. Table 3 below indicates that likely sales cost of Jatropha biodiesel in India may be around Rs 30-32 per liter. The variation in the cost may depend upon the procurement cost of Jatropha seeds.

As per Table 4, capped price of HSD is still around Rs 41 per liter. In future with the adoption of market based pricing mechanism for retail sales price of HSD in India, economics of diesel with respect to Jatropha biodiesel needs serious consideration.

Table 4: Retail price of HSD in Bhopal (INDIA) for 1 liter as on 01.07.2010

Heads	Unit	Rate	Total
Ex depot price	Rs/KL	32904.90	32904.90
Reduction	Rs/KL	91.19	-91.19
Entry tax	%	1%	329.05
RPO factor	Rs/KL	21.27	21.27
Local transport	Rs/KL	44	44
Other levies	Rs/KL	1	1
VAT payable	%	23%	7568.13
License fee recovery	Rs/KL	15	15
Net retail price	Rs/L		40.79

Retail sales price of diesel at Bhopal M. P., INDIA, comprises of various taxes like: value addition (VAT), levies and entry. VAT comprises of 23% of retails sales price of diesel, i.e. almost one fourth, a major source of revenue for state of Madhya Pradesh, India. Similarly Indian government too has levied taxes and duties on petroleum products to earn very high revenue. Table

5 below indicate that current retail selling price of diesel and kerosene in India are capped and subsidised. With the current pricing of crude oil as 90-95 $ per barrel in international market actual selling price of diesel and kerosene are lower than their likely actual prices. Capped and subsidized pricing leads to under recoveries for oil marketing companies (OMC). Taxation on petroleum products is also non-uniform. 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. It has been reported that the under-recovery on kerosene has grown from Rs. 3,751 crore in 2003-04 to Rs.28,225 crore in 2008-09 [40]. Lower price of kerosene w.r.t. diesel in India and its neighboring countries leads to lot of diversions and smuggling of kerosene hence there is need to raise its price to discourage its misuse in rural areas due to very low pricing.

Table 5: Crude price in $ per barrel Vs Indicative diesel and petrol price in Rs in Delhi [40]

Crude pricing in $ per barrel	Indicative Diesel price in Rs	Indicative Kerosene price in Rs
60	32.23	23.82
70	36.08	27.29
80	39.92	30.76
90	43.76	34.23
100	47.61	37.7
110	51.45	41.18
120	55.29	44.65
130	59.13	48.12
140	62.98	51.59
150	66.82	55.06

Corruption in public distribution system (PDS) kerosene and residential LPG has led to diversion of fuel, fuel shortages for the poor and hindered reform through the creation of powerful stakeholders with an interest in maintaining access to black market-subsidized fuel. Energy-sector subsidies, even when they are not part of the formal budgeting process—as in the case of gasoline, diesel, natural gas and electricity in India—have resulted in government having less revenue to finance welfare measures affecting the poor.

CONCLUSIONS

In India the greatest impediment to overall development is positive rate of urbanization and population growth. Problems like transmission losses and power thefts can be minimized by involvement of local people themselves as a part of localized energy generation and transmission system.

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 the food security and environmental issues. Development of biofuel can provide supplementary income source for rural people including woman which will help in eradicating social evil like 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 rural poor.

Lacunas in PDS related to kerosene and LPG has also made the subsidized fuel costlier for rural people. 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 which can run efficiently on biodiesel also [42]. Design and development of efficient chulhas for cooking using Jatropha biodiesel may be a turning point in improving the living standards of poor rural people. 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.

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