Small-scale Electricity Generation from Biomass

Experience with Small-scale Technologies for Basic Energy Supply

Part III: Vegetable Oil

HERA
Poverty-oriented
basic energy services

On behalf of
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Preface

Energy is essential for human development. Without adequate basic energy supply people cannot cook food, light their homes or keep essential medication chilled. Alongside the introduction of efficient and clean thermal use of traditional biomass for cooking, the provision of electricity from renewable energy sources can provide basic energy services for lighting and communication and promote local economic growth.

Renewable energy from photovoltaics, wind turbines and small hydro plants is highly suitable for off-grid electricity supply and has been successfully introduced in countless cases in developing countries. However, although the application of biomass as a sustainable electricity source seems promising, it is still seldom perceived as an option for providing electricity to the rural poor.

To generate electricity, biomass can be combusted, gasified, biologically digested or fermented, or converted into liquid fuels propelling a generator. Several research institutions and international agencies rate biomass as one of the cheapest available renewable energy sources for power generation. Furthermore, the conversion of biomass into electricity is a low-carbon process as the resulting CO2 can be captured by plant regrowth. In contrast with solar PV or wind power, biomass power technology can generate electricity on demand at any time, as long as a sufficient supply of biomass stocks is assured. Many agricultural and forest product residues can provide feedstock for energy conversion without increasing land requirements. Local farmers can generate additional income by providing biomass fuels to small local power plants.

However despite the apparent benefits, there has been little experience in building small electricity-generating biomass plants in off-grid areas of developing countries. In approaching this issue, the GIZ ‘Poverty-oriented Basic Energy Services’ programme (HERA) assessed the lessons learnt from former GTZ and non-GTZ pilot activities and identified the most important potentials of and obstacles to different biomass power technologies. This assessment resulted in a three-part series of papers on **‘Small-scale Electricity Generation from Biomass’** covering **biomass gasification (part I), biogas (part II)**, and **vegetable oil (part III)** for electric power generation.

1 Introduction

Vegetable oil can be used as fuel for diesel engines, either as straight vegetable oil (SVO) or as biodiesel (after chemical conversion). Given rising crude oil prices and the search for renewable fuel solutions, there was a worldwide hype surrounding biofuels - especially as fuel for vehicles - in industrialised countries some years ago. However frustration instantly followed, as export-oriented biofuel mass production appeared fraught with environmental and social problems. Local production and use of biofuels came back on the agenda. Since then the potentials of local electricity production based on plant oil have been more seriously considered for rural areas in the developing world.

In this paper the GIZ programme on Poverty-Oriented Basic Energy Services (HERA) attempts to assess the current state of local off-grid electricity generation based on plant oil for rural areas in developing countries in Africa, Latin America and Asia. The paper's initial concept was to analyse the operational data of ongoing projects and develop general conclusions regarding potentials and limitations from existing project experience. However, as it will become clear in this paper, genuine operational data is extremely rare - in contrast to boastful or misleading statements by companies and projects whose activities are in fact only at pilot or initial phases.

2 Vegetable Oil as Fuel

2.1 Technical Aspects

Vegetable oil can be used to fuel diesel engines as straight vegetable oil (SVO) or as biodiesel following conversion. It can be used either for cars or for stationary use to power machinery or an electricity generator.

The more advanced the engine technology, the more complicated or limited the use of SVO. Hence for use in modern cars with direct injection engines the conversion of SVO to biodiesel is mandatory. However SVO can be directly used as fuel for most simple stationary diesel engines used in generator sets or pump stations. Special SVO engines are also available.

For robust stationary (non-vehicle) engines, the use of pure SVO is the most attractive option. This way the additional and somewhat dangerous biodiesel conversion process (due to some highly inflammable components) can be avoided; furthermore the energy yield per gallon of vegetable oil is higher when using SVO directly. This paper will in general focus on the direct use of SVOs only.

Listed below are the potential benefits of SVOs as fuel for power generation in rural areas:

- SVOs are a renewable energy source low in greenhouse gas (GHG) emissions.
- Local production is possible and can contribute to value generation in rural areas.
- SVOs are liquid, hardly evaporate and are thus easily handled, stored and transported.
- SVOs are neither flammable nor explosive and do not release toxic gases.
- SVOs can be burnt in a relatively clean manner.
- SVOs do not cause major damage if accidentally spilt.

Almost all vegetable oils have a calorific value that is very similar to that of diesel fuel. However vegetable oil differs from diesel considerably with regard to viscosity, which is 10–20 times higher for SVOs. Furthermore, the solidification points of SVOs can be rather high. Coconut oil for example solidifies at temperatures below 22°C. This can cause major problems particularly in cold regions.

Oil characteristics can differ considerably between different types of SVOs as their composition of fatty acids varies. This can lead to plugging and gumming of lines, filters and injectors, as well as cause deposits inside the motor or excessive engine wear.

There is long-term experience particularly with rapeseed oil, which has been used in Germany and other countries as fuel for cars, trucks and tractor engines for several years. There is no doubt that rapeseed oil is relatively easy and reliable to use in diesel engines.

Other oils like palm oil, sunflower, soybean, coconut, jatropha and cotton oil have also been used to fuel motors. Many examples are regularly presented at conferences and can be found in publications. However there does not yet seem to be much large-scale and long-term practical experience regarding the proper and economic long-term functioning of such plant oil motor-generator systems.

For economic long-term use all machines need clean homogenous oil with specific characteristics. Elsbett, a German company that specialises in the construction of motors for plant oil fuel states, ‘Standardising of the fuel is a must.’ (Elsbett, 2003)

Some engines are specially designed to operate with vegetable oils. Elsbett produces vegetable oil engines and provides sets for the conversion of tractor or truck engines to be fuelled by SVOs. Small (< 20 kW) Lister type diesel engines produced in England or India are also appropriate for SVOs as fuel; they are very common worldwide.

A 'how-to guide for small stationary engines' published by the World Bank (2009) gives a good overview of the technical details for quality SVO production and the necessary properties for engine modifications.
There are several companies offering small generator sets especially for SVO use.

2.2 Sources of Vegetable Oil

Man currently uses over one thousand different oil plants. Some of their seeds are extracted from natural forests; some are cultivated in small plots or hedges, while others can be produced in plantations with intensive agricultural methods. The most cultivated oil plants of the tropics are oil palm, coconut, soy, castor, sunflower and cotton. In many cases oil is only a by-product that is rarely extracted.

In the discussion on biofuels **jatropha** received particular focus due to its attributes:

- Wide adaptability to diverse climatic zones and soil types combined with high drought tolerance.
- Cultivable in areas where food production is not possible, therefore not competing with food crops.
- Short gestation period, easy multiplication and high pest and disease resistance.

However according to the GTZ study 'Jatropha Reality Check' (GTZ, 2009) these claims 'have proven highly exaggerated.' This is confirmed by USAID that stated, 'Jatropha does not deliver the anticipated yields and benefits that are often attributed to it.' (USAID, 2009)

Jatropha's reputation for wide environmental adaptability does not guarantee high yields. Recent observations of plantations across developing regions confirm that jatropha may survive precipitation as low as 300 mm, but will not produce significant quantities of seeds at those levels. Although much has been written about the agronomic parameters within which jatropha will grow and thrive, very little is actually known about the optimal conditions for obtaining the highest yields. Apparently about 650 mm of precipitation and good soils are the minimum conditions for good production.

Jatropha yields can vary considerably. The main reason is that jatropha is not a domesticated plant; there are no standardised varieties available. The available 'certified' seeds guarantee a certain germination rate but not a specific yield. Most of the jatropha seeds used in Africa during the last few years were seeds of no particular origin.

The oil from cottonseed can be used as an energy source. **Cotton** oil can also be used for human consumption. However it is of minor value and due to the intensive use of chemical pest control in cotton culture its agrochemical content can be problematic for alimentation. In cases where cotton oil is available at reasonable prices it might serve as a sound source of energy. Usually cotton oil is not extracted as the cottonseed is used as forage for domestic animals.

Palm oil is produced at both industrial and small-scale levels. The oil palm is one of the most productive oil plants in terms of produced oil per hectare. **Coconut** and **sunflower** are also important sources of vegetable oil. All these oils have high value for human consumption and are therefore preferably used for nutritional purposes. However, in some particular circumstances the energetic use of these oils might prove reasonable.

There are considerable advantages for a farmer if he has several options to market his oil produce. So in cases of low quality oil production or very low prices for edible oil he can sell or use it for energy purposes.

There are many other agricultural plants cultivated for food, fodder or fibre that contain oil. Some wild or semi-wild growing trees are also occasionally used as oil sources. In some cases this oil can be available at costs and in quantities that allow its use as fuel. The use of kapok oil in Cambodia is an example.

Besides fresh vegetable oil, **waste oils** - for example from restaurants - can also be used as a fuel source. Almost all countries (should) have regulatory frameworks that inhibit irregular disposal of oils and fats. Hence the recycled fraction of these materials is high. Much of this is processed at industrial level. But examples of small-scale oil and biodiesel productions do exist.

FAO's Small-Scale Bioenergy Initiatives Report (2009) describes two small-scale businesses working at the informal level in Peru that recycle vegetable oil in peri-urban areas around Lima. They produce between 300,000 and 500,000 l of biodiesel per year (FAO, 2009). In Brazil similar activities are carried out which are documented in an ICLEI case study, the Eco-oil Programme in Volta Redonda.

In contrast to pure primary vegetable oil, the oil from waste is of ever changing quality. Hence its conversion to biodiesel is the method of choice to get a produce with more or less constant characteristics. In certain cases where waste oils are available in large quantities the conversion process of waste oil to fuel can become economically sound. As this is a rather exceptional case that is mainly applicable in peri-urban environments it will not be further discussed here.

2.3 Extraction

The two main processes of extracting oil from seed feedstock are **mechanical press extraction** and **solvent extraction**.

The solvent process extracts more of the oil contained in the oilseed feedstock but requires costlier equipment. Oil extraction by a mechanical press is the standard technology for small-scale applications. During mechanical press extraction, the oilseed is crushed and pressed in a screw press. The oilseed is heated either before or during the pressing. After most of the oil is removed, the remaining seed meal can be used as animal feed.

Hand presses are not appropriate for extraction of larger seed quantities. Screw presses driven by combustion engines are standard and widely available in the market. The efficiency and durability of the different available presses will probably be a topic for future research and development.

After the crushing and pressing, the oil has to be filtered. Chamber filters with fine mesh textile filters are the most common option.

2.4 Market Development

The developments in the world biofuel market are important for any local approach. Many jatropha and other oil plant plantations have been established due to the biofuel hype of the recent years. Even though their yields do not fulfil the original expectations, these plantations will produce considerable amounts of oilseeds within the next few years. This will probably lead to an increasing availability of SVO on the markets; SVO production know-how will grow considerably with the lessons learnt from cultivation during this time.

And the gold rush mood is not yet over. New crops and plants are being touted as 'new oil wells,' e.g. the Acrocomia palm tree in Southern America was recently promoted as an insider tip (Oberländer, 2008). The implications of this gold rush mood are not yet clearly visible.

The demand for vegetable oils as a base for car fuels will persist and increase on the global market. There are some sectors like the aviation business with high purchasing power and technical applications that have no alternative to liquid fuels. Their demand for liquid fuels will therefore remain or increase further.

The development of environmental and social standards will most likely ensure that in future only certified SVO or biodiesel will find its way into the formal market. This will probably lead to high competition and low availability of cheap SVOs in the local markets of developing countries. However, some quantities of SVOs that do not meet international standards might remain for local use.

In any case the development of the global markets will increase infrastructure and know-how about SVO production and use, including high yield varieties, agricultural extension service, availability of appropriate engines etc. Local initiatives will probably also benefit from this development.

2.5 Energy Balance

Energy production from biomass is always a question of input-output balance: it is necessary to not only relate investments and running costs with economic outcomes, but also to compare energy inputs with energetic outputs. In case of wood collection for cooking purposes a rural family clearly sees the positive balance of invested effort versus energy services gained. However in the case of oilseeds, the necessary effort for production is far higher.

The study 'Energy analysis of Jatropha Plantation Systems for Biodiesel Production in Thailand' compared energy inputs and outputs of intensive jatropha plantations. The study, which is based on experiments rather than fieldwork, revealed that the overall energy balance is frequently negative. Clearly positive energy balances were only achieved when the energy content of all jatropha products were considered (including for e.g. pruned wood and seed cake besides the oil itself). A negative or just slightly positive energy balance was achieved when the energy content of only the oil was considered. Only by adding the much higher energy content of the pruned wood and seed cake did the energy gains rise far above the invested energy (Prueksakorn, 2010).

The following examples of attempts in various countries will show that it remains questionable whether and how profitable SVO production is possible.

3 Existing Experience in Different Countries

Numerous publications from all over the world claim that vegetable oil is used to power small power plants. However reliable independent reports about the day-to-day operation of SVO-based power generation units are very rare. Some reasonably documented examples are listed in the following chapters.

3.1 India

India has launched an ambitious biofuel programme including biodiesel production from jatropha and Pongamia (Pongamia pinnata) oilseeds. The programme focuses mainly on the large-scale production of biofuels for the global market. However, it also comprises of multi-functional platforms for rural shaft power and electricity generation.

In the framework of this programme, Winrock International India (WII) has engaged in the electrification of three villages in the state of Chhattisgarh with the objective of demonstrating the technical and financial viability of operating diesel generators with SVO.

The first and apparently only implemented part of this project was the installation of a power plant for SVO use in 2007 in the Ranidhera village. Located in the Kabirdham district, the village comprises 110 households with 600 people.
The main components of the approach are:

- Community mobilisation and capacity building regarding the management and operation of the facilities including tariff setting, and collection of electricity fees including establishing and training of a Village Energy Committee (VEC).
- Planting of jatropha saplings on farm boundaries, roadsides and wasteland. No farmland was used for jatropha plantations. External financing covered the costs of the saplings, but the villagers volunteered to plant them.
- Installation and commissioning of a power plant consisting of four gensets (3 x 3.5kW and a backup unit of 7.5 kW), oil expeller, filter press and a boiler in April 2007. All equipment was installed in a power plant building with sufficient storage capacity for jatropha seeds.

The electricity is distributed within the village through a mini-grid from 6 pm to 9.30 pm. It provides power supply to 30 streetlights, light points in 107 households and sockets (for entertainment) in 65 households.

A visit by the scientific group COMPETE (Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems - Africa) in February 2008 found it to be in continuous operation for almost one year without any technical failure. The power plant has experienced no failure and the three operators are confident in handling the day-to-day operation as well as small repair and maintenance work.

According to this visit report the electrification project has shown excellent performance with respect to technical, financial, social and institutional sustainability since its start in April 2007 (COMPETE, 2008).

Since May 2007 the villagers have been paying for the electricity services (INR 20 per light point per month, INR 30 per socket per month) that goes into a Village Energy Fund (INR 56 ~ EUR 1)). So far all payments have been made and the money has been used to pay the operators' salaries, cover maintenance expenses and generate surplus for future larger maintenance work.
According to project reports:

- The villagers (50% women) collect the jatropha seeds at INR 4 per kg.

- Jatropha seeds are harvested in April/May and July/August. During the off-season seeds need to be acquired at a market 60 km away from the village.
- The VEC is responsible for ensuring seed supply.
- The fee of INR 20 per light point compares with expenses of about INR 40 for lighting with kerosene lamps.
- The total revenue derived from electricity sales is INR 3,500 per month.
- Engines used for electricity generation are Indian Lister engines.
- Adjustment of the engines to operate on straight jatropha oil includes preheating of the oil through a coil around the engine exhaust.
- Maintenance (e.g. filter change, engine cleaning) is conducted after 250 hours of operation.
- The 7.5 kW genset is used as a mechanical drive for the oil expeller.
- A wood fuelled boiler had to be installed to preheat the jatropha seeds to increase oil-expelling efficiency.
- The expeller has a capacity of 30 kg per hour. After five hours of operation about 40 l of oil is expelled, sufficient to operate the three engines for four days.
- Jatropha oil can be stored up to 15 days.

(COMPETE, 2008)

According to email information from WII in July 2010 the power plant still operates daily with three generating units and one standby unit that doubles up as an oil expelling unit.
The power plant has been operating with almost zero downtime over the past few years. However the availability of oilseeds is a serious concern. Apparently a considerable amount of additional fossil fuel will still be necessary to ensure the steady operation of the generator system. No clear data has been made available in this regard. WII states, ‘Jatropha is the best renewable energy-based decentralised power generation option in remote villages.’ ‘If’ – and this word seems important – ‘if the seed supply is ensured it would beat any other option hands down.’

This project is also listed as Case 8 in FAO’s 2009 Small-Scale Bioenergy Initiatives Report. In this study it is clearly stated that ‘up to now the recently built up local production does not cope with this demand. First results are that the collection of fruits in the young plantation is a daunting task and threatened by poisonous snakes.’

An example of the different approaches to using vegetable oil as fuel is the activities of the Applied Environmental Research Foundation (AERF). This NGO set up four ‘biodiesel resource centres’ in the state of Maharashtra. These centres buy oilseeds from small farmers and process them into SVO and not biodiesel as their names might indicate. The oil is sold on the local market. Most of it is blended with fossil diesel to run pumps, taxis, mills or backup generators of hotels. A small quantity of the oil is also used as protective coating for boats. The interesting fact is that the NGO’s main aim is not energy provision but biodiversity protection. Hence they looked into incentives for forest conservation. AERF does not buy oilseeds from cultivated plants but from native trees like Pongamia pinnata and Madhuca indica. About 15 villages deliver oilseeds to each of these centres achieving about 4 t of seeds or 1,200 l of SVO per year. Activities are limited to two months of seed collection and to about 40 days of extraction and processing per year (Rai, 2009 and personal information from Jayant Sarnaik).

The Renewable Energy Supply in Rural Areas (RESRA) project implemented by GIZ aims to provide rural target groups with a sustainable and independent supply of electricity by focusing on a system of tree borne oilseed (TBO) SVO production and gasification of the press cake. However the electricity generation for some 30 villages on the basis of local biomass had not yet begun by November 2010 (personal communication Herz, 2010).

3.2 Cambodia

Near the Cambodian village of Sisophon in the Banteay Meanchey Province, a small generator powered a mini-grid for about 80 households for about one and a half years using jatropha oil exclusively as fuel. The operator and his family members had cultivated jatropha. The engine was adapted to use SVO by the German company Elsbett and it ran without any problem during this time. It was put out of operation after the national power grid reached the site and private power generation was prohibited.

The oil from the kapok tree (Ceiba) has also been used as fuel for a short period. In this region kapok trees are common and the local cottage industry produces mattresses filled with kapok fibres. Hence the oil was an available by-product. However the availability and price of the oil fluctuated considerably. Hence its use was stopped after some initial tests.

Today the same small company is operating two small generator sets fuelled with jatropha oil in the Paoy Char community delivering electricity to 300 households. The village households themselves cultivate jatropha to keep costs down. One kWh costs KHR 3,500 (the electricity produced from diesel fuel in a neighbouring village costs about KHR 4,500 or nearly EUR 1/kWh) (personal communication: Dunja Hoffmann, Peter Bolster, GIZ, 2010).

3.3 Pacific Islands

The most promising reports come from the Southern Pacific Islands where imported diesel fuel is quite expensive due to high transportation costs. Meanwhile the abundance of under-utilised coconut trees provides high potential as a local source of SVO.

Hence over the recent years there has been increasing interest in the use of coconut oil as a source of energy for rural electrification. Many scientific theses and feasibility studies have been conducted in the last 10 years and produced promising results (example: Cloin, 2005). Some pilot projects tried to make use of coconut oil as fuel in practice. For example, on the Fiji islands of Vanubalavu and Taveuni dual fuel generators were installed in 2001 with the intention of making electricity more affordable by using SVOs as fuel. Cost reductions of about 40% were reported. However, three years later both generators were running entirely on diesel.

A similar attempt was made again in 2009. To explore the feasibility under real conditions the South Pacific Islands Applied Geoscience Commission (SOPAC) installed a small coconut processing mill with an SVO-fuelled genset as a research unit. SOPAC received financial support from the Technical Centre for Agricultural and Rural Cooperation (CTA). The equipment, including a copra cutter, a cold press expeller and an 18 kVA diesel engine generator, was installed in July 2009 at the Centre for Appropriate Technology and Development (CATD) in Fiji. The fuel produced and used in the genset is a blend of 80% coconut oil and 20% diesel fuel. The cost of this ‘biofuel’ is reported to be about 10% below the retail price of fossil diesel in Fiji. Additionally, the production of other products from coconut oil are promoted as soap, body oil and lotion and copra meal to increase income generation and profitability (Vukikomoala, 2010).

The results seem to be so convincing that Fiji has declared its intention to install more than 20 additional biofuel mills in the coming years. Future developments will show how realistic these plans are.

In any case, the Pacific Islands can serve as an example of showing how high the share of VO as fuel can be compared to the crude oil consumption of a society. Due to their geographical situation, potentials are easy to calculate. While on small islands with a rural structure the potential coconut oil production could substitute more than 60% of total actual crude oil consumption, the share is considerably below 5% on bigger islands like Fiji and Papua New Guinea (Cloin, 2007).

3.4 West Africa

Jatropha projects have been active for many years in Western Africa, especially in Mali. Jatropha is well known in Mali and old jatropha hedges exist in many parts of the region. Hence, fruits are readily available. Traditionally the seed is harvested by women and used for medical treatments and local soap production.

In Mali several national programmes have been supporting the dissemination of jatropha for years. In the beginning hedges were planted for erosion control. Over the last few years they have been planted explicitly as an energy source for rural electrification. In cooperation with the World Bank and KfW, AMADER (Agence Malienne pour le Développement de l'Energie Domestique et de l'Electrification Rurale) developed plans for a rural electrification programme based on jatropha oil (Owsianowsky, 2008).

Since 2004 the Malian 'Programme National de Valorisation Energetique de la Plante Pourghere' has been focusing on electricity generation from jatropha oil. The programme's first phase was planned for between 2004 and 2008. Its objective was to provide fuel for 20 vehicles and five generator stations.

In 2005 the first plant was installed in Keleya about 100 km south of Bamako near the road to Abijan. The project is executed by CNESOLER (National Centre for Solar and Renewable Energies) and has the following target figures:

- To provide electricity to 90 customers, including households and five social or administrative buildings with a grid of a linear extension of 2.210 m.
- A motor of 16 kW power that drives a 60 kVA generator.
- At a running time of 10 hours daily the generator set reportedly consumes 37 l of jatropha oil per day that is equivalent to about 100 kg of seeds.

(http://www.jatropha.de/mali/FICHE%20TECHNIQUE%20SUR%20KELEYA.pdf)

The USAID study 'Empowering Agriculture' describes a West African project under 'Case Study 9: Jatropha Oil as Renewable Fuel Source for Multi-function Platforms in West Africa.' The aim is to retrofit the existing multifunctional platforms (MFP) with their small 10 kW Lister type engines introduced in the 1990s so that oil from jatropha can be used as fuel. A multifunctional platform is built around a simple diesel engine, which can power various tools, such as a cereal mill, husker, alternator, battery charger, pump, welding and carpentry equipment, etc. It can also generate electricity and be used to distribute water. The Mali Folkcenter for Renewable Energy (MFC) is mentioned as the provider of the necessary know-how (USAID, 2009).

One of the most frequently mentioned projects is the 'Rural Electrification in Commune de Garalo, Mali'. The Mali Folkcenter (MFC) implemented it in cooperation with several Dutch companies and NGOs. The project started in 2006. Its aim was to set up and operate a village electricity system for 10,000 people with jatropha fuelled generators. Oil plant production, pressing, electricity generation and consumption are to be concentrated in one single area. 1,000 ha of village oil plantations - mainly jatropha - were estimated to cover the electricity need of the target population. Electricity generation started in December 2007 with 170 customer connections and street lighting. Three generator sets were installed; one or two were used for electricity production and the third as a standby. In December 2007, about 35 kW of power was provided for five hours per day (175 kWh). However in those days the generators were still fuelled with diesel. Only short tests with jatropha and palm oil were carried out. Plant oil was not yet available, as jatropha plantations had just been set up. A 2 ha nursery had produced 320,000 seedlings and 413 ha jatropha plantations had just been planted involving about 200 farmers. Initial experiences with jatropha cultivation were analysed and it was noted that plantation spacing of 3 x 3 m of the jatropha bushes was inappropriate for intercropping. Hence later plantations with a spacing of 5 x 5 or 6 x 5 were created to intercrop beans, corn and other crops for several years. The project receives strong support from the Dutch FACT Foundation and special technical support from the company, Brodtech (http://www.jatropha.de/mali/FICHE%20TECHNIQUE%20SUR%20KELEYA.pdf).

The project is also mentioned in the Small-Scale Bioenergy Initiatives Report (FAO, 2009) as 'Case 1' with a budget of USD 756,000 and an electricity price of USD 0.38 per kWh. The study also states that it is unclear how much plant oil has contributed to this result.

Recent enquiries revealed that the project is very successful in terms of energy provision. Over 250 connections have been set up, the village has transformed enormously, a lot of economic activity has begun and a private company has set up a cellular network.

However the FACT Foundation explicitly declared that the use of jatropha has not been very successful, as just minor demo quantities of oil have been produced and used. Seed yields were very low and the farmers were disappointed. FACT does not recommend jatropha as experience showed that is very difficult to make the utilisation of jatropha economically feasible (Personal communication, FACT Foundation, Nov 2010).

It was not possible to get a similarly clear statement regarding the other two mentioned projects from West Africa. However informal sources indicate that SVO is not considerably used as fuel.

3.5 Tanzania

There are several examples of initiatives, pilot projects and plans for electricity generation from vegetable oil in Tanzania.

GTZ's country report mentions that a total of eight companies have been registered by the Tanzania Investment Centre (TIC) to develop biofuel activities in Tanzania including Sun Biofuels Tanzania Ltd, CAMS Agri-Energy Tanzania, Sweden's Sekab Company, and FELISA (Farming for Energy for Better Livelihoods in Southern Africa) which is involved in palm oil production for energy. The German company, PROKON, is also registered (http://www.gtz.de/en/themen/umwelt-infrastruktur/energie/31106.htm).

PROKON, which is a private company and an experienced commercial rapeseed oil provider in Germany, carried out a PPP project in Tanzania in cooperation with GTZ. The project's aim was to produce sufficient jatropha oil to fuel a 500 kW block of the local power plant. PROKON mobilised 1,800 farmers in the Rukwa region to plant jatropha and agreed to buy seeds from them. A seed collection centre, which included an oil press, was set up in the town of Mpanda. The PPP project ended in 2007 before any electricity from jatropha had been produced. The project was delayed, as the production of jatropha oil was slower than expected. Almost all of the fruits had been used as seeds, rather than for oil production. The project is however still ongoing, as a private activity of the company.

In 2010 an appropriate press was shipped from Europe to Tanzania to build up the oil extraction unit. The latest information in August 2010 revealed that at least some of the company's cars and tractors are expected to run mainly on jatropha oil from December 2010 onwards.

TaTEDO has already installed three multifunctional platforms (MFPs) in Tanzania and in a project with Hivos about 30 more MFPs are to be installed with financing from the EU.

As opposed to official claims, the MFP in Leguruki was still running on fossil diesel at the beginning of 2010. Jatropha oil was only used during trial runs. The mill and press equipment in use do not yet produce oil of appropriate quality.

There are many more ongoing initiatives. The NGO, KAKUTE Limited, has long-term experience with jatropha use at local level and is frequently contracted by private companies. Furthermore, the Dutch company Diligent Ltd has built up a jatropha production plant. The Arusha Times of 6 June 2009 reported under the headline ‘Simanjiro to Produce Own Power Using Jatropha’ that a non-governmental organisation, Ilaramatak, of Simanjiro in the Manyara region has started constructing an electricity production plant that is expected to use jatropha oil as fuel in Terrat in the Simanjiro district. However up to now there has apparently been not a single reported case on the day-to-day operation and electricity is in fact being generated from vegetable oils (http://allafrica.com/stories/200906081203.html).

In Tanzania, the Better-iS research programme was started in 2009, with a running period of three years. The German Leibniz Centre for Agricultural Landscape Research (ZALF) is carrying out this research programme in cooperation with GIZ. Better-iS aims to identify the potential for linking low-productivity farming to small and medium enterprises to enhance livelihoods through biofuel value chains. Up to now no results have been documented.
The researchers affirmed that at present there is high demand for oilseeds in Tanzania as several stakeholders are trying to run their pilot activities, but that currently there is hardly any electricity generation through SVO.

3.6 Kenya

According to the GTZ country report (http://www.gtz.de/de/dokumente/gtz2009-en-regionalreport-kenya.pdf) there are various ongoing jatropha plantation initiatives in Kenya with an estimated cultivation area of over 4,000 hectares. The largest stakeholders involved are Better Globe Forestry (an international commercial forestry developer) and Green Africa (a local NGO).

Based on the experience of these very different plantations the GTZ study ‘Jatropha Reality Check - A field assessment of the agronomic and economic viability of jatropha and other oilseed crops in Kenya’ was carried out in 2009.

The report reveals the following critical results regarding jatropha:

- Yields were very low and variable. While the literature from around the world reported yields of about 2 kg per tree, the yields found in Kenya were about 0.25–0.8 kg/tree for 8 year-old trees.
- Empirical evidence from the field showed that jatropha is susceptible to many pests and diseases. More than three quarters of the jatropha farmers in Kenya reported at least one pest or disease.
- The cultivation of jatropha for monoculture planting or in intercropping had a negative economic balance. Only the cumulative return of a fence scenario was positive after seven to eight years of cultivation.
- Based on in-depth field research the study comes to ‘the clear conclusion that smallholders in Kenya should not pursue jatropha as a monoculture or intercrop plantation crop at the present time’ (p. 10) and that ‘the only type of jatropha plantation that can be recommended for smallholders at this time is the fence.’ This form of cultivation is already widespread, and farmers would likely be willing to adopt it quite easily. The fence has the additional benefit of protecting valuable plantation crops from trespassing wildlife and people instead of reducing food production.

The study also covers oilseeds beyond jatropha:

- It concludes that it is essential to consider a range of potential feedstocks and plants instead of just one. ‘There is no single “miracle crop” that will enable sustainable biofuel development to succeed. However, some very promising opportunities exist in the short term with castor, croton, and other oilseeds. If developed comprehensively, these crops could contribute to the significant expansion of a mature industry within a few years.'

- The study also saw most advantages for castor when used in a fence system compared to the monoculture system.
- The study saw potential in croton as a semi-wild forest plant. However not enough is known about its appropriate integration into livelihood systems to conduct economic calculations.

For local production and the energetic use of all these oil bearing plants, certain potential is only considered if the various bioenergy products of these plants are combined, using oil, 'eco-charcoal', fertiliser, or biogas feedstock from the same plant.

3.7 Mozambique

In Mozambique there are ongoing activities to produce jatropha oil for the self-supply of communal energy. There are already small diesel generator sets in various parts of the country. Hence, the potential for their operation with vegetable oil is self-evident.

An ADPP-FACT progress report states that 25 rural communities are going to produce jatropha on 250 ha and that a local biofuel centre shall be built up. However up to now, no SVO based electricity has been generated yet.

The 'Sustainable Biomass Electrification' component of GTZ's 'Access to Modern Energy Services' project aimed at providing electricity to 3,000 people. However after two years of efforts the following lessons have been learnt:

Setting up a BioGrid is much more difficult than originally expected due to the following facts:

- No significant vegetable oil production for use as bioenergy is in place.
- A complete biofuel value chain is not yet developed.
- It is not clear whether the production of electricity from SVO is economically feasible.
- To build up the mini-grid the project would need to start from scratch in supporting smallholders, providing support to extension services etc.

The conclusion is that in principle the sustainable production of biofuels is feasible in Mozambique. However much investment is needed for capacity development to avoid the risks involved in biofuel production.

The study 'Jatropha! A pitfall for Mozambique' (Justiça Ambiental 2009) elaborated by Mozambican NGOs and published by Swissaid even comes to the devastating conclusion 'that jatropha in Mozambique has not met any of the expectations created, and is at high risk of worsening livelihoods and food sovereignty in rural areas.' The study focused on biofuels for the global market. However large parts of it also hold true for local production and use. The FACT Foundation criticised some of the statements of this study as claims that are as little backed by evidence as the unsubstantiated euphoric claims that were common during the hype (FACT Foundation, 2010). However, today even FACT does not promote jatropha as a source for biofuel anymore (see chapter 3.4 West Africa).

3.8 Multi-country Experience from Energiebau Köln

The German company Energiebau Köln conducted a project with Inwent - Capacity Building International between 2002 and 2008 to implement small power generating systems including SVO generator sets. According to Inwent publications the following installations were implemented:

- Busunu, Ghana: implementation of a solar hybrid system with SVO genset to provide electricity to 360 households.
- Matemanga, Tanzania: implementation of a jatropha fuelled system with a water pump.
- Mbinga, Tanzania: installation of a solar hybrid system with SVO generator to provide electricity to a training centre with 12 buildings.
- Sumba Island, Indonesia: installation of a solar hybrid system with plant oil generator in a training centre.

However plant oil is not an issue today in the company’s presentations. A short telephone conversation revealed that Energiebau Köln still supports the operation of these systems on a private basis. However very little SVO is used in these systems and the company gave up the SVO business to concentrate on photovoltaics. Oil yields were too low and unreliable.

4 Conclusions

After the worldwide hype surrounding biofuels as a global commodity and the resulting general frustration, many expectations nowadays focus on the local use of vegetable oil for power generation.

The use of SVO as fuel for combustion motors driving pumps, multifunctional platforms or electricity generators is no serious technological challenge. **Robust engines appropriate for the use of SVO as fuel are already installed in diesel driven appliances or are readily available on the market.**

SVOs can be used as the only main fuel, or blended with diesel, or even alternated with diesel in conventional generator sets or MFPs. **Hence from a technology point of view SVOs constitute a very viable option for decentralised small-scale applications in rural areas.**

The oil of many plants can be used as straight fuel in appropriate engines. **The most widely discussed oil plant is jatropha. But oil from many other oil bearing plants can be used as fuel, e.g. edible oils from oil palm, coconut, sunflower, or cotton or such as castor, croton, pongamia and many other tree borne oilseeds, many of which are still not well examined.**

The conversion of SVOs into biodiesel is also possible on a small scale. However it is not necessary for use in common stationary engines. Conversion to biodiesel might be an option for the utilisation of waste oil or other oils of low quality.

Research has revealed that in contrast to the proven technical feasibility and the positive economic calculations of several reports and feasibility studies, **there are hardly any projects on the ground where SVO is used as a fuel in considerable amounts in daily operation**. Most generators, pumps and MFPs still rely on diesel. As yet, SVOs are mainly used for trials or to a limited extent. The main reasons for this are:

- **SVOs are not available in quantities and at prices that allow steady power generation**:
    - In the last few years, during the biofuel hype, oilseeds were too precious to be used for oil production. Rather they were used as seed to establish new cultivations. Still today the price-enhancing competitive search for oilseed goes on.
    - Field experiences and research have revealed that yields are lower than expected.

- **Expectations especially regarding jatropha as an economic source of SVO for fuel were far too high**:
    - The yields are generally far lower and less reliable than expected. Jatropha remains an undomesticated plant and long-winded breeding efforts are still necessary before jatropha can become a productive and reliable oil crop.
    - Planting jatropha on wasteland does not generate commercially relevant yields.
    - The cultivation of jatropha on good farmland causes competition with food crops.
    - Jatropha oil production seems to be costlier than expected. In many cases it is not profitable and farmers abandoned its cultivation.
    - The energy balance of intensive cultures of jatropha is either not positive or only slightly positive when only the oil is considered as output.
    - The cultivation of jatropha in hedgerows with a valuable multipurpose function seems to be the only profitable option for farmers.
    - There are several oil mills and presses available on the market. However an economically sound and reliable extraction of qualitative acceptable oil is still a chal-

lenge. Many presses used in the projects are still being improved. At least in Africa a standard extraction technology is not readily available.

- Building up a complete local electricity supply system is far more complicated and costlier than expected. The upstream part especially with logistics for collection, transport, processing, and oil fruit or fuel storage turned out to be very challenging. In many cases growers are geographically dispersed and have yet to produce sufficient quantities of seeds to achieve the economies of scale necessary for efficient biofuel processing.

Information from the field indicates that the real efforts and costs that go into producing SVOs are considerably higher than what most reports or feasibility studies indicate. Field experience reveals costs for SVO fuels to be slightly below the retail price of diesel and hence questions the profitability of SVOs.

SVO markets and availability will change considerably in the next few years. The demand from industrialised countries for biofuel will persist. However only certified biofuels will have a chance on this global market. The implications of the global market for local consumption can be manifold but still remain largely unclear. Prices can rise due to high demand. However production of SVOs will increase, the infrastructure and services will develop from agriculture extension services, over transport, storage and processing facilities to the availability of appropriate engines. Leftover oil that is not appropriate for the global market may become available and affordable for local use..

5 Outlook & Recommendations

The quest for locally available energy from plants should not focus exclusively on oil. Most of the biomass energy produced by oil plants is not fixed in the oil but in its woody parts. Hence **an integrated energetic use of the plants including the woody parts could lead to profitability and to a more positive energy balance for local energy generation**. Appropriate livelihood systems for the integrated use of oil-bearing energy plants have to be studied and concepts for the beneficial utilisation of plants as a whole have to be developed. This could include usage as forage, digestion in biogas plants or application as solid fuel for household stoves, industrial processes or power plants. The profitability of a plant oil producing system depends considerably on the possibilities for an economically sound use of all by-products.

The quest for appropriate locally produced fuel should not focus only on one plant such as jatropha, but consider all possible oil sources and their flexible use. Besides jatropha there are numerous wild growing species like croton. Oil, which is generally appropriate for human consumption, might be used as fuel in case of very low prices or low quality. The flexibility of engines to use diesel or SVO provides the opportunity for flexible fuel use according to the current market situation.
One reason for the public focus on jatropha was the expectation that this plant would not compete with food crops. However projects worldwide showed that non-edible oil plants compete with food crops spatially. For farmers it is an advantage to produce oil with multiple purposes that can be sold on different markets. In any case the balance between food and cash crops has to be considered.

Several international standards for sustainable biofuel production have been developed or are being discussed. Most of them focus on biofuel production for the international market. **Future projects on local biofuel use should be based on minimum standards for sustainability.** Such standards and related indicators have to be effective and transparent but also have to be easily applicable and practicable in rural environments with large groups of smallholders. An example of such an approach is the Dutch 'Testing Framework for Sustainable Biomass' that was tested in Mozambique in the context of the Dutch-German Partnership 'Energising Development' (GTZ, April 2009). Further developments of this kind are necessary.

Documents and Literature

Burell, Tom: Rijssenbeek, W. & Wijgers, I. 2007: Garalo Bagani Yelen - Jatropha-fuelled rural electrification for 10,000 people in the Commune of Garalo. Progress Report Dec. 2007. 22p. http://www.fact-foundation.com/en/Biofuel_Projects/Biofuel_Projects/Mali/Output.

CENTRE NATIONAL DE L'ENERGIE SOLAIRE ET DES ENERGIES RENOUVELABLES (CNESOLER), 2004: Programme National de Valorisation Energetique de la Plante Pourghere. 2p. Folder of Programme 2004-2008, MINISTERE DES MINES DE LENERGIE ET L'EAU, Mali
http://www.riaed.net/IMG/pdf/depliantPNVEP-2.pdf

Cloin, J. et. al., 2005: Cocogen Feasibility Report: The use of coconut oil in EPPC power generation, Final Draft. SOPAC, Fiji Islands.

Cloin, J. 2007: Liquid biofuels in Pacific island countries. SOPAC Miscellaneous Report 628. South Pacific Applied Geoscience Commission, Suva, Fiji.

COMPETE, 2008: Summary report on COMPETE India Field Visits & 5th International Bio-fuel Conference February 4 - 8, 2008.
http://www.compete-bioafrica.net/events/events2/seminar_india/ppt/COMPETE-FieldVisitIndia-Feb2008-Summary-080215-Final.pdf

Expert Group Meeting on Small-scale Production and Use of Liquid Biofuels in Sub-Saharan Africa: Perspectives for Sustainable Development, 29-30 March 2007, United Nations, New York.
http://www.un.org/esa/sustdev/sdissues/energy/op/biofuels/biofuel_programme.pdf

FACT foundation, 2010: FACT comments on "Jatropha! A socio-economic pitfall for Mozambique" by Justiça Ambiental (JA) & União Nacional de Camponeses (UNAC). 2p.
http://www.tanariverdelta.org/tana/9101-DSY/version/default/part/AttachmentData/data/FACT%20comments%20on%20JA-UNAC%20Jatropha%20Study.pdf

FAO, 2009: Small-Scale Bioenergy Initiatives: Brief description and preliminary lessons on livelihood impacts from case studies in Asia, Latin America and Africa. FINAL REPORT. Prepared for Policy Innovation Systems for Clean Energy Security (Pisces) and Food and Agriculture Organization of the United Nations (FAO) by Practical Action Consulting. Rome, January 2009.
http://www.fao.org/docrep/011/aj991e/aj991e00.HTM

GERES 2004: Project description Biofuel for Sustainable Development and Poverty Alleviation in Rural Cambodia.
http://www.jatropha.de/Cambodia/CambodiaBiofuelProjectDescription%20WebDe.pdf

GTZ, Dec. 2009: Jatropha Reality Check - A field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya. Study conducted by Endelevu Energy World Agroforestry Centre on behalf of GTZ - Regional Energy Advisory Platform East Africa. Nairobi, Dec 2009. 147p.
http://regionalenergynet.com/images/Publications/Reports/GTZ%20Oilseed%20Study%20Kenya_2009.pdf (9MB)

GTZ, Aug. 2009: Access to Modern Energy Services Mozambique (AMES-M) - Final Report of the component "Sustainable Biomass Electrification" (Biogrid) 30 August 2009.

GTZ, April 2009: Testing Framework for Sustainable Biomass - Field Evaluation Analysis in Mozambique & Enabling Framework for Implementation. Eschborn, 43p.

Justica Ambiental & Uniao Nacional de Camponeses, Aug. 2009: Jatropha! A pitfall for Mozambique. 52p.
http://www.swissaid.ch/global/PDF/entwicklungspolitik/agrotreibstoffe/Report_Jatropha_JA_and_UNAC.pdf

Oberländer, Dieter, 2008: Lateinamerikas neue Ölquelle entspringt auf einem Baum. Steinbeis-Transferzentrum Agrar-, Umwelt- und Energietechnik an der Universität Hohenheim. (Latin America's new oil source comes from a tree. Steinbeis Transfer Centre for Agricultural, Environmental and Energy Technology, University of Hohenheim)
http://www.bioregio-stern.de/lateinamerikas_neue_oelquelle_entspringt_auf_einem_baum

Owsianowski, Rolf Peter et.al. (2008): Projekterschließung Senegal - Erneuerbare Energien und ländliche Elektrifizierung. Länderreport & Marktanalyse. Ein Projekt im Rahmen der Exportinitiative Erneuerbare Energien. 84p (Senegal project development - Renewable energies and rural electrification. Country report and market analysis. A project in the framework of renewable energies export initiative.)

Prueksakorn, Kristina et.al. 2010: Energy analysis of Jatropha plantation systems for biodiesel production in Thailand. In Energy for Sustainable Development 14, p.1-5.

Rai, Kavita and Sarnaik, Jayant, 2009: Successful utilisation of indigenous bioenergy resources for economic advancement in rural Maharashtra, India. In Boiling Point, Issue 56 p.18-20.

USAID, 2009: Empowering Agriculture: Energy Options for Horticulture. 86p.
Prepared by Winrock International. Chapter 6: Biomass-Based Fuels for Shaft Power, Electricity and Process Heat describes options and limitations of vegetable oil as fuel for local use and case study: Jatropha Oil as Renewable Fuel Source for Multifunctional Platforms in West Africa.
http://www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/empowering_agriculture.pdf

Vukikomoala, Frank, 2010: Coconut oil - combining energy supply and income diversification. In: Rural 21 - 06/2010 p. 29-31.

The World Bank, Asia Sustainable and Alternative Energy Program, 2009: Pacific Islands - Coconut Oil Power generation: A how-to guide for small stationary engines. 40p. http://siteresources.worldbank.org/EXTEAPASTAE/Resources/Coconut-oil-Power-gen_How-to-guide-for-small-stationary-engines-Feb-10.pdf

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