THE JATROPHA ENERGY SYSTEM: AN INTEGRATED APPROACH TO DECENTRALIZED AND SUSTAINABLE ENERGY PRODUCTION AT THE VILLAGE LEVEL

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ABSTRACT: Conceptual analysis of a village-based biofuel and energy production system, with the purpose of demonstrating that a Jatropha system represents an impulse for village economies as well as a sustainable energy route for many rural realities in the developing world.
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1 THE ENERGY SITUATION IN RURAL AFRICA

Providing energy to rural communities in the developing world has proved to be a great challenge. Today, still more than half the world's population lives in rural areas, with most sub-Saharan African countries having even larger rural populations. The vast majority of these people is dependent on the traditional fuels (wood, crop residue, dung), often using primitive and inefficient technologies. For many, this combination barely allows fulfilment of the basic human needs of nutrition, warmth and light, let alone the possibility of harnessing energy for productive uses which might begin to permit escape from the cycle of poverty. [1] Demographic trends tend to exacerbate the situation, with high birth rates amongst rural populations increasing competition for rural energy supplies, while social dynamics such as rural-urban migration tend to concentrate policy efforts and government investments in energy projects in the cities.

Besides the absence of an electricity infrastructure, many of those rural communities suffer under high and volatile fuel prices, which adds to the negative spiral of additional costs, lowering their agricultural and overall economic productivity even more. Research indicates that the effect of today's rising oil and fuel prices is much stronger in rural and remote parts of Africa, than in developed countries. And in all probability, this situation will only worsen in the future. [2]

Access to sustainable and affordable energy has a positive impact on a wide range of factors influencing rural communities: from improved health, to changes in the division of labour, to better educational facilities, economic prosperity and increased social mobility. Since, at the village level, it is traditionally the task of women to provide energy (inefficient technologies and appliances mean that precious wood fuel resources are wasted and high indoor smoke pollution severely impairs health of the women doing the household cooking), the introduction of a more rational and sustainable energy system will have positive gender effects as well, by changing traditional social roles and tasks.[3]

In itself, the dependence of rural communities on traditional fuels is not wrong, but the unsystematic and unsustainable way in which these resources are managed can be improved upon.

Previous attempts at remediating this lack of basic energy infrastructures have been mostly unsuccessful. In many parts of Africa, there even exists a political "culture of State-promises" about grid extensions, which keeps people in doubt about their future, and damages the credibility of the State when it comes to servicing rural communities. Decentralized options (like solar, wind or small hydro-electric plants) are often not economically feasible or require a certain degree of technical expertise which is often too difficult to acquire for local people.

The authors analyze a new integrated approach to those problems and propose a system based on the cultivation and exploitation of the oil-bearing Jatropha plant. *Jatropha Curcas L.* is a perennial shrub that grows well in semi-tropical conditions, on poor soils and requires little care. It can easily be integrated into the rural economy at the village level. Under optimal conditions, Jatropha seed yields of up to 8 tons can be achieved, resulting in oil yields of up to 2200 kg per hectare. The crop can be grown as protective hedges around fields, where they protect food crops against predators, or in dedicated plantations. Finally, because of its drought resistance it can play a role in combating desertification and soil erosion. This energy system based on the local cultivation of Jatropha, is both decentralized, durable, relying on local knowledge and sustainable, in the true sense of the word.

2 JATROPHA CURCAS, A PROMISING PLANT

2.1 Short Description of the Plant

Jatropha Curcas is a hardy shrub, traditionally known in many subtropical and semi-arid regions for its medicinal properties. It is widely used in the form of protective hedges around fields, to prevent animals from grazing crops. As Jatropha seeds and green leaves are poisonous, it works as a very effective barrier. Long qualified as an interesting but "underutilized" crop, it is now being increasingly used in reforestation programs in tropical countries because it thrives on poor soils and on land that is suffering under erosion. Jatropha prefers alkaline soils, but it easily grows on a large variety of other soils, including sandy ones. It needs a minimum of 600mm of rain, even though in times of extended drought, it survives by shedding its leaves. Propagation from cuttings offers good results, but for the establishment of plantations geared towards oil production, seedlings from a nursery have higher yields. In unkept hedges, Jatropha yields around 4 tonnes of seed [4], while under optimal conditions, yields of up to 8 tonnes can be achieved.

2.2. Agronomic Information

Although Jatropha is adapted to low fertility sites and alkaline soils, better yields seem to be obtained on poor quality soils if fertilisers containing small amounts of calcium, magnesium, and sulphur are used . Mycorrhizal associations have been observed with Jatropha and are known to aid the plant's growth under conditions where phosphate is limiting.

Application of 1/2 kg of organic fertiliser yields satisfactory results.[5] In the Jatropha Energy System, the processing of the seeds results in such an excellent organic fertilizer, part of which can be returned to the plantations or be used for cash crops.

Jatropha can be intercropped with high value crops such as sugar, coconut palm, oil palm, and various fruits, vegetables (red and green peppers, tomatoes), and export crops such as coffee and cacao. The plant not only protects crops from grazing livestock, but it also has a phytoprotective action against pests and pathogens providing additional protection to intercropped plants.

2.3 Jatropha and its Products

Jatropha seeds contain around 34.5% oil, thus, depending on seed yields, up to 2200kg of oil per hectare can be achieved. Raw oil can be obtained by simple cold pressing of the seeds.

After residual decantation and filtration, pure Jatropha oil makes for a suitable diesel substitute for use in wide range of stationary engines that are commonly used in rural African settings (such as irrigation pumps, mills and generators). The engines require only minor modifications. [6] Jatropha oil also functions as a replacement for kerosene (which can be used in the household as a fuel for oil lamps and cooking stoves.) Processing of the seeds results in a seedcake, which, thanks to its mineral contents of nitrogen (6%), phosphorous (2,75%) and potassium (0.94%), is similar to chicken manure and can be used as excellent organic fertiliser. The application of 1 tonne of this fertilizer is equivalent to around 200kg of mineral fertiliser (NPK 12:24:12).

The residuals, a substance obtained from the sedimentation of the oil during the purification process in the tank, is commonly used for soap production, when mixed and boiled with caustic soda and water.[7]

3 DESCRIPTION OF THE JATROPHA ENERGY SYSTEM (JES)

The JES is based on several sub-systems, each with associated activities which allow for different implementation options, and where each module can be operated independently, offering its own potential economic benefits. When these activities are integrated into one system, more value is added.

The JES offers a *decentralized and localized* energy option. This mere fact empowers rural communities: it reduces their dependence on imported fuels, prices of which are highly volatile, given irregular supplies, bad infrastructure and the remoteness of the communities from urban centres. Given the likelihood of oil prices reaching ever higher levels in the future, a localized biofuels production system becomes increasingly attractive. Moreover, the system diminishes their reliance on State actors and the culture of political promises which are rarely realised.

Unlike other decentralized energy systems, the JES is *sustainable* in the true sense of the word, for it relies on local knowledge and skills. The transfer of knowledge needed to introduce the system is very limited, whereas the introduction of solar, micro-hydro or wind power systems to small communities, requires outside and continuous technical expertise. It moreover offers ecological advantages (retroactively or proactively combating erosion and desertification) and allows local communities to gain full ownership of the technology, in such a way that they can easily make decisions about the expansion and replication of the module, according to their own needs. This "bottom-up" approach has the potential to actively engage communities in producing their own energy (which is less likely with more "static" technologies such as wind power and hydro-electric power.)

Finally, as a CO2 neutral system, the JES offers a *renewable* source of energy, based on simple plantations of the energy crop, which can be fully integrated in the village's existing practises.

3.1 Implementation strategies

The first step in the introduction of a Jatropha Energy System consists of building a reliable source of Jatropha seeds. Producing Jatropha seedlings at the village level could become a highly profitable activity in itself: seedlings can be sold to plantation owners, or they may be used as natural hedges to protect other crops. Several micro-entrepreneurial activities surrounding the cultivation and trade of these mere seedlings have proved to be successful. Jatropha also makes for a suitable base-crop for intercropping systems.

Even though Jatropha is well known in many tropical countries, at the first stage of the introduction of a JES, a constant and reliable source of seeds must be assured, creating the need for a dedicated Jatropha-plantation. Jatropha seeds from hedges could be collected by households once the JES is well established, after which they could be exchanged in a kind of simple "seeds for light" program. [8]

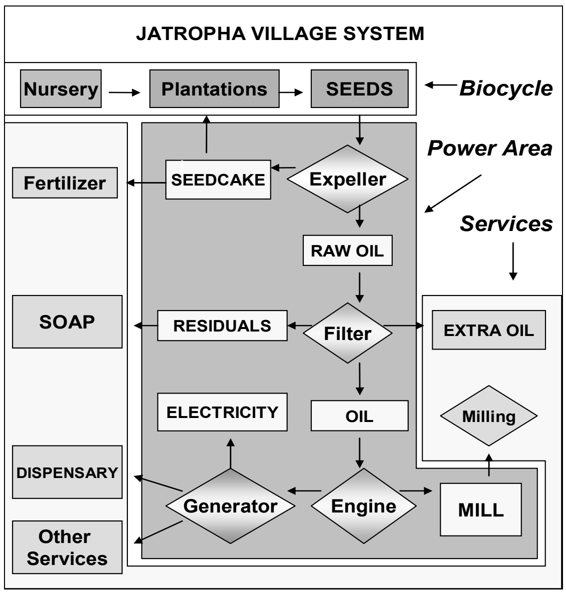

Figure 1: Flow diagram of the Jatropha Energy System

For the system to power more (community) services and machines, a configuration with local plantations can easily be implemented. In order to support a single power unit with a diesel engine running around 5 hours at day, an average of 4 hectares are needed. In itself, the cultivation of mature Jatropha trees becomes a profitable activity. After 3 years Jatropha plants start to yield, reaching maturity in the 5th year. The seeds from Jatropha will be bought either directly by engine owners or by independent millers who process them into biofuel until the cost of Jatropha oil will be lower than diesel.

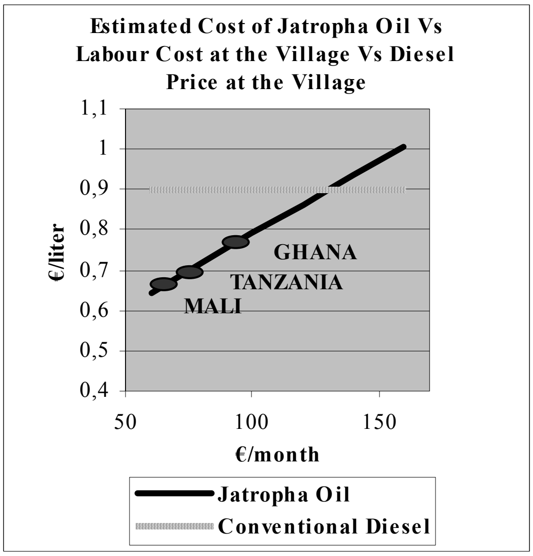

Figure 2: Estimated Cost of Jatropha Oil Vs Labour Cost at the Village

As figure 2 shows, the estimated production cost of Jatropha oil can be sensitively lower than conventional diesel for many rural communities in sub-Saharan Africa. Low labour and investment costs make the JES a low-risk system, which allows communities to save money on fuel. As diesel or gasoline tends to be a big cost factor in local village life, with those fuels making up even the biggest cost in marketing agricultural produce, the JES offers an attractive opportunity to generate income (through the sail of oil) and savings (on operating costs of local production processes). When a cooperative approach is taken, these extra-savings can be used to lower milling charges, to support social services or to be invested in extensions of the system.

Once a community has gained experience with the system and acquired a routine of replicating it, it may even begin to think of entering wider regional markets as a biodiesel feedstock producer.

3.2 A note from the field

Haubi, a small town in Tanzania, located around 250km north of the capital Dodoma, has a small State-run dispensary providing basic health care services to the community. The dispensary in question runs on a small photovoltaic installation for its electricity, which provides enough for basic radio equipment, but not much else, thus limiting the capacities of the dispensary. Due to this lack of electricity, the dispensary cannot function as a stop for vaccinations, which require refrigeration for storage. Moreover, the existing solar energy system was incorrectly installed (showing the need for outside expertise), exacerbating the situation. Adding more solar panels remains an option, but since the dispensary is thinking of expanding its compound and services, it actively considered searching for an alternative and robust energy solution.

For these reasons, the author undertook a small research-trip to Haubi, for the NGO *Ingegneria Senza Frontiere*, to study whether the JES could provide a solution to this local problem.

A careful micro-economic and technical analysis showed that the JES could remediate the problem elegantly, even though the implementation of the system posed certain legal, managerial and ownership issues. The modularity of the JES makes it a flexible energy solution though, capable of accommodating these issues.
The basic intention was to see whether a cooperative organization could adopt the entire system and operate both the nursery, the plantation, the milling service and the generator, and to sell the much-needed electricity to the dispensary ("bottom-up" approach). But as the dispensary is State-run, doubts arised over whether such a cooperative organisation is legally allowed to sell electricity to the state. Another option consisted of joining two para-statal enterprises, whereby one would own and manage a nursery, a plantation on a government or communal plot, a mill (thus offering a number of jobs to local people), and a generator, while the other para-statal (the dispensary) would buy electricity from the first one.

SEEDS PRODUCTION COST (€/ha)		
	Installation	Annual
Nursery	275 €	55 €
Leasing the land		3,75 €
Clearing		38 €
Organic Fertilizer		180 €
Planting		19 €
Pruning		38 €
Harvesting		475 €
Management		250 €
TOT cost per ha		1059 €
Cost of 1 kg of seeds		**0,18 €**
COST OF BASIC POWER SYSTEM		
	Installation	Annual
Cost of Seeds		2091 €
Expeller	3000 €	467 €
Filter machine	150 €	50 €
Engine	2500 €	250 €
Extraction		100 €
Conventional Diesel		145 €
Extra costs	200 €	80 €
TOT.	**5850 €**	**3183 €**
COST OF JATROPHA OIL		
Income from Seedcake		280 €
Income from Residuals		30 €
Cost of Jatr. Oil (€/l)		**0,70 €**
Diesel cost in Haubi (l)		0,95 €
Savings for Milling		**1009 €**

Table 1: Estimated Production Cost of Jatr. Oil in Haubi

A careful social impact-assessment showed that the last option opened a micro-economic dilemma. On the one hand, Haubi would for the first time have a strengthened and full-service dispensary benefiting the entire community, but on the other hand, the arrival of a new milling service operated by a state enterprise would have meant that local millers would have had to accept a new competitor in their market. As these existent mills are still using conventional diesel fuel, they will have to compete against the mill working on cheaper Jatropha oil (see table 1), which may be an incentive for the old millers to adopt the Jatropha system too, thus spreading the wider adoption of it within the community.

The Haubi case illustrates that local conditions, power relations and economic circumstances must first be analysed in depth, before a project is implemented. One basal but crucial fact remains, though: regardless of who owns which part of the system, a consistent, cheaper and large enough amount of energy might arrive in Haubi for the first time, and the dispensary would finally be supplied with electricity allowing it to provide decent health care services.

3.3 Stakeholder analysis

As the Haubi case illustrates, the JES presents a flexible energy solution that can be adapted to local realities, according to the needs of the stakeholders involved. An NGO might introduce the system to show its relevance to the beneficiaries, aiding local actors to gradually take it over and replicate it.

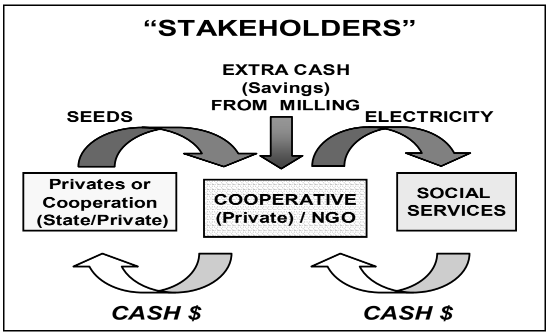

Figure 3: Relations between Stakeholders at the Village Level

The JES offers *local state enterprises* an opportunity to change the widely held view that the State has no interest in rural communities. It actively engages state representatives who are often perceived as mere passive bureaucrats. The system might be implemented using state-owned waste-lands. The employment opportunities that arise, might improve the relations between the state representatives and the local community. And finally, the system provides a steady income to the state enterprise which might be used to provide better local services to the community.

Compared to other energy solutions, the JES requires a relatively small investment and it is a low-risk enterprise. This makes it perfectly suited for a *community approach* as well, whereby a cooperative controls the entire system, and invests savings back into the community.

Finally, the JES represents an excellent commercial opportunity for private individuals and *entrepreneurs*. When introduced, the system creates a competitive environment in the local economy, whereby those who are involved in operations based on the use of diesel fuel (mill operators and others), will naturally have to switch to using the cheaper Jatropha oil. This in turn creates a situation where the introduction of a renewable energy source by one player, forces others to adopt it too, in order to compete.

4 CONCLUSIONS

Throughout this first conceptual analysis, the authors tried to demonstrate the benefits of a renewable energy system for a typical rural village setting in Africa, based on locally available resources, skills and knowledge. The results suggest that such a system can be elegantly integrated into local economies, and adapted to the needs of different stakeholders, yielding a wide range of small but crucial social and economic benefits. Both authors are now in the process of implementing pilot projects, to measure the concrete effects of the system on local communities more in depth. We hope that the Jatropha Energy System finds wider acceptance in the developing world, so that more people might enjoy a clean, sustainable and bright future.

NOTES:

[1] *The Challenge of Rural Energy Poverty in Developing Countries*, World Energy Council, London, 1999.

[2] A recent study carried out by the EU Dept. of Energy shows that the impact of rising fuel prices on the economies of the least developed countries can be up to eight times higher than the effect of debt relief. John Vandaele,Gie Goris, 'Wild kapitalisme laat niets over voor de zwaksten', in: MO*, Mondiaal Magazine, september 2005.

[3] Indoor air pollution resulting from cooking and heating affects the health of millions of women and children. According to the World Health Organization, it is a silent and underestimated killer, causing over 1.6 million deaths per year. WHO Fact sheet N°292, June 2005: http://www.who.int/mediacentre/factsheets/fs292/en/

[4] Henning, Reinhard K. "Use of Jatropha curcas L. (JCL): A household perspective and its contribution to rural employment creation. Experiences of the Jatropha Project in Mali, West Africa, 1987 to 1997." Presentation at the "Regional Workshop on the Potential of Jatropha Curcas in Rural Development & Environmental Protection", Harare, Zimbabwe, May 1998.

[5] Personal communication by Mr. Emilian Kavishe, Forrest Officer in Haubi, Tanzania (3 September 2005).

[6] A small amount of regular diesel is used to start and stop the engine (less than half a liter for a typical village mill).

[7] Henning, Reinhard K. "A manual to the exploitation of the Jatropha plant", s.l., s.d.

[8] The so called "Multifunctional Platform" as it exists in Mali, is an extension of such "seed for light" schemes, whereby a community collects seeds, processes them and provides the oil to a communally owned diesel-generator. http://www.ptfm.net/mfpwhat.htm