Jatropha facts

Can jatropha improve the energy supply of rural households in Africa?

There is still discussion regarding whether liquid biofuels can contribute to rural energy security in the global South. We argue that transitioning to a village energy supply based on jatropha hedges around smallholder plots is possible, but requires collective effort for the acquisition and maintenance of processing equipment and for the running of village generators. The use of jatropha oil for lighting in rural households is affordable and technically possible, but not ideal if more efficient electric solutions exist. Cooking with jatropha oil or press cake is also possible, but quantities produced in hedges can only substitute a small part of the firewood used by rural households.

Policy message

- While considerable barriers and challenges exist, jatropha can potentially contribute to rural energy supply, particularly in areas without access to electricity
- Initial technical costs of processing and using jatropha are currently too high for most households; further innovation, external support, or co-operative approaches could reduce individual costs.
- Plot-based jatropha production is a high-risk investment for smallholders. Hedge-based production, although more advisable, may be insufficient to substitute traditional and/or fossil fuels

Figure 1: A jatropha oil lamp made from a recycled can in Arusha, Tanzania. A copper tube is added around the wick to conduct heat from the flame to the reservoir. Preheating the oil reduces its viscosity and improves capillary action along the wick. Deposits of soot on the wick necessitate frequent cleaning or cutting. (©Ehrensperger)

Why is energy security a key development issue for rural households?

Access to affordable, clean and sustainable energy is a key aspect of poverty reduction and rural development, as highlighted by the Secretary General's High Level Group on Sustainable Energy for All (2012). Access to energy can increase health by supporting hygienic food preparation, immunisation cold-chains and lower levels of indoor air pollution. Improved lighting can also contribute to education outcomes, and access to energy can support a range of household-level income-generating activities requiring the use of electric machines such as saws, welding machines, etc.

In East Africa, firewood and charcoal are the primary fuels for about 90% of rural and low-income urban households. The number of people that depend on these fuels is projected to increase over the next two decades (GEA 2012), leading to growing pressure on remaining forest resources. Diffuse settlement structures, high investment prices and vulnerability to theft will continue to cripple the development of modern energy services like electric grids and photovoltaic devices. Therefore, a large portion of the population will continue to depend on firewood, charcoal, and fossil fuels.

Are liquid biofuels an alternative to traditional solid biomass energy?

Affordable alternative energy sources are urgently needed in order to reduce pressure on forest resources and dependency on fossil fuel imports. Liquid biofuels were recently identified as a possible alternative energy source and are obtained from oleaginous plants or from starch and sugar-rich plants to produce biodiesel and bio-ethanol, respectively. In East Africa, there were high hopes for jatropha, as it was thought that this oil-producing shrub could be grown in arid areas and on degraded soils. The initial hype, however, has since given way to scepticism. Farmers started abandoning jatropha when expected high returns did not materialize, and worries about food security emerged when it became apparent that good jatropha yields could only be achieved on good farmland. Today, opinions are still strongly divided about the potential for jatropha to improve energy security in rural East Africa. Decision-makers are therefore uncertain about which policies they should adopt.

Featured case studies

Jatropha oil on trial for diesel engines, lighting and cooking

During the jatropha hype (2006-2009), Energy Africa (EA) a limited company based in Kwale, in the Kenyan coastal region, started contracting local smallholder farmers to cultivate jatropha. They bought seeds from these farmers at USD 0.60 per kilogram. EA used an oil expeller with a processing capacity of 70-100 kg of jatropha seeds per hour and an extraction rate of about 25% (1 litre oil for 4 kg seeds). The straight jatropha oil (SJO) was first tested in motorcycle diesel engines, the engine of EA's oil expeller, oil lamps and cooking stoves.

Farmers reported that using SJO for household lighting is less hazardous to health than kerosene, which causes indoor pollution. Additionally, lighting with SJO is very economical due to the lower volatility: one litre would last for a whole month, whereas the same amount of kerosene would only last one week. If the above is correct, households using kerosene for lighting spend around four times more per month (USD 4.10) than those using SJO.

However, there were also challenges using SJO: machines clog more easily than with diesel, and SJO proved to be more expensive than conventional diesel to power stationary or vehicle engines, at the current price of USD 1.25 per litre of fossil diesel (ERC 2013).

Figure 2: Jatropha press cake being poured into an experimental cooking stove in Arusha, Tanzania. The central cylinder is removed after filling the stove, and the fire is lit within the hollow tube. Smoke is given off during combustion because the press cake contains oil residues, especially following pressing with low efficiency ram presses. (©Ehrensperger)

Is jatropha a suitable fuel for rural households?

Jatropha oil can be used, without further processing, in generators, lamps and stoves. Since its performance properties are different from those of fossil fuels, adaptations must be made to diesel engines, lamps and cooking stoves. Jatropha oil can be used in simple floating wick lamps and in lamps that use a copper tube around the wick to conduct heat from the flame to the reservoir (Figure 1). Similarly, to allow for optimal usage of jatropha oil, pre-heating devices have been developed for stationary engines such as generators. Jatropha oil leads to clogging of stove wicks and nozzles, and currently there is no satisfactory or affordable solution. Similarly, jatropha press cake has been tested in simple cooking stoves with unsatisfying results and further work is needed on the development of clean burning stoves (Figure 2).

What types of cultivation are appropriate for smallholders?

Jatropha needs around eight years to reach maturity. The long growing period poses a high risk for smallholder farmers, who depend on immediate returns on investments. Plot-based cultivation of jatropha by smallholder farmers should be discouraged to avoid investment failures and increased food insecurity. Instead, cultivation of jatropha in hedges around existing farmland and pastureland is an interesting option (Figure 4). This type of production does not cause opportunity costs of land and enables farmers to take advantage of two complementary functions of jatropha: fencing for crop protection, or animal corralling, and production of seed harvests for processing into liquid biofuel. However, this also means that the amount of jatropha oil that smallholders can produce is limited by the length of hedges that they can establish around their plots.

How much jatropha oil can smallholders produce from hedges?

According to the African Development Bank (2010), smallholders with farms averaging 2.5 hectares in size produce 75% of the total agricultural output from Ethiopia, Uganda, Kenya and Tanzania. Depending on farm layout (one or several separate or adjacent parcels), these smallholders could establish 500-1000 metres of jatropha hedges to protect their fields or to corral animals. According to published statistics, jatropha yields from 0.2 to 5 kg

Figure 3: A ram press fixed on a wooden beam in Arusha, Tanzania. Seeds are placed in the yellow funnel; the resulting oil flows over an iron plate into a bucket below. Extraction of the oil is slow and tedious, and it requires filtering after extraction. (©Ehrensperger)

of seeds per metre of hedge, but an average yield of 1 kg per metre is realistic. Smallholders in East Africa could therefore generally harvest between 0.5 and 1 ton of jatropha seeds every year from hedges. With simple ram presses (Figure 3), 100 to 200 kg of oil and 400 to 800 kg of press cake can be extracted from this quantity of seeds.

Can smallholders produce enough jatropha oil to substitute other fuels?

Research conducted in Kenya and Tanzania shows that rural households use 50 to 100 litres of kerosene or paraffin per year for lighting (Ehrensperger et al. 2012). Considering the figures in the previous section, smallholders could substitute their entire kerosene or paraffin use with about half of the jatropha oil produced from hedges, while keeping the other half for sale, or for running village-based generators.

Estimates on quantities of firewood consumed annually by rural households in East Africa vary from 1.5 to 6.5 tons (Openshaw 1983). The energy density of jatropha press cake is around 18 MJ / kg (Achten et al. 2010), which is comparable to wood (Smil 2008). Thus, the harvested amount of press cake is insufficient to re-

Figure 4: In Bati, Ethiopia, jatropha is used as a fence around plots and as a soil and water conservation structure to rehabilitate erosion gullies. (©Portner)

place firewood and is therefore not a realistic alternative for cooking. This could change if press cake cooking stoves are developed that have a much higher level of efficiency than traditional firewood cooking places. Smoke generated from burning press cake is another challenge that needs to be addressed and clean burning equipment should be developed.

The economic feasibility of firewood substitution through jatropha press cake is linked to the success of kerosene substitution. The cost of improved press cake cooking stoves could represent an additional hurdle. However, if clean burning cooking stoves can be produced locally, the added value would remain in the region. Alternatively, the press cake could be used as organic fertiliser on crop fields as a substitute for mineral fertiliser.

Definitions

Liquid biofuels: These fuels include: (1) straight vegetable oil (SVO) gained from oleaginous plants such as jatropha or Croton, and which can be further processed into biodiesel through trans-esterification, and (2) bioethanol gained through fermentation and distillation of glucose and other sugars contained in plants such as sugar cane, maize, etc.

Opportunity costs: Value of the best alternative foregone, in a situation in which a choice needs to be made between several mutually exclusive alternatives given limited resources.

Press-cake: Solid part remaining after extraction of the oil from the seeds. With other plants, press-cakes are often used as animal feed. In the case of jatropha, such use is not possible due to toxicity. Alternatively the press-cake can be used as fertilizer.

Ram press: Device or machine used to press items with a mechanical ram such as with a plunger, piston, force pump, or hydrolic ram. In the case of jatropha, an oil seed ram press, or oil ram press, is commonly used.

Smallholders: Farmers owning a smallholding, which is a farm that can support a single family or household with a mixture of cash crops and subsistence farming.

Straight Jatropha Oil (SJO): Virgin vegetable oil, also termed pure plant oil or straight vegetable oil, is extracted from plants solely for use as fuel.

Is a jatropha-based energy affordable for smallholders?

Data collected in 5 case study sites in Kenya and Tanzania indicate that rural households buy kerosene (Figure 5) at about 0.8 USD per litre (Ehrensperger et al. 2012). Hence, by substituting jatropha oil for kerosene, rural households could reduce annual fuel purchasing expenses by 50 to 100 USD. Supposing that a healthy and stable demand arises, they could also increase their income by 25 to 100 USD by selling excess jatropha oil at current prices (GIZ 2009). However this hypothetical calculation does not take into account costs for processing equipment. Simple ram presses cost around 150 USD and replacement of gravity filters costs an estimated 75 USD per year. Substitution of kerosene therefore only makes economic sense if processing equipment is purchased and maintained collectively by as many households as possible.

Firewood

			Litres/week		Costs/litre ($)		Costs/week ($)	
Country	**Site**	**N**	**mean**	**median**	**mean**	**median**	**mean**	**median**
Kenya	Bondo	54/69	6.3	5.0	0.3	0.2	1.7	1.4
	Kibwezi	96/109	5.1	5.0	0.4	0.4	1.7	1.4
	Kwale	83/99	3.8	3.0	0.4	0.4	1.5	1.1
Tanzania	Engaruka	120/120	2.1	2.0	0.8	0.6	1.7	1.3
	Mpanda	137/140	2.9	3.0	1.1	1.3	3.7	2.5

Kerosene

			Litres/week		Costs/litre ($)		Costs/week ($)	
Country	**Site**	**N**	**mean**	**median**	**mean**	**median**	**mean**	**median**
Kenya	Bondo	60/69	1.9	1.0	0.9	0.9	1.7	0.9
	Kibwezi	101/109	2.4	1.0	0.8	0.8	1.8	0.8
	Kwale	83/99	1.4	1.0	0.8	0.7	1.1	0.7
Tanzania	Engaruka	118/120	1.1	1.0	0.9	0.9	1.1	0.9
	Mpanda	136/140	1.0	1.0	0.9	0.9	1.0	0.9

Figure 5: Expenditures for firewood and kerosene in 5 case study sites in Kenya and Tanzania.

Policy implications

Transitioning to jatropha-based rural energy supply requires collective effort or external support, as initial technical costs of processing and using jatropha are too high for most households. Using cropland to sustain this transition should be avoided, and only hedge-based jatropha production should be taken into consideration.

Jatropha oil can be used at household level to substitute kerosene or paraffin for lighting, but lighting with electricity is much more efficient. Thus, jatropha oil lamps should be considered as a second priority, if other options, such as rural electrification through the grid, village-based generators fuelled with jatropha oil, solar lamps, etc., are not feasible.

Households can also use jatropha oil or press-cake for cooking, but further technical improvement of stoves is needed to make them more efficient and user-friendly. A careful estimate of fuel requirements and production potentials should be made before advocating this solution.

Jatropha oil can be used at village level to power stationary engines, supplying households with electricity for lighting and cooking, or supplying small enterprises or communal infrastructure with electricity to power machines. Such a solution can only be achieved through a cooperative approach, which implies the need for strong local commitment to invest in such infrastructure and maintain it.

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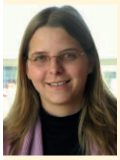

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References

Achten W.M., Nielsen L.R., Aerts R. (2010): Towards domestication of Jatropha curcas: a review. Biofuels, 1 (1), pp. 91-107

African Development Bank (2010): Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities. Working Paper Series; No 105, April 2010 http://econpapers.repec.org/paper/adbadbwps/242.htm

Ehrensperger A., Portner B. and Kiteme B. (2012): Potentials and limitations of jatropha curcas for rural energy supply in East Africa: A case study based comparative assessment in Ethiopia, Kenya and Tanzania. Presented at the Tech4Dev 2012 conference in Lausanne (Switzerland), May 2012. Available at: http://cooperation.epfl.ch/2012Tech4Dev

ERC (2013): Press Release of the Energy Regulatory Commission of Kenya on maximum retail pump prices of petroleum. http://www.erc.go.ke/erc/news_and_publications/?ContentID=7

GEA (2012): Global Energy Assessment: Toward a Sustainable Future: Key Findings, Summary for Policymakers, Technical Summary. Cambridge University Press, Cambridge UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria, 2012.

GIZ (2009): Jatropha Reality Check - A field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya. Sustainable Management of Resources in Agriculture. Institute Study conducted by Endelevu Energy in collaboration with World Agroforestry Centre and Kenya Forestry Research, Kenya; www.worldagroforestry.org/downloads/publications/PDFs/B16599.PDF

Openshaw K. (1983): Measuring fuelwood and charcoal. In: Wood fuel surveys / FAO, Rome (Italy). Forestry Dept., 1983, p. 173-178.

Secretary-General's High-Level Group on Sustainable Energy for All (2012): Sustainable Energy for All: A Global Action Agenda. Pathways for Concerted Action toward Sustainable Energy for All.

Smil V. (2008): Energy in Nature and Society. General Energetics of Complex Systems. Massachusetts Institute of Technology. ISBN 978-0-262-19565-2.

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Josef Rathbauer, Andrea Sonnleitner, Roland Pirot, Rudolf Zeller, Dina Bacovsky, Characterisation of Jatropha curcas seeds and oil from Mali, Biomass and Bioenergy, Volume 47, December 2012, Pages 201-210, ISSN 0961-9534, 10.1016/j.biombioe.2012.09.040. (http://www.sciencedirect.com/science/article/pii/S0961953412003807)

Jatropha Facts *Jatropha Facts* is a series of five policy briefs providing research insights on important issues of jatropha and bioenergy. Each policy brief addresses a specific, policy-relevant aspect: (1) jatropha growth and oilseed production in Africa; (2) the potential of jatropha for climate change mitigation; (3) the potential of jatropha for rural energy supply in Africa; (4) the economic feasibility of biofuels in Africa; and (5) the food security implications of jatropha and other biofuels.

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