BIODIESEL AS A POTENTIAL ALTERNATIVE ENERGY SOURCE IN HOUSEHOLDS STOVES OF DEVELOPING COUNTRIES

Teshome Dengiso Megiso, Arba Minch University, Institute of Technology, Department of Mechanical Engineering, ArbaMich, Ethiopia

Abstract: *There is an increasing interest to search for suitable renewable fuels that are eco-friendly in every country. In many parts of the developing countries like Ethiopia, wood-based fuels will remain leading sources of energy. Dependence on biomass resulted in a high pressure on forests for supply of domestic energy. To satisfy the basic need of increasing population like housing and land for agriculture, let the forests to be cleared and deforested. In this background, the role of liquid biofuels as substitutes for firewood and charcoal, to help reducing pressure on woody biomass and contributing to a better energy security of rural communities. One of the emerging energy alternatives being explored is biodiesel, which has been produced from varieties of plant and animal resources which is reliable and sustainable energy source. Similarly, in Ethiopia, lots of consideration were given by the government to support foreign and local investors to produce biodiesel in a large scale from jatropha curcas. This work assesses the potential of biodiesel extracted from Jatropha curcas can replace domestic energy supply for cooking and lighting. Field survey, interviews and structured questionnaires are applied to get responses from households about energy consumption customs, cook and lighting devices, costs of fuel and burden in entire family especially women and children to source firewood. This paper concludes that jatropha curcas hedges have a significant potential for the substitution of kerosene or paraffin for lighting. The data analysed using inferential statistics and recommendations are formulated.*

Keywords: *Renewable fuels, jatropha curcas, Biodiesel,* energy consumption customs, *eco-friendly, Ethiopia*

1. INTRODUCTION

1.1. Bioenergy

The World Energy Council defines bioenergy to include traditional biomass (example forestry and agricultural residues), modern biomass and biofuels. It represents the transformation of organic matter into a source of energy, whether it is collected from natural surroundings or specifically grown for the purpose. In developed countries, bioenergy is promoted as an alternative or more sustainable source for hydrocarbons, especially for transportation fuels, like bioethanol and biodiesel, the use of wood in combined heat and power generation and residential heating. In developing countries bioenergy may represent opportunities for domestic industrial development and economic growth. In least developed countries traditional biomass is often the dominant domestic fuel, especially in more rural areas without access to electricity or other energy sources.[1] There are multiple challenges and opportunities for bioenergy as a potential driver of sustainable development, given enough economic and technological support. Lower energy prices do not favour short- to medium-term development of first-generation biofuels and investment in research and development (R&D) for advanced biofuels produced from lignocellulosic biomass, waste or non-food feedstock is also set to decline. Decreases in crude oil and biofuel feedstock prices should lead to a decline in ethanol and biodiesel prices. Global ethanol and biodiesel production are both expected to expand to reach respectively, almost 134.5 and 39 billion litres by 2024. Subsequently, both ethanol and biodiesel prices are expected to recover in nominal terms close to their 2014 levels. [1]

1.2. Energy Sector in Ethiopia

In March 1994, the Transitional Government of Ethiopia (TGE) released its energy policy, the first of its kind. As of 2012, this is still in force as the policy of the government of Ethiopia. It aims to address household energy problems by promoting agroforestry, increasing the efficiency with which biomass fuels are utilized, and facilitating the shift to greater use of modern fuels. The policy paper states that the country will rely mainly on hydropower to increase its electricity supply, but also take advantage of Ethiopia's geothermal, solar, wind and other renewable energy resources where appropriate. In addition, it aims to further explore and develop oil and gas reserves. It also refers to the need to encourage energy conservation in industry, transport and other major energy-consuming sectors, to ensure that energy development is environmentally sustainable and, to provide appropriate incentives to the private sector.In February 2013, the Ministry of Water and Energy published the second draft of its national Energy Policy. The policy paper aims to enhance bio energy supply and increase bio energy use efficiency. A major objective is to integrate environmental sustainability into energy production and supply. [2] Specific bio energy objectives include:

- Sustainable forest management
- Enhance diverse and efficient bio-energy production
- Ensure bio-energy security
- Promote availability of end-use devices

Under the National Growth and Transformation Plan (GTP) the National Clean Cook Stove Programme Ethiopia (NCCSPE) addresses the energy demands of rural households, while recognising the reality that wood is likely to continue to be the main source of energy for many. However, rural households that use open wood fires to cook household meals *suffer health problems associated with indoor air pollution*. As part of the NCCSPE programme, World Vision has been promoting fuel-efficient stoves, known as *Tikikil*, in Ethiopia. This stove produces little or no smoke and consumes less fuel wood. World Vision's pilot project in the Oromia region of Ethiopia disseminated 2,500 *Tikikil* stoves, and expanded to other regions such as Amhara, using an inclusive approach.

1.3. Biomass Energy strategy Ethiopia

As in most sub-Saharan countries, a marked feature of Ethiopia's energy sector is the high dependence on biomass (firewood, charcoal, crop residues and animal dung). The bulk of the national energy consumption is met from biomass sources. It is estimated that biomass energy accounted for 89 percent of total national energy consumption in 2010. Nearly 60 million tons of biomass is consumed for energy purposes with about 81% of the estimated 16 million households using firewood and 11.5% of them cooking with leaves and dung cakes. The very high degree of dependence on wood and agricultural residues for household energy has impacts on the social, economic and environmental well-being of society. Growing demand for biomass together with increased demand for agricultural output (land for crop production, livestock feed) has resulted in reduced access to wood fuels. [2] Total national consumption of wood (including charcoal equivalent of wood) is estimated to be 105.2million tons per year with 5.7 million tons of charcoal (table 1). Total consumption of residues and dung are 19.7 million tons per year and 22.8 million tons per year respectively. Oromia, SNNP and Amhara regional shares of wood (including charcoal equivalent of wood) consumption are 37percent, 25 percent and 23 percent respectively. [3]

Table 1 National Consumption of Biomass Fuels Ethiopia (2013)

REGION	Round wood tons/yr	BLT tons/yr	Charcoal as wood tons/yr	Total wood tons/yr
Addis Ababa	684,228	-	1,060,439	1,744,667
Afar	830,552	-	1,195,154	2,025,706,
Amhara	9,549,847	88,042,277	6,603,169	24,287,123
BSG	419,308	271,709	202,893	893,911
Dire Dawa	219,831	54,698	359,246	633,774
Gambela	181,653	74,736	96,236	364,659
Harari	136,728	38,463	225,685	400,876
Oromia	17,812,299	11,070,636	9,921,703	38,804,638
SNNPR	15,264,304	7,185,536	3,564,630	26,014,470
Somali	2,520,644	211,155	3,203,569	5,935,369
Tigray	614,995	1,284,533	2,167,743	4,067,271
TOTAL	**48,234,389**	**28,233,742**	**28,600,468**	**105,172,465**

Source: *Biomass Energy Strategy Ethiopia* Published *23rd December 2013*

**BLT: Branches, Leaves, and Twigs*

1.4. Biofuels Development & Utilization Strategy of Ethiopia

A Biofuels Development and Utilization Strategy has been formulated by the Ministry of Mines and Energy of Ethiopia in August 2007. The overall objective of the strategy is to facilitate adequate production of biofuels from indigenous resources to substitute imported petroleum and export excess products. The strategy is formulated based on principles that development of biofuels should not have unintended consequences on food security, land access, the environment, cultural values and the economy. It has also outlined that biofuels development should participate farmers and pastoralists so that they can be beneficiaries of the development. The biofuels strategy document identified some energy crops such as sugarcane, jatropha, castor and palm trees as potential feedstock for biofuels production.

Molasses, the by-product from sugar production, is the preferred feedstock for ethanol production while jatropha, castor and oil palm are crop types suggested for production of biodiesel. [4]

Table 2 Gross potential areas for Jatropha and castor oil plantation in Ethiopia (in hectares)

	Region	Area m^2
1	BSG	3,128,251
2	Gambelia	2,829,999
3	Somali	1,485,000
4	Oromia	17,234,523
5	Amhara	966,535
6	SNNPR	49,025
7	Tigray	6,500
8	Afar	N. A

Source: Ministry of Mines and Energy, 2007

It has been a couple of years now since the first company started growing energy crops for biodiesel production in Ethiopia. Several local and international private and non-private biofuel developers have registered in the country since then. Most of these companies have the intention of going for large-scale commercial development. Currently there are over 50 developers registered for the cultivation of energy crops for biodiesel production of which 14 of them have started operations. [5]

1.5. Jatropha as a Sustainability energy source

Jatropha has been promoted globally as a plant that may be used to make biodiesel and carries the added advantage of helping to rehabilitate degraded lands [4][5]. Using simple technology, high quality oil may be extracted from Jatropha seeds and used as biodiesel. [6] In the Bati region of Ethiopia, the dual use of Jatropha to provide energy and to rehabilitate land has been practiced to some extent for at least 40 years. Today, however, cultivation of Jatropha plants is being promoted at a never-before-seen scale. Traditionally, farmers in Ethiopia mainly used Jatropha plants as living fences and as a structural means of conserving soil and water. With respect to green economy goals, the Ethiopian government has begun promoting cultivation of Jatropha to make biodiesel for transportation [7]. At the same time, several private Jatropha production projects, launched as early as 2005 and engaged in production of biodiesel from Jatropha plants [8].

1.6. Potential of biofuel in Ethiopia

Concerning the energy sector, the GTP sets as its target during the plan period of an additional 8,000 MW energy generated from renewable energy resources. This plan aims to address both the domestic demand and the export of power to neighbouring countries and beyond. The need to expand the transmission and distribution system is also emphasized to deliver the energy generation to the consumer in an efficient and reliable manner. The plan further envisages increasing the customer base of the power utility from the current level of 2 million to 4 million and the general access rate from 41% to 75%.1 Regarding bio-fuel usage and production the plan targets to increase the bio-ethanol production and usage to 194.9 million litters and *biodiesel usage to 1.6 billion litters*. It further aims increasing the dissemination of alternative energy technologies to reduce effectively the deforestation rate and alleviate the burden of the widely dispersed rural settlers. [9]

Ethiopia has portrayed itself as one of the countries with the highest potential for biofuels in Africa, and the government has proposed about 23.2 million hectares (Table 2) of marginal land be converted for biofuel feedstock production, mainly jatropha. One hectare yields around seven tonnes(7ton) of seeds per year (in case of jatropha plantation) The oil pressed from four kilograms of seeds is needed to make one litre of biodiesel. The potential of 23.2 million-hectare times seven ton divided by four kilograms is equals $4.06x10^{10}$ Lit/Year. The yield increases as the age of the jatropha curcas increases [5]

1.7. Plant oil Cookers/stoves

There are a wide variety of plant oils that have potential for cooking, including coconut, jatropha, soya bean, corn, peanut, cotton, sunflower and many more. The *Protos stove (figure 1*) was developed in the Philippines by Leyte State University (LSU) in collaboration with Bosch and Siemens Home Appliance Group (BSH), who have supported and funded the work, alongside the German government (Guarte). A key feature of this type of stove is that fuel can be bought in very low quantities – and for people on small incomes, not having to save for a refill means that the tradition of buying enough just for the next day can be continued. Plant oil is safe to use: it does not burn under normal room conditions, and burns cleanly, so is good for health. Those piloting the use of the plant oil stove say that it cooks faster than a traditional kerosene stove and the cost of fuel tends to be lower. Most of the stove parts are manufactured locally, although the high precision components are still made by BSH. The German agency, GTZ, is testing the stove in the longer term in Tanzania. Already there is wide demand for the stove. The plant oil is filled in the tank. The burner is pre-heated with a small amount of alcohol or other available fuel source. Through application of the pump, the tank is pressurized with approximately 2 bars. The oil rises into the vaporizer where the heat of the flame converts the liquid into a gaseous mixture. The gas flux emits from a nozzle into the burning area, where it mixes with surrounding air and burns in a blue flame. The power output can be adjusted with a valve in the fuel line. [9]

Figure 1 The PROTOS plant oil cooker www.bsh-group.com

1.8. Cooking with Plant Oil

Plant oil for cooking can be generated from coconut, soybeans, jatropha, rapeseed, etc., and has an average calorific value of around 33 MJ/l, comparable to the calorific value of kerosene of around 35MJ/l. Plant oil differs from other liquids when used for cooking. They pose a challenge because they have a high viscosity and only ignite at temperatures above 200° Celsius. Depending on the oil type, simple wick-stoves are not suitable and sometimes preheating of the oil with another fuel that burns at lower temperatures is required. Pressurising enhances the performance and power-output, but adds more challenges and increases the cost of the stove. Given that plant oil can be supplied in a sustainable and reliable way at affordable market prices, it may become a suitable option for cooking, especially in regions where households already rely on purchasable fuels. However, the use of plant oil for cooking can have an impact on issues such as land use, food market prices and availability, as well as on agricultural practices. [9] [10]

1.9. Background on Cooking Fuels

Wood and Charcoal

As shown in table 1 charcoal is a renewable resource made from wood that is baked in a kiln. But the baking process requires 1-3 times as much wood to deliver the same amount of energy for cooking. It thereby exacerbates the demand for wood. When burned in inefficient stoves, losses are further multiplied. Even so, it is a preferred cooking fuel in many countries because it is lightweight, easy to transport and store, resists attack by insects, burns in a controlled fashion without much smoke or flame, can be made in uniform sizes to fit conveniently into inexpensive stoves, and often costs much less than fossil fuels. Moreover, it can be made locally and contributes to the national economy.

Utilization of the biodiesel cooking stove can produce numerous ecological, economical, and sociological benefits in developing countries. The biodiesel is a sustainable energy source ensuring sufficient cooking energy for adequate meal preparation. Introduction of the biodiesel cooking stove can be readily acceptable to people in tropical and sub-tropical countries since its operation is similar to the well-known kerosene stoves. In some parts of Ethiopia some German made Biofuel stoves were introduced for heating and cooking purpose. Hence in the present work, an attempt was made to use jatropha oil/Biodiesel as a potential substitute for kerosene in wick stove. [10] [11]

2. MATERIAL AND METHODS

The methodology of this study was developed by the rigorous literature review. In the literature review part, study undertaken by various organizations and individual experts on jatropha, jatropha oil, appropriate technology development, bio fuel appliance and manufacturing process were reviewed. The study regarding technologies for end use of jatropha oil consists of formulations and investigations techniques to find out low technology suitability. The method composed of data collection to develop technology and review the existing process and technology was done through secondary sources, especially on electronic communication and various literatures. But the data to support recommendation of technology is obtained from primary sources i.e. Field surveys, interview and structured questionnaires.

2.1. *Household survey*

Fifty (50) households were interviewed in June-July 2016 about their energy consumption habits and the costs of their fuel procurement in terms of money and labour. A structured questionnaire and field investigation was used for the survey about utilisation of firewood and charcoal. Survey results were analysed in MS Excel using descriptive statistics.

Table 3 Household Energy Resources

Cooking	Most households (41) use traditional open fire stoves, 5 households use improved cook stoves (ICS) and 4 use earthen woodstoves. None has an electric stove, biofuel or a gas stove used
Lighting	All fifty are use kerosene floating wick lamp No biofuel used for lighting

2.2. Cost of firewood and charcoal

Table 4 Household Cost of firewood and charcoal

Usage	**Firewood**	**Charcoal**
Amount	48 household (96%) for cooking 100 to 340 kg per month (Av. 250Kgs)	7 households (14%) use only for cooking 150-100kgs(av.75Kgs)
Costs	50-150 Birr per month (Average 100 Birr)	About 150 Birr/Month Av. 120 Birr/Month
Sourcing	40 (80%) households collect by themselves and 10 (20%) households purchase from local market	Local market Door to door suppliers
Who take care for sourcing	In 30 households (60%) house wife/head, in 12 (24%) children, in 5 entire family (10%) and in 3 households (6%) another person is responsible for collecting firewood	Spouse/ elderly persons
Distance covered	2.5 km -10 kms	
Time spent	1-3.5 hours(Av.2hrs)	

2.3. Kerosene consumption and costs

Table 5 Household kerosene consumption &cost/Birr/month

	Consumption/lit/month			Consumption /lt/ month		
	Min	Max	Average	Min	Max	Average
Kerosene	1.0	3.0	2.4	20.00	60.00	47.40

RESULTS AND FINDINGS

3.1. Types of Stoves Used

The analysed data revels that, the leading cook stove type is traditional open-fire stoves (82%) as shown in figure 3. According to the respondents throughout the region biomass/firewood is the most significant for cooking and kerosene the second most important fuel lighting by using flat wick lams at night. for domestic use. In the considered areas, firewood is almost exclusively used for cooking and kerosene for lighting.

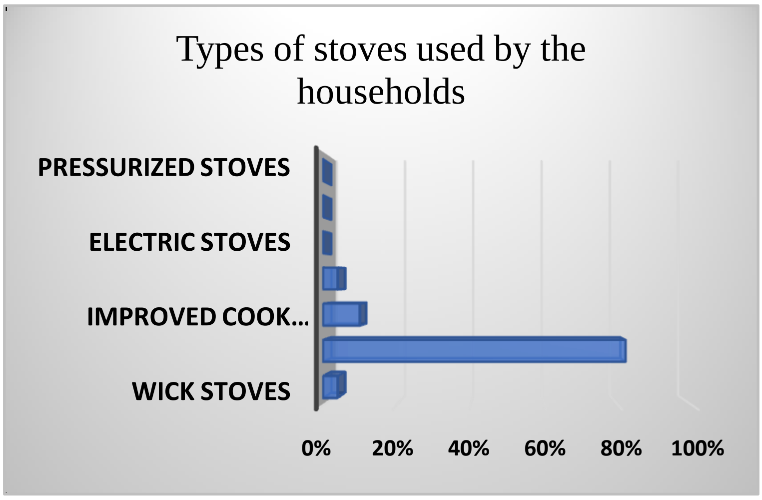

Figure 2 Different types of cook stoves

3.2. Sourcing firewood

According to the fields survey and structured questionnaire response a great burden is on women (60%) and children (20%) (figure 3). This load on the women and children influenced them greatly not to be involved in their education and it consumes their time and energy which makes them ineffective in economic and social welfares.

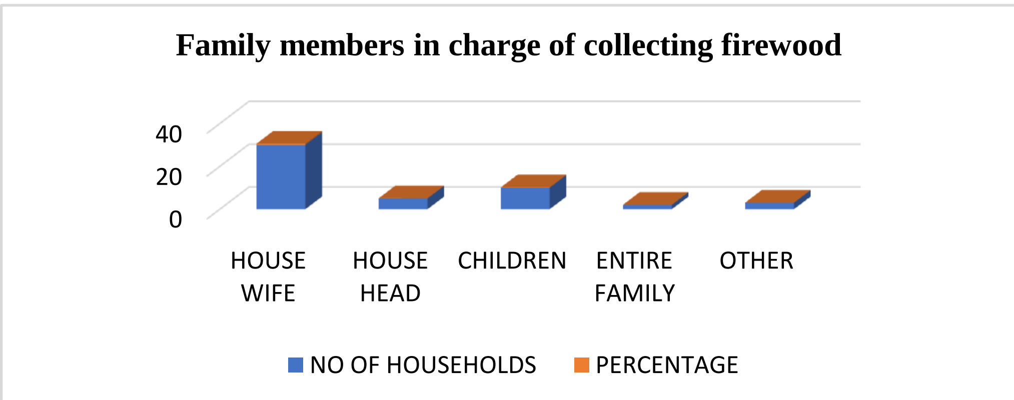

Figure 3 Family members responsible for sourcing firewood

3.3. Energy for Lighting

Figure 4 shows the energy source for lighting specially at night, kerosene wick lamps are still dominating and accounts for 80%. As he kerosene cost is going higher and higher, the rural societies cannot afford this high cost. Again, this influencing the women and the students not to perform homework, assignment and their study at night after school.

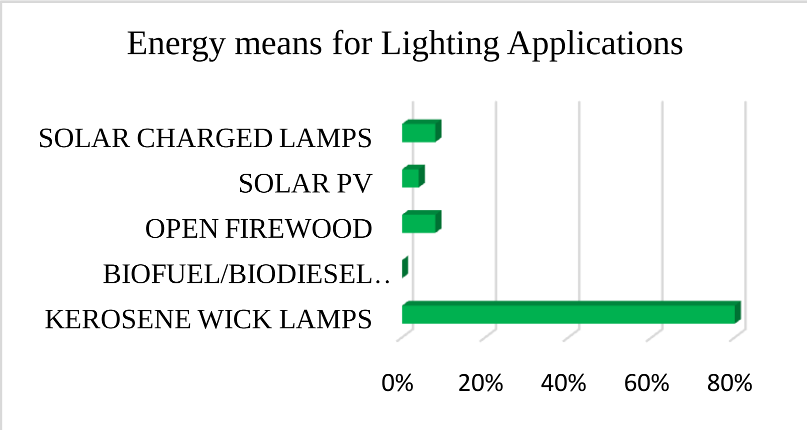

Figure 4 Households energy usage for lighting

3.4. Cost of kerosene

As shown figure 5 the average cost of kerosene for one-month time is 2.37 litters/month for only lighting 1-3 hours at night per day. And its cost average is 47.40 Birr/month. The maximum cost is 3.0liter per month which is 60.00 Birr.

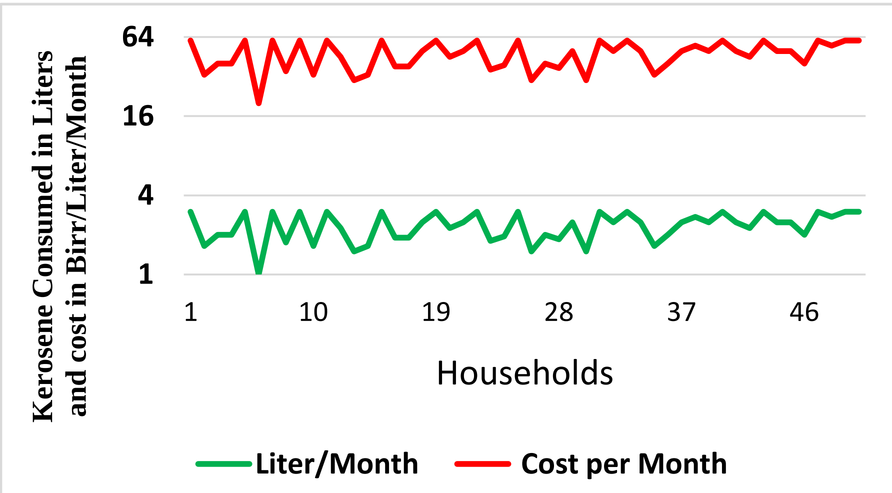

Figure 5 kerosene consumed and its cost(lit/Birr/Month)

3.5. Cost of Biodiesel Economical analysis

Since there is no available date for the cost of production biodiesel from Jatropha in Ethiopia, the Indian and the *D1 Oils – the UK's biggest biodiesel company production costs were taken for the analysis.*The cost of 1kg of jatropha seeds in India is 6 Rupees (equivalent to around £0.07). Jatropha seedlings yield seeds in the first year after plantation. After the first five years, the typical annual yield of a jatropha tree is 3.5kg of beans. Jatropha trees are productive for up to 30-40 years. 2,200 trees can be planted per hectare and one hectare should yield around 7 tonnes of seeds per year. The oil pressed from 4kg of seeds is needed to make 1 litre of biodiesel. About 91%+ of the oil can be extracted with cold pressing and one hectare should yield around 2.2-2.7 tonnes of oil. Press cake (seedcake) is left after the oil is pressed from the seeds. This can be composted and used as a high-grade nitrogen rich organic fertilizer (green manure). The remaining oil can be used to make skin friendly soap. [14]

One job is created for each 4 hectares of jatropha plantation. – The average Indian agricultural worker earns less than $40 per month. Biodiesel costs around 16-20 rupees per litre to grow and refine in India.

Glycerol, a biproduct of biodiesel refinement, can be sold in India for around 45-70p per kilogram. One hectare of jatropha plantation yields 25,000 Rupees / year (around £300) in India.

The following stats come from D1 Oils – the UK's biggest biodiesel company: [15]

Crushing 1 tonne of Jatropha seeds costs around $40 (£23).

1 tonne of seedcake (the leftovers after pressing) can be sold for $100 (£55).

The transport costs of shipping 1 tonne of jatropha from India to Northern Europe is $100 (£55).

The landed cost of 1 tonne of jatropha oil to Northern Europe is between $348 and $500 for oil contents of 29% to 40% (£180 to £260).

Refining jatropha oil into biodiesel costs less than $125 (£65) per tonne. Jatropha oil can be used as a kerosene substitute for heating and lamps and Jatropha oil burns with a clear smokeless flame. [14] [15]

Figure 6 Simple ram press used for oil extraction

CONCLUSION

Food cooking stoves using jatropha oil are not yet reliable and affordable for most rural households in East Africa. According to the analysis, there a huge potential of biofuel production all over the country. By introducing the available technology of cooking stoves, lighting devices and locally production of biodiesel by using locally manufactured simple oil press machine (Figure 6) a household can make their own oil for their energy need. In conclusion jatropha curcas hedges have a significant potential for the substitution of cook stoves (like *Protos stove figure 1* designed and manufactured by siemens, Germany) and completely replace kerosene for lighting. This would help rural households to save much needed cash resources or to invest them into other farm activities, or into health and education.

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