Lao
Institute for
Renewable
Energy




Viability village-scale study for rural electrification by straight vegetable oils in Ban Bouampoh, Luang Prabang Province, Laos

Final Report

Vientiane, 10.11.2010

Lao Institute for Renewable Energy

LIRE

FINAL REPORT # FONDEM-BF-RE-2.1

Viability village-scale study for rural electrification by straight vegetable oils in Ban Bouampoh, Luang Prabang Province, Laos

Maja Bormann
Edward Allen
Tom Koskella
Gregoire Pelletreau

Vientiane

10.11.2010

About us

LIRE is a non-profit organisation dedicated to the sustainable development of a self sufficient renewable energy sector in the Lao PDR. The institute offers agronomical, technological and socio-economic research services, and works to provide a free public resource of information and advice on the use of renewable energy technologies in Laos. LIRE strives to support the development of the country by exploring commercially viable means to establish renewable energy technologies in rural parts of the country, in areas without connection to the national grid and with little access to technical expertise.

ສູນຄົ້ນຄ້ວາ - ທົດລອງດ້ານພະລັງງານທົດແທນ

Lao-Thai Friendship Road, House No. 366,
Wattnak village, Vientiane, Lao PDR
P.O. Box 8010

Tel: +856 21 353 430. Fax: +856 21 353 897.
Email address: contact@lao-ire.org.
Web-site: www.lao-ire.org

Contents

List of figures

List of tables

List of abbreviations

ADB	Asian Development Bank
DAFO	District Agriculture and Forestry Office
EDL	Electricite du Laos
FGD	Focus Group Discussion
GoL	Government of Laos
NTFP	Non Timber Forest Products
PAFO	Provincial Agriculture and Forestry Office
PDEM	Provincial Department of Energy and Mines
SVO	Straight Vegetable Oil

Exchange Rate (November 2010):

8,070 LAK = 1 US$

11,300 LAK = 1 €

Executive summary

The rural village Ban Bouampoh is located in Phoukhoun District, Luang Prabang Province. Ban Bouampoh is considered a low-income village, based mainly on low accessibility and subsistence farming. NTFPs and fishing are important nutrition sources next to rice cultivation and the production of sesame, garlic and peanuts. Villagers are farmers and occupied all year long. However, the additional labor capacity is estimated at 0.5 ha per person. Furthermore, each household possesses an additional unused 0.6 ha that could be used for energy plantations. Economic activities are quite undeveloped in the village due to a lack of market. So far, only traditional lighting sources, mainly kerosene lamps, are used. Hence the current electricity demand is low, used mainly for lighting purposes, but economic and social activities could increase after electrification.

Jatropha curcas and cotton are the main existing wild crops in the village. Jatropha curcas is used for fences only, with a measured length of approximately 1,000 m of matured plants within the village. Cotton is cultivated to produce yarn for weaving by women on a subsistence level, with a small number of plants in front of each house. Women are interested in the extension of the production if a market is available. Villagers agree on the potential, facing labor and land capacity, to extend Jatropha and cotton production for village electrification purposes.

The evaluation of energy demand entails different scenarios including electricity demands of 4 and 8 hours per day. With regards to the current available feedstock of Jatropha and cotton, there is currently sufficient supply for only 24 minutes per day to service all households. Hence additional cultivation of Jatropha as hedges or plantations, extension of cotton plantations and/or the purchase of feedstock of neighboring villages are considered in this report in order to address short and long term feedstock supply.

The economic analysis for the 4 hour per day scenario is viable, however this assumes a market price for the selling of residues. The 8 hour per day scenario is mainly limited by the inability of villagers to pay a higher monthly tariff. However, with an increase in economic activities, spending power should increase over time.

After evaluating the collected data from a thorough site visit, this report supports the implementation of electrification using Straight Vegetable Oil (SVO). Villagers are very interested in village electrification and agreed on providing land, labor and time for the cultivation of oil crops. Furthermore, they also showed a willingness to pay for the connection and monthly bills. Ban Bouampoh shows a favorable local environment and a potential production under high environmental conditions. All these indicators make Ban Bouampoh a potential location for the implementation of this pilot.

A literature review on similar projects identified a successful pilot using SVO in India. The Life Cycle Analysis of this method of electrification reduced greenhouse gas emissions by a factor of 7 compared to a diesel generator or to a grid connection.

1 Introduction

1.1 Context

The Fondation Energies pour le Monde (Fondem) has been implementing rural electrification projects based on renewable energies in Laos for 15 years. Fondem has now decided to investigate the possible use of Biofuel for rural electrification projects in a Lao context, in line with the new national and provincial strategies. In 2008 a first study was conducted and Ban MuangChiem, Phoukhoun District, Luang Prabang Province was identified as a potential pilot village. However, due to new electricity plans the village had to be changed to Ban Bouampoh located in the same District.

Biofuel technology on a village scale is at an infancy stage in Laos with very little data available and no current experience. In this context Fondem wants to go deeper into the analysis of the conditions for viability of an electrification project using vegetable oils in Ban Bouampoh, in cooperation with a local expert consultant, the Lao Institute for Renewable Energy (LIRE). The detailed understanding at village scale as well as indicators and the methodology developed for the study is necessary to proceed with the study of Biofuel opportunity in Lao PDR.

1.2 Biofuels development in Lao PDR

The Lao People's Democratic Republic (Lao PDR) is a landlocked country that is among the Least Developed Countries worldwide. Most of the population depends primarily on biomass (fuel wood and charcoal) for its domestic energy needs and on petroleum products (100 % imported) for its commercial and transportation energy needs. In 2008, about 350 million liters of petroleum (gasoline and diesel) were imported, costing US$203 million[1]. Since 2000, the importation of oil to the Lao PDR has increased by 5 % annually and it is estimated that the use of fuel oil will increase by 10 % annually in the future, which will further increase the burden on the national economy. Since 2006, the national government has recognised that the production and use of bio-energy offers multiple advantages: protecting the local environment and fighting against global warming[2], sustaining economic growth and reducing poverty while better balancing its dependency on fossil fuel imports and controlling inflation[3]. Besides the production of Biofuels on a commercial scale which mostly intends to produce Biodiesel for the transport sector, it can also be produced and utilized on village and community level. Rural electrification which is operated by locally produced Biofuel offers a good opportunity to achieve a great benefit from locally produced Biofuel based on an environmental friendly source of energy.

Currently 80 % of the population is living in rural areas and only 43 % of these people have access to a modern energy forms, such as electricity. Having access to modern energy could enable people in rural areas to pump clean water and light their houses and schools. The government of the Lao PDR is planning to extend grid electricity in remote rural areas. However, it is expected that they will not be able to provide electrification to the whole country because it is too expensive to construct new

[1] Lao State Fuel Company

[2] The Government of the Lao PDR ratified the Kyoto Protocol in 2003

[3] National Socio-Economic Development Plan 2006-2010, Government of Laos, Vientiane, Lao PDR

grid lines for small villages. Therefore, off-grid renewable energy technologies are crucial tools for reaching the ambitious government aim to provide 90 % of the total population with electricity by 2020. The National Biofuels Decree has been enacted, stating that the Government of Laos is committed to 10 % biofuels by 2025.

LIRE's own research work on Biofuels continues to focus on finding appropriate pro-poor sustainable approaches to Biofuels development. We understand that different Biofuels production works best at different geographic scales, with Straight Vegetable Oil (SVO) being an appropriate village scale technology. This is due a low investment requirement, no required external chemicals and the only waste-stream of press-cakes, which does not require treatment. All in all, it has been shown in other countries to be an appropriate technology for an off-grid setting.

1.3 Village change

According to the information provided by the Provincial Department of Energy and Mines (PDEM) and Electricite du Laos (EDL) located in Luang Prabang, there are no electrification plans for Ban MuangChiem, Phoukhoun District, Luang Prabang Province. However, arriving in Phoukhoun at the District Office the team was informed by the Administration Office that EDL actually has plans to electrify Ban MuangChiem by 2015. On further investigation it appears that the District authorities have applied to the Provincial authorities for Ban MuangChiem to be electrified but the Provincial authorities have not currently included it in any of their plans. The study team decided to visit Ban MuangChiem in order to recheck this information. However in Ban MuangChiem the team was informed by the village chief that the village will in fact be electrified in the next 5 years. This new up to date information is the main reason for changing the village. Furthermore with villagers believing electrification is coming very soon, they appeared to have no interest in a vegetable oil based energy generation solution.

During this trip, the Administration Office recommended Ban Bouampoh, a site in the same District with potential Jatropha reserves and no planned connection to the national electricity grid. The next section describes the site visit to the changed village and the report's findings.

1.4 Methodology

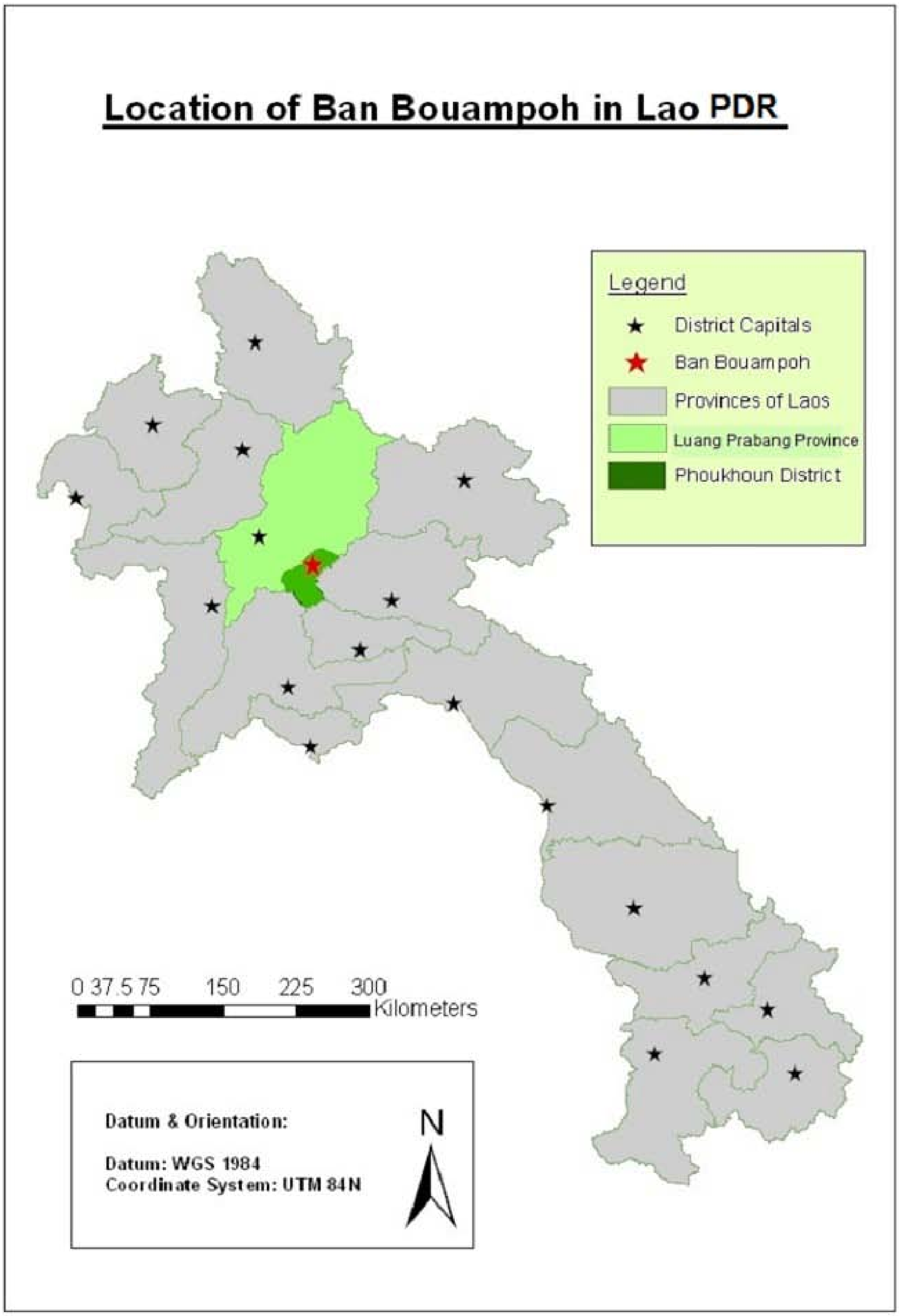
The field trip was conducted between the 5^{th} and the 9^{th} of September, 2010. In Phoukhoun the consultants visited the governmental District Office to inform the District Deputy Chief and the Chief of the Agriculture and Forestry Office about the scope of this field mission. It is important to mention that there is no representative of the Ministry of Energy and Mines located in Phoukhoun. However, the Provincial Department of Energy and Mines (PDEM) contacted the District Office and informed them of the scope of the project. Mr. Somai from the District Agriculture and Forestry Office (DAFO) was assigned to join the team in the field. It turned out that Mr. Somai is very knowledgeable of the village situation and was a great help collecting the required data.

The consultants stayed one and a half days in Ban Bouampoh. During the first day a comprehensive village survey was conducted in order to gain an overview of the village. In the afternoon a village meeting was held with 80 % of the villagers participating, explaining the scope of the study. To ensure a mutual understanding, the prepared information sheets were provided and staff were available to directly answer any questions raised by villagers. In order to estimate the interest of villagers the group was divided into two groups: interested and less interested groups. Encouragingly, more than 80 % of the villagers were interested in the project.

In order to conduct the Focus Group Discussion (FGD) the consultants randomly selected people out of each group to ensure a gender balance. Furthermore the Village Chief, Mr. Siphan, and the head of the Development Group, Mr. Boualoy, were also participating in these discussions. All the involved villagers showed a high interest and freely shared their viewpoints. However, where estimations (yield estimation, risk assessment etc.) were asked for, it was difficult for the villagers to provide reliable answers. In this area the experiences and knowledge of consultants were used to estimate these aspects. The second day was used to conduct individual interviews and inventory the non-domestic facilities. In total 27 individual interviews were conducted, representing 30 % of the village population. Interviews were conducted with one representative of each household. Furthermore, technical analysis was conducted and in the end a summarizing clinic session was provided to the villagers.



1.5 Overview Ban Bouampoh



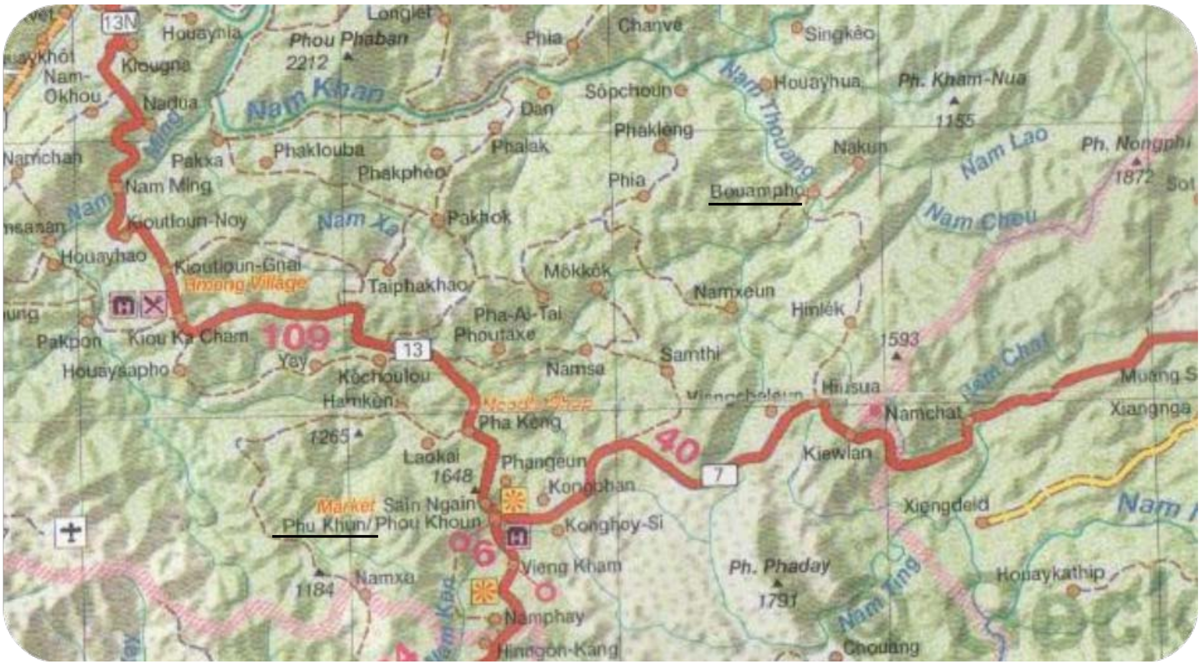


Table 1: Overview Ban Bouampoh

Indicator	Content
Households	86[a]
Total population	686 (305 women)[a]
Average size of households	6.9 person per hh[b]
Ethnic groups	Lao Loum; Lao Theung[c]
Average income (2010)	329,327,000 kip/year (3,360,000 kip/hh); Low income village[b]
Village chief	Mr. Siphan
Accessibility from District capital	Rainy season: 30 km on asphalt road and then 35 km dirt road (2 to 2 ½ hours); Dry season: 30 km on asphalt road and 35 km on dirt road (1 ½ to 2 hours)
Climate	Tropical climate zone
River	2 rivers
Main food crops	Rice, maize and vegetables
Main cash crops	Sesame and garlic
Economic activity	Low and stable
Availability of wild oil species	Jatropha curcas, Stone Jatropha and Cotton
Possible crops for plantation	Jatropha curcas, Stone Jatropha and Cotton
Availability of Jatropha hedges	1000 meters (within village)[c]
Labor force	79 male; 109 female (approximately 0.5 ha/person)[c]
Irrigation system	Traditional system
Additional need of irrigation	Additional need for approximately 5 ha[c]

[a] Information received by DAFO; [b] Information based on Individual Interviews; [c] Information based on FGD

Ban Bouampoh is located in a valley in the South-East of Phoukhoun District, Luang Prabang Province (GPS coordinates: 48Q lat 19,6219166 long 102,6263611). With 86 households, Ban Bouampoh is considered a large village. Two main ethnic groups are represented in the village: 80 % of the population Lao Theung and 20 % Lao Loum. These figures are based on the total number of 686 villagers, with the following gender distribution:

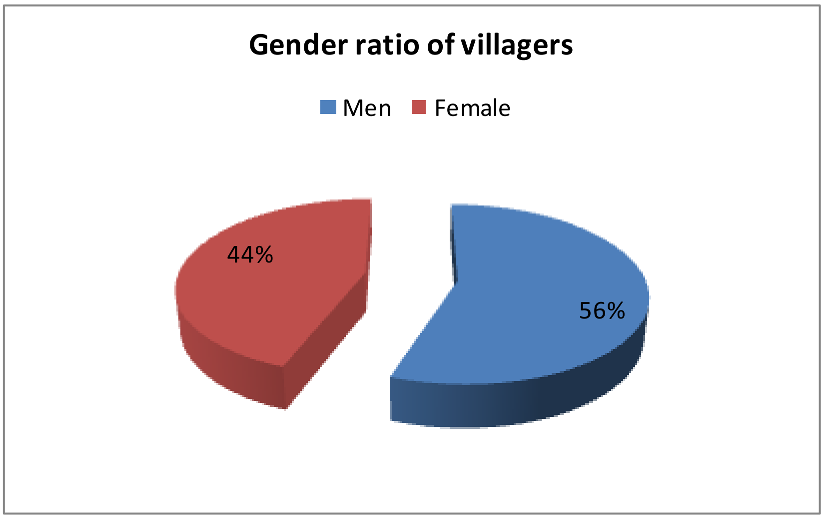


Figure 1: Gender ratio of villagers

The village is located in a tropical climate zone with high temperatures (32 °C during the day and 19 °C during rainy season, in the dry season it is cooler but never drops below 10 °C) and an elevation of 462 meters. Two rivers, Nam Thouang and Nam Lao, cross the village. Both rivers have a span of 20 meters during the rainy season and 10 meters in the dry season. During rainy season the village is more difficult to reach by car, however from the District capital Phoukhoun it is possible using 30 km asphalt road and 35 km on narrow dirt road, totaling 2 to 2 ½ hours. The accessibility is often limited in the rainy season due to soil erosion along the way. Furthermore it needs to be mentioned that after heavy rain, accessibility is reduced due to slippery roads, even with a 4x4 vehicle. Accessibility is an important aspect to keep in mind and it is recommended to plan major transport activities during the dry season.

Ban Bouampoh is located in a village cluster, including Ban Hinlek and Ban Nakun. The villages are between 1 and 4 hours travelling time apart, depending on weather conditions. Furthermore, relations between the villages are good and stable, with 2 to 3 meetings per year and 2 traditional celebrations in January and May. Mr. Boualoy is the Head of the Development Group. He is employed by the GoL and responsible for the development of the cluster. Hence he is under close leadership of the GoL and can be seen as a link between the village cluster and District authorities. Problems identified by the Development Groups are directly reported to the Chief of District in order to discuss solutions.

The average total income of the village is 329,327,000 kip/year (2010), dividing this amount by number of households results in a figure of 3,360,000 kip/hh/year. This information is based on the FGD, comparing the figure with the result of individual interviews (300,000 kip/hh/month) increases the reliability of this figure. However, based on the average agricultural income of 500,000 kip/hh/month in rural Laos, this would be classified as a low income village. Another indicator that underlines these poor conditions is the need to buy additional food, in particular pork meat. The following graph shows the distribution of households affected and unaffected by food shortage:

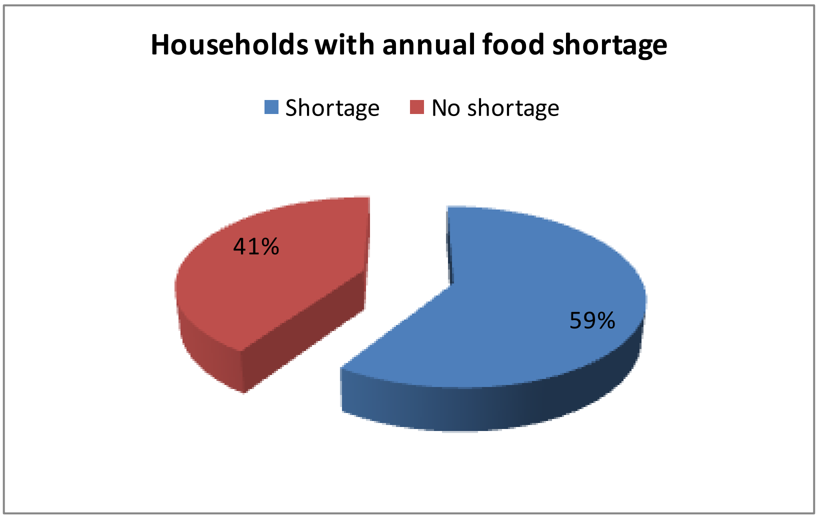


Figure 2: Households with annual food shortage

Based on the FGD, the rice production is sufficient in the village and basic food crops are meeting the subsistence demand of the households. However during the individual interviews 60 % of those interviewed mentioned that their households are facing rice shortages along with meat and fish, occurring in August, September and October. These peak times are mainly referring to rice shortage in the month before rice harvest in November. It is important to note that multiple answers were given by the interviewees.

The graph below shows the peak month of food shortage based on all interviewed households:

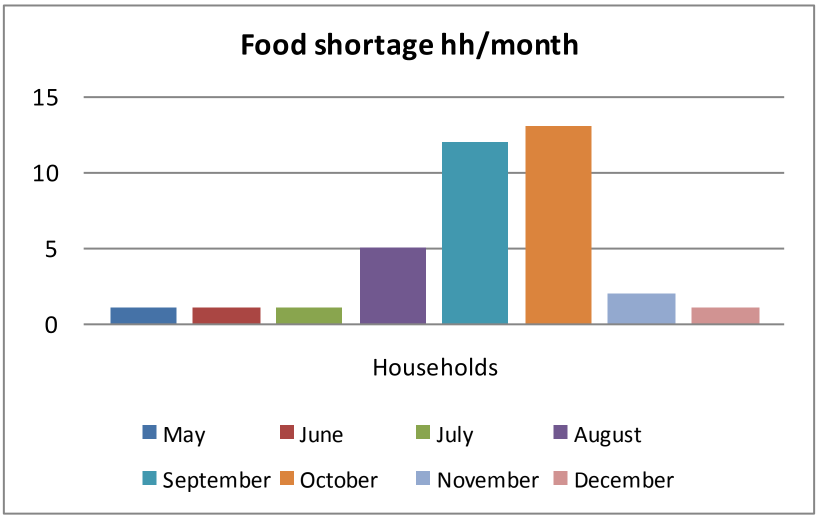


Figure 3: Food shortage household per month

In addition, the economic activities in the village are quite basic: there are 6 small grocery shops, 9 rice mills and an unknown number of alcohol processing equipment. Grocery shops are very basic and mainly located in the main room of a household or in a small bamboo hut in front of the house. Rice mills are located close by the households and shared with the community. The production of alcohol is on a small-scale and for self consumption. Evaluating this subsistence economy leads to the assumption that village-based economic activities are basic but stable.

2 Agricultural profile

2.1 Overview

Agricultural activities are the main income for villagers. According to the FGD, the soil is good and all types of tropical crops can be grown. The village mentioned that there are regular droughts between June and July and that the rain is sometimes not enough for rice production in the rainy season. They combat this by using a traditional irrigation system. Traditional irrigation systems do not need any manual pumping. Instead, channels are formed in order to flood the rice fields with water.

Important food crops of Ban Bouampoh are rice (upland and lowland), maize, cucumber, chili and eggplants. These products fulfill the demand of households and surpluses are sold on the market in Phoukhoun. Surpluses are sold as raw material; there are no forms of value-adding taking place. Extra meat needs to be purchased, especially between July and October. This is the peak time for agricultural activities and less time can be spent on hunting and fishing. However, next to rice, NTFP and fishing are important food sources to meet the nutrition demands of the households. Villagers do have a large number of pigs, however butchering facilities are located in Phoukhoun, with the meat then purchased at a higher cost.

The most important cash crops are sesame and garlic. Villagers sell these products on the market in Phoukhoun and consume surpluses. There is no market available within the village. In this case surpluses are sold as raw material as there are no forms of value adding taking place. Of interest to this study is the possibility of villagers producing oil out of sesame, however at present no crops are used in this way.

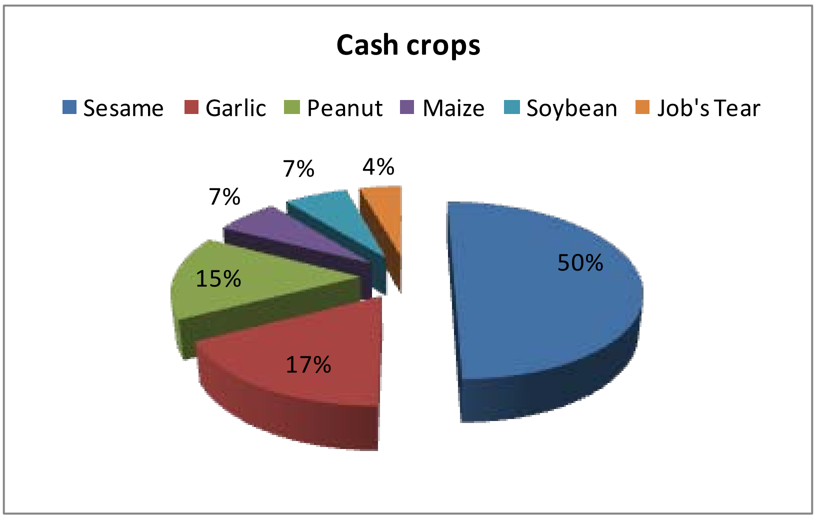


Figure 4: Cash crops

The livestock sector is of secondary importance for village income. Interesting to note in this survey is the fact that pigs are kept within fences. In general it is more common in Laos that animals are freely grazing on village land. In Ban Bouampoh, pigs are partly fenced by bamboo hedges but there are also many Jatropha hedges used. There is also further potential to increase the use of Jatropha hedges for pig fencing.

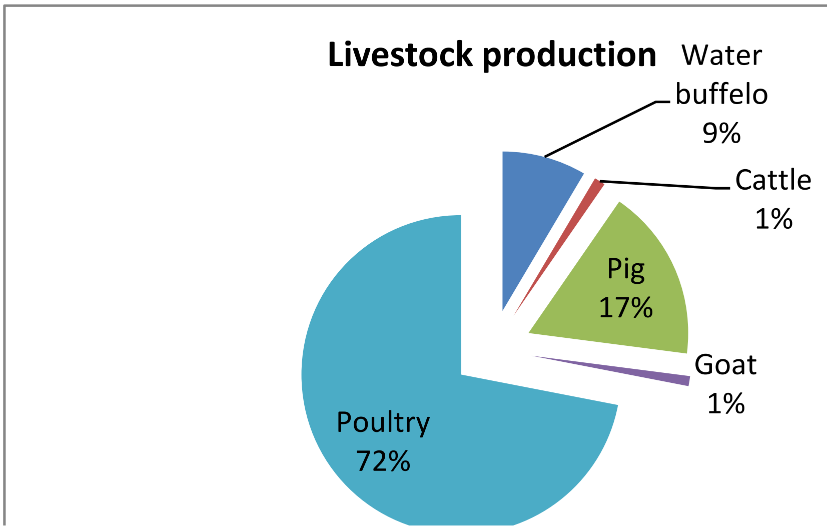


Figure 5: Livestock production

The main crop used as animal fodder, for pigs in particular, is the rice husk as a by-product of the milling of the rice. Furthermore there is a small amount of cassava, maize and vegetables used directly as animal fodder. All other livestock graze naturally. This information is also confirmed by individual interviews. Farmers do not have large areas dedicated to animal fodder production. Only a small amount of land around the house is used for cassava and maize cultivation.

Non-Timber Forest Products (NTFPs) are very important for villagers, particularly between December and January. During this time they collect suitable grass for traditional broom production. In addition, NTFPs are an important food source for the villagers, mainly in low agricultural seasons (November to April).

The labor aspect is of high importance in the Lao context. Due to the low population density, a shortage of labor is the main constraint to agricultural productivity. Based on the information of the FGD one person has the capacity to cultivate approximate 0.5 ha. This figure is also confirmed by the figures found in the individual interviews, listed as 0.7 ha. However, the consultants will use the conservative figure of 0.5 ha for further calculations in the report.

Apart from these labor availability figures, it was also shown that each household has access to uncultivated 0.6 ha of land which could be cultivated for additional energy crops.

The total amount of arable land in the village amounted to 6298 ha. The main food crop, rice, is cultivated as upland rice on 76 ha and as dry rice on 14 ha. 177 ha are used for cash crop production but unfortunately detailed data on each crop is not available. Around the village is 1,350 ha used as conservation forest (no NTFP and no logging), 1,650 ha as utilization forest (for NTFP collection and logging) and 920 ha as protection forest (for NTFPs collection but not logging).

Table 2: Characterization of forest classification

Classification	Characterization
Conservation Forest	Protection of biodiversity. Collection of NTFP and logging is not allowed.
Utilization Forest	Villagers are allowed to use forest for NTFP collection and logging but have to ask the GoL for permission. Furthermore the GoL is also allowed to use this forest for logging activities.
Protection Forest	Forest that is located close to rivers, on sloping land and close to slash-and-burn areas in order to reduce soil erosion. Collection of NTFP is allowed but not logging.

2.2 Seasonal cropping calendar

Table 3: Overview seasonal cropping calendar

	Rice	Sesame	Garlic	Peanut	NTFP
January			No activity		Peak collection
Febuary		Field prep.	Harvesting		
March		Planting			
April		Planting			
May	Field prep.	Weeding			
June	Planting	Weeding			
July	Planting	Weeding		Planting	
August	Weeding	Weeding		Weeding	
September	Weeding	Harvesting		Weeding	
October	Weeding		Planting	Weeding	
November	Harvesting		Planting	Harvesting	
December			No activity		Peak collection

Note: Based on initial survey

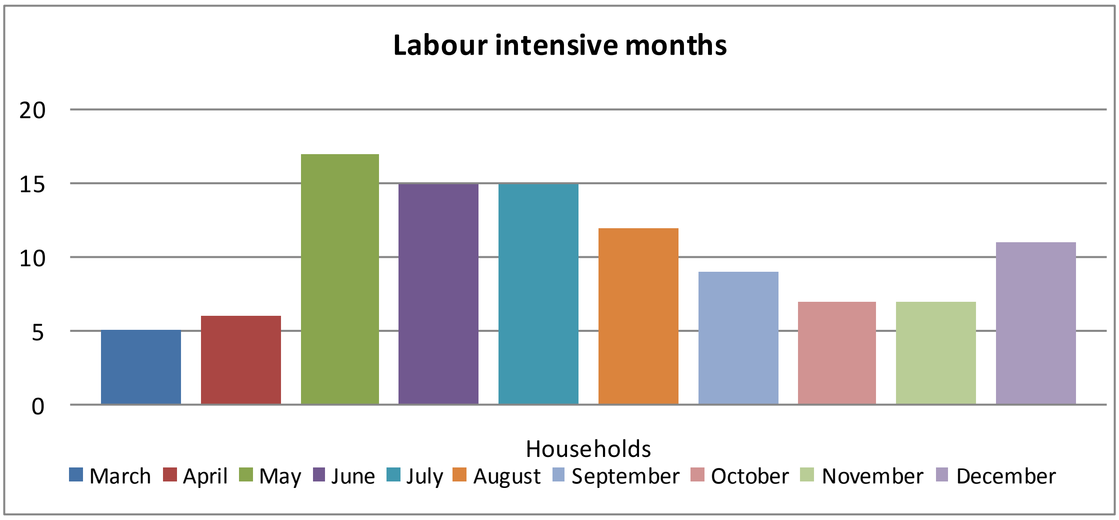


Figure 6: Labour intensive months

This graph shows a constant labor intensity with main peak times in May, June and July due to rice cultivation and weeding. There should be another peak in November due to rice harvest, however this information is not clear due to the small sample size.

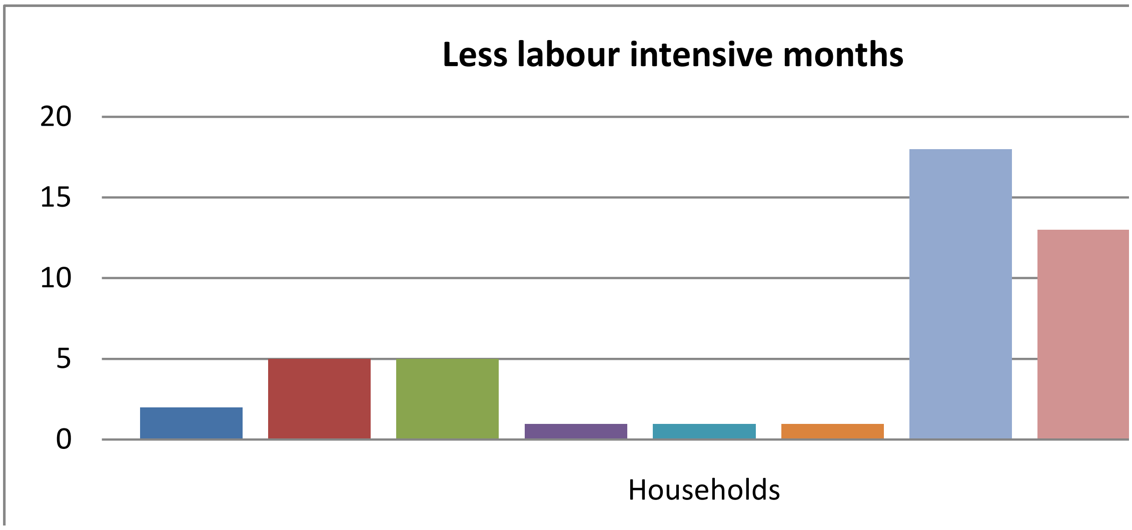


Figure 7: Less labour intensive months

January and February are less labour intensive in regard to agricultural production. However in this case it is important to mention that villagers are occupied with the collection of NTFP, which is an important food source.

Based on these graphs it is assumed that villagers are occupied with agricultural production all year round.

2.3 Conclusion

Villagers of Ban Bouampoh are mainly subsistence farmers, only selling surpluses on the market. NTFPs and fishery are important nutrition sources next to rice and crop production. The small labor force is the main constraint to agriculture productivity. The actual labor capacity is 0.5 ha per person. Each household possess additional 0.6 ha which are unused and could be used for energy plantations.

3 Energy demand survey

3.1 Economic activities

The economic activities in the village are quite basic: there are 6 small grocery shops and 9 rice mills. So far, the dynamics of village-based economic activities are stable, however the use of rice mills did increase in recent years due to population growth. Unfortunately, there are no detailed figures of recent population growth available, however this issue may be addressed in the next field trip. Based on the Individual Interviews, there is a peak time for the use of rice mills after the harvesting of rice in November.

3.2 Social activities

Social activities are also basic, there are celebrations and ceremonies such as weddings and funerals all year round. Nearly every interviewee mentioned that light bulbs, TV and CD player are fundamental appliances and will be purchased after connection to an electricity source.

3.3 Domestic demand

Based on the FGD, electricity will be needed every day, especially at night time. The demand will increase due to increasing uptake of lighting in houses and shops and the potential economic activities, including a repair shop and carpenter. Some villagers are also interested in purchasing a refrigerator but this would require a 24 hour supply. This requirement would increase the fuel demand and is addressed later in the report.

3.4 Current energy sources

There is one solar system installed at the health center, donated by the ADB. 16 households receive electricity from private Pico hydro turbines. However, these are only used in ideal flow conditions depending on the availability of water. Although the system is relatively simple, regular maintenance is performed by the owners on a monthly basis. Basic knowledge of turbines, generators and transmission lines is therefore already present within the community and this technology awareness should transfer easily to other electrification methods proposed.



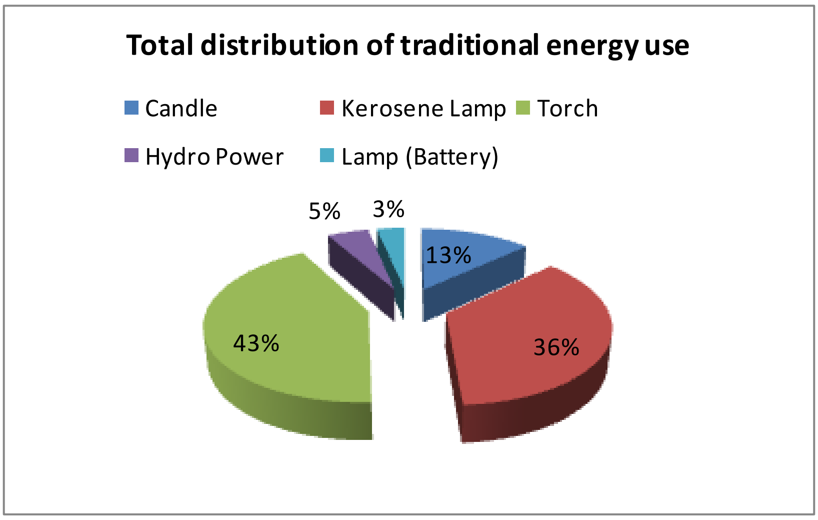


Figure 8: Total distribution of traditional energy use

Kerosene lamps are the main source of current energy, used mainly for lighting purposes. Some families use candles as these are cheaper than kerosene. Torches are in particular used for hunting and walking in the village and surroundings at night.

3.5 Inventory non-domestic facilities

The amount of non-domestic facilities is low. However the consultants conducted a representative inventory concerning potential electrical consumption. All interviewed facilities are interested in receiving electricity and are willing to a pay a connection fee and monthly bills. The most important appliance would be the installation of light bulbs. This would increase activities in the night: Additional teaching and village meetings would also be held at night. The grocery store would also include other electric appliances including a refrigerator if possible.

Table 4: Inventory non-domestic facilities

Type	Amount	Electrification
Primary and secondary school	1	Yes
Public health center	1	No (Solar home system)
Village office	1	Yes
Association (Development group)	1	Yes
Grocery shop	6	Yes
Rice mills*	9	Potential

*Rice mills currently use diesel generators. Potential for switching to SVO powered grid. Rice mill power demand currently unknown.

3.6 Irrigation

23 households are using traditional irrigation systems. In total there is a 1 km long canal that irrigates 14 ha of rice in the rainy season and onions in the dry season. Villagers mentioned that there is a need for additional irrigation for approximately 5 ha of potential rice production.

Villagers currently use traditional techniques and no technical equipment is used. In addition, electrical equipment is difficult to access. There are no nearby markets to purchase this equipment, with the closest market in Luang Prabang. Furthermore, villagers do not have the financial capacity to buy irrigation equipment. Irrigation is needed for rice in the rainy season and for cash crop production in the dry season. Hence, there would be an electricity load throughout the year, however still low due to the small amount of area.

The irrigation policy of the GoL encourages people to contribute and participate in the expansion of irrigation development. The goal is to obtain high efficiency irrigation, to set standards and criteria for water use management and to protect the environment. LIRE is not aware of any small scale electrified pumping systems in Laos used by villages to increase agricultural yield.

3.7 Conclusion

Economic and social activities are quite undeveloped in the village. However this is partly due to the lack of electricity. The current electricity demand is low, mainly for lighting purposes, however economic and social dynamics might increase after electrification. 100 % of the villagers are interested in electricity and are willing to pay a single connection fee and monthly bills.

4 Evaluation of energy demand

The evaluation of energy demand entails different hypotheses and predictions on the use of energy. In the following chapter, the energy demand of the village will be categorized into three scenarios:

- Low-demand scenario (Scenario 1)
- High-demand scenario (Scenario 2)
- Irrigation scenario (Scenario 3)

For each scenario, the data collected from Ban Bouampoh will be used and an energy demand calculated. This will help in estimating the amount of electricity to be produced to ensure sufficient supply using vegetable oil.

4.1 Scenario 1: Low-demand

In this scenario, it is assumed that the demand of energy in the village is only a domestic one, only concerning households. In accordance with the Foundation's past experiences in Laos, the mean daily demand in energy of a rural household is characterized by the following elements:

- Monthly energy demanded per household = 3.5 kWh / month
- Maximum power demand per household (W) = 40 W
- Duration of use = an average of 4 hours per day (in the evening)
- Connection rate of households in a village = 75%

Total demand can be calculated with the following formula:

Total energy demand (*kWh/month*) = *Amount of households***Connection rate** *Energy demand* (*kWh/month*)

The peak power demand can be calculated with the following formula:

Power peak demand (*W*) = *Number of households* **Connection rate* * *Peak demand* (*W*)

Table 5: Low demand scenario

Scenario 1	
Village	Ban Bouampoh
Energy demand kWh/month	226
Peak demand (W)	2,580

4.2 Scenario 2: High-demand

In this scenario, it is assumed that the demand in the village is composed of a domestic demand for the village households, as well as a demand in energy for economic and social activities. In accordance with the Foundation's past experiences in Laos, the daily demand in energy in the village is evaluated based on the following elements:

- Mean monthly energy demanded per household = 5 kWh / month,
- Duration of use = an average of 8 hours per day
- Maximum power demand per household (W) = 90 W
- Connection rate of the households in a village = 70%

Total demand is calculated with the following formula:

Total energy demand (*kWh/month*) = *Amount of households***Connection rate** *Energy demand* (*kWh/month*)

The peak power demand can be calculated with the following formula:

Power peak demand (*W*) = *Number of households* **Connection rate* * *Peak demand* (*W*)

Table 6: High demand scenario

Scenario 2	
Village	Ban Bouampoh
Energy demand kWh/month	301
Peak demand (W)	5,418

4.3 Scenario 3: Needs for irrigation

Daily needs in water for irrigation can be estimated in the following way:

- for rice = 175 m^3 per day per hectare
- Irrigation time is estimated for 4 month per year
- Estimated for currently uncultivated 5 ha x 4 meters pumped head
- Estimated for 14 ha x 2 meters pumped head currently irrigated by traditional system but potential for pumped irrigation to reduce labor force

The daily amount of energy that the pump needs to supply is expressed according to the following formula:

$$E_{(Wh/day)} = \frac{Daily volume of \quad water_{(m3)}}{pump\ yield_{(75\%)}} \times Pumping \quad height_{(m)} \times 2.725$$

Table 7: Irrigation scenario

Scenario 3	
Village	Ban Bouampoh
Energy demand kWh/month (5 ha)	381
Energy demand kWh/month (14 ha)	534
Total energy demand kWh/month	915

Based on the calculations above, the energy demand for total pumped irrigation would account for 915 kWh/month for a duration of 4 months. Due to field constraints, this report will only assess the potential of irrigating the currently uncultivated 5 ha plot.

4.4 Annual energy demand

The following table gives an overview of all 3 scenarios according to the energy demand of Ban Bouampoh.

Table 8: Annual energy demand

Annual energy demand	Ban Bouampoh	
	kWh/month	kWh/year
Scenario 1	226	2,580
Scenario 2	301	3,612
Scenario 3	381	1,524*

*Estimate for 4 months per year

5 Feedstock supply survey

5.1 Natural biomass resources

Ban Bouampoh has a modest amount of existing available oil species including (1) Jatropha curcas, (2) Cotton, and (3) Stone Jatropha.

(1) The main species present is Jatropha curcas used as fences by the villagers. The study found approximately 1,000 meters of Jatropha fences with an approx. maturity of 3 years. About 5 to 10 trees are located on one meter. The plants have a height of between 2 and 3 meters, are in good condition and have developed fruits. Furthermore there are younger fences along pathways and pig stables with an age of 1 to 2 years. Previously, seeds were burned on a stick and used for lighting. Now villagers do not harvest or process the seeds anymore, and only plant if additional fences are needed.



(2) Cotton is cultivated by almost every household for local consumption only. Every family possesses around 10 to 20 trees, in front of their houses. There is a bigger cotton plantation 1 hour away from the village that could be explored for future feedstock supply. The cotton seeds are separated from the fiber by traditional ginning machines. Then the fiber is spun to yarn and traditionally woven for clothing. Some of the seeds are kept for planting cotton in the next season; however most of the seeds are not used and thrown away in the general area of the houses.



(3) Only 3 Stone Jatropha trees were found. The trees were cultivated in 2009 and already have a size of 3 to 4 meters. This shows that the village has good soil and climatic conditions for proper development of Stone Jatropha.

In general, the climatic and soil conditions at Ban Bouampoh provide very good conditions for the development of the existing oil crops. Furthermore, the villagers have experience in the cultivation of these crops and there is a high potential for extending production. The villagers are interested in the cultivation or extended cultivation of these crops.

The cultivation of Jatropha as hedges could also be extended around all the existing plots. This would reduce the use of arable land, is less labor intensive, and would protect the crops from grazing livestock. However, it is difficult to provide a precise estimate on additional meters of hedge that could be planted. To provide a realistic maximum figure, every household could cultivate Jatropha fences around their, on average, 1 ha upland rice plots. This would result in 30 km of additional fences to be used as future feedstock. As this only includes the fencing of upland rice, additional hedges could be planted around other crop fields if needed.

Interestingly, for further cotton production, female villagers have the skills to process the cotton. So far, it is only on a subsistence level but villagers mentioned that they are interested in extending the production if traders and markets are available. Currently women are not organized in cooperations; they are working individually and processing only the amount needed for each household, which is pretty low and based on the fiber of 10 to 20 cotton trees per household. Women are responsible for planting and taking care of the cotton plants in front of the houses, harvesting, ginning, spinning and then weaving the yarn.

It is difficult to provide an estimate on the yield developed by the villagers. However, based on observation by the consultants, the plants are in very good condition. They show proper development with respect to maturity, with a high amount of fruits. A risk indicator can be seen in the reduction of rain in the rainy season. However, their Jatropha is mainly located along the river so there might be potential for irrigation. In addition, villagers mentioned a few problems with insects: there are a few young Jatropha roots attacked by termites and worms. These issues with insects are quite common and in general there is indigenous knowledge in Laos available about a sustainable and environmental friendly coping strategy, using old dead wood to prevent termites eating the fresh wood, and there are other natural insect repellants available. The insect management strategy will form part of the training given to the villagers at the implementation phase.

In order to secure a continuity of feedstock supply, the consultants recommend including Ban Nakun, located in the village cluster (distance about 1 hour closer to the asphalt road). It is interesting to report that there a high number of Jatropha used as fences, which could be a potential supplier to Ban Bouampoh, ensuring the continuity of feedstock. Unfortunately, at this stage it is not possible to provide an estimate of the amount of existing feedstock in Ban Nakun. The consultants only passed the village and observed the high amount of Jatropha hedges. However, the potential can be easily assessed during a second field trip.

Ban Bouampoh does possess a total of 2 pickups and 3 Tock Tocks, showing the potential to collect and transport Jatropha seeds. Some of the villagers are traveling regularly to Phoukhoun and back. Ban Nakhun is located on the road to/from Phoukhoun. Hence villagers could combine business in Phoukhoun with buying Jatropha seeds from Ban Nakhun. Villagers of Ban Nakhun could harvest seeds beforehand and sell it for the market price of 1,500 kip per kg. However, these aspects needs to be further analyzed, in particular the willingness and capacity of villagers in Ban Nakhun to join this project, keeping in mind that their village will not be electrified in this project. A more detailed assessment is necessary concerning how the collection could be organized from villagers in Ban Bouampoh.

5.2 Maximum existing production

Table 9: Maximum existing production

Type of wild species	Availability in village	Amount of oil crops	Annual seed yield (kg)	Annual oil yield (liter)	Annual electricity production (kWh)
Jatropha (hedge)	High/continuous	1,000 meters	500	110	363
Cotton	Medium/continuous	1,700 plants	1,270	210	693

Conservative assumptions for entire study:

- Jatropha hedge: 0.5 kg seeds/meter, 20 % oil yield
- 3 year old mature Jatropha: 2 tons yield/ ha, 20 % oil yield
- Cotton plants: 1.85 tons yield/2,500 plants (1 ha), 15 % oil yield
- 1 liter of oil results in 3.3 kWh (based on a 7 kW generator)

Note: These are conservative estimates based on LIRE's extensive experience in Lao PDR and appropriate to the context of Ban Bouampoh.

5.3 Energy plantations

In order to provide sustainable recommendations on the use and extension of energy plantations, land and labor availability needs to be considered. According to the information based on the individual interviews, one person could cultivate an additional 0.5 ha alongside their current farming activities. Each household possesses an additional 0.6 ha that is unused and could be used for energy plantations. These figures are provided by the villagers keeping in mind the labor intensity of food and cash crops.

In order to ensure an efficient energy plantation, training courses would be recommended. Farmers do have experiences in basic planting; however there is a lack of knowledge regarding proper nursery, pruning and fertilization.

It is difficult to estimate short term feedstock availability for the energy plantations. However, the consultants would recommend diversifying plantations to address this risk. Cotton seeds can be collected in the first year, whereas 3 years are necessary for new Jatropha saplings to yield seeds. This diversification could ensure continuity in supply and avoid delay. See conclusions for this report's recommendations.

The figure below shows that most of the villagers are interested in energy plantations:

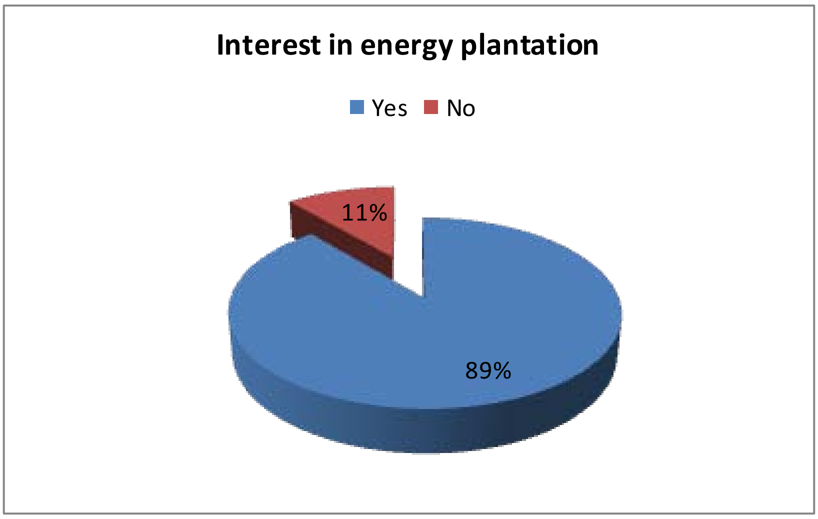


Figure 9: Interest in energy plantation

Most of the villagers are interested in the extension of Jatropha due to basic experiences with its cultivation and the potential to use it as hedges. Next to Jatropha, the extension of cotton is interesting for the villagers due to the potential of being an additional income source, in particular for women. There was little interest in the cultivation of Stone Jatropha. There are only 2 to 3 trees available in the village and villagers do not use any products of the trees nor are experienced in cultivation.

A proper risk assessment is difficult at this stage of development. Based on the consultants' experiences, Ban Bouampoh provides suitable environmental conditions including appropriate climate and soil conditions. One risk present is the lack of rain during rainy season as mentioned by villagers, and further investigations are necessary in order to explore the potential of using irrigation during dry spells. In order to deal with uncertainties of yields the consultants use conservative figures throughout the study to reduce the risk of underproduction.

Based on this information Ban Bouampoh provides potential to cultivate energy plantations on a total area of 40 ha. This calculation is based on following information provided by villagers: 0.6 ha of land are available per household x 86 hh x 0.75 hh (not every household shows interest and capacity in energy plantation) = 39 ha. However, as further calculations below point out, this amount of land is not all required if supplying electricity for less than 24 hours per day.

The environmental aspects of energy plantations are essentially no different than any shrub plantations, food or otherwise. Given that the energy plantations will be rain-fed, and the energy crops chosen here have relatively shallow roots, there will be a negligible effect on the local water table.

In addition, energy crops grown as hedges are the most effective way to reduce soil erosion from slopes if planted as contour lines. Jatropha has been used for many years in this manner in Lao PDR.

With respect to biodiversity, it is estimated that there will be very little impact as the potential area for planting is so small.

It is therefore understood that the environmental impacts of the energy plantations in Ban Bouampoh will be at worst neutral environmentally, but possibly positive given the reduced soil erosion by the planting of hedges.

5.4 Adequate supply

The following table shows a selection of plant species' maximum oil yield according to the available area. In particular, it shows the possibilities of an energy mix. Note that for small plantations, the total 40 ha area could be divided among different species.

Table 10: Potential cultivation

Type of species	Maximum area to be planted (ha)	Annual seed yield (tons)	Annual oil yield (liter)	Annual electricity production (kWh)
Jatropha curcas	40	80	17,800	58,740
Cotton	40	74	12,300	40,590
Jatropha hedge	30 km	15	3,300	10,890

As already mentioned above, the maturity aspect of different crops is essential in order to ensure continuity of supply throughout the year. Hence, the consultants recommend diversity of agricultural production.

Table 11: Seasonal cropping calendar including Jatropha and cotton

	Rice	Sesame	Garlic	Peanut	Jatropha	Cotton
January			No activity			
Febuary		Field prep.	Harvesting			
March		Planting				
April		Planting			Planting	
May	Field prep.	Weeding			Planting	
June	Planting	Weeding			Weeding	Planting
July	Planting	Weeding		Planting	Weeding	Planting
August	Weeding	Weeding		Weeding	Harvesting/ Weeding	Weeding
September	Weeding	Harvesting		Weeding	Harvesting/ Weeding	Weeding
October	Weeding		Planting	Weeding	Harvesting/ Weeding	Weeding
November	Harvesting		Planting	Harvesting		Harvesting
December			No activity			Harvesting

As already mentioned above, an external market for Jatropha seeds could include Ban Nakun, located in the village cluster (distance about 1 hour closer to the asphalt road). It is interesting to report that there appears to be a high availability of Jatropha as fences, which could be a potential supplier for Ban Bouampoh and ensure a continuity of feedstock. Unfortunately at this stage of development no estimate can be provided, however this may be calculate in further site visits.

5.5 Efficient energy plantation systems

As with the vast majority of agriculture in Ban Bouampoh, energy plantations will be expected by villagers to be rain-fed in, resulting in an efficient cost of labor.

With respect to Jatropha, planting in a nursery and then transplanting has some advantages; as you are only planting out viable seedlings, as opposed to direct sowing. However, this has to be balanced with the damage to the root networks done by transplanting, which does not exist with direct sowing. The use of a nursery will be an option to be presented to the villagers at the beginning of the implementation phase.

With respect to intercropping with Jatropha, it simply depends on the spacing of the trees and whether or not they are grown as a hedge. With hedging, normally a tight spacing laterally is chosen to maximize the effectiveness of the hedge as a viable barrier.

If a standard 2x2 meters spacing is chosen, intercropping is viable for the first 3 or 4 years. For example if maize or upland rice is chosen as an intercrop plant. Beyond that, assuming standard spacing the benefits of intercropping are questionable as the Jatropha trees will deplete the soil around their roots, resulting in low yields of the intercrop plants.

However, if a wider spacing is chosen, say 4 m or 5 m, spacing intercropping is a more viable option for the long-term but the benefits may be reduced by the increased space required to grow Jatropha.

Pruning is vitally important to achieve satisfactory Jatropha yields, and as part of the implementation phase proper villager training must be included.

Fertilizer application would be beneficial, but inorganic fertilizers are unaffordable/unavailable in this particular villager. However, part of the implementation phase will include training on applying organic fertilizers to the new crops.

Historically in Laos the yields of Jatropha have been somewhat disappointing. From initial analysis, the soils in Ban Bouampoh would be unlikely to yield more than 2 tons per hectare of Jatropha seeds after 3 years, with a 10 % increase in yield in subsequent years as the plants mature. The soil quality needs to be verified, but yields may be as low as 400 kg per ha in marginal land.

Because of the logistical challenges faced by changing villages at the beginning of the site visit, the Jatropha Harvesting Case study was not included in the data gathering, but remains an option for the next phase of the study.

5.6 Conclusion

Jatropha curcas, cotton and Stone Jatropha are existing wild crops in the village. These plants show very good development due to preferable soil and climate conditions. Jatropha curcas is used for fences only, with a measured length of approximately 1,000 m within the village. Cotton is cultivated to produce yarn for weaving on a subsistence level, with a small number of plants in front of each house. Stone Jatropha exists only in a very small amount. Due to the fact that these naturally growing crops produce seeds that are not currently used, (apart from a few cotton seeds for reproduction) there are no environmental constraints seen in further harvesting. Additional training courses are recommended in order to secure sustainable and qualitative feedstock supply.

6 Supply / Demand analysis

Based on the analysis from previous sections and on LIRE's past experiences with village electrification, the main criteria for the supply/demand analysis are the peak village demand and the hours required per day of electricity supply.

Scenario 1 from previous section: Electrification according to peak demand. For this initiative, a 1x100 % generator running for 4 hours/day from 6-10 in the evening. The predicted yearly oil demand is calculated at approximately 3,000 liters.

Scenario 2: 1x100 % generator 8 hours/day in the early morning and evening. The predicted yearly oil demand is calculated at approximately 6,000 liters.

For this study, both demand scenarios 1 and 2 could be met by a 7 kW modified diesel generator. See technical analysis for more detailed information. For scenario 3, a larger generator could be purchased, increasing the demand for feedstock. This aspect of the need of a larger generator and the low amount of irrigation potential leads the consultants not to elaborate further on scenario 3.

	Biomass supply			
Natural resources	Currently Available wild oil crops	Annual oil yield (liter)	Daily Electrical Supply based on 7 kW generator using 2.1 liters/hour (hours)	Annual electricity production (kWh)
	Jatropha (1 km hedge)	110	8 minutes	363
	Cotton (1,720 plants)	210	16 minutes	693
	Total Existing Supply	320	24 minutes	1,056
Maximum future feedstock from new hedges and 40 ha area	Selected species	Annual oil yield (liter)	Daily Electrical Supply based on 7 kW generator using 2.1 liters/hour (hours)	Annual electricity production (kWh)
	Jatropha curcas (40 ha)	17,800	23	58,740
	Cotton (40 ha)	12,300	16	41,000
	Jatropha (30 km hedge)	3,300	4 hours 20 minutes	10,890

6.1 Conclusion

In summary, the currently available feedstock would only supply electricity to the village for 24 minutes per day, assuming a 2.1 liters/hour consumption rate of a small 7 kW generator.

As the table shows, additional hedges and/or plantation will be needed to adequately meet future feedstock demands.

As an example, a 6 ha plot of Jatropha would provide enough feedstock to meet these requirements.

Alternatively, a 15 km hedge extension combined with a 4 ha cotton plantation would also meet the demand.

This feedstock analysis assumes yields from mature hedges and small plantations. It is apparent that in the initial three years, feedstock would need to be sourced in a different way. Please see Conclusions section for final recommendations.

7 Technical analysis

Table 12: Inventory of current equipment used in village

Type	Amount
Pick up	2
Motorbike	34
TockTock	3
Pico hydro power	16
Solar system	1
Rice mill	9

The consultants identified one technician that is interested in taking charge of oil production. Mr. Bounthan finished secondary school and has 3 years experience working with different engines and repairing rice mills in the village. He wants to contribute to the village development but there is an essential need for further trainings.

According to the electrification scenarios presented earlier, this report considers the technical solutions for initially powering Bouampoh village for either 4 hours or 8 hours. Previous initiatives in India have proven that a single modified diesel generator can reliably deliver village electricity for 4 hours per day. In the case of future increased electrification availability, the village may need to install a 2x100 % generator system, and use a cycling routine to ensure reliability.

From previous electrification studies and discussion with small generator manufacturers, this report recommends purchasing a 7 kW modified generator. Although accurate fuel consumption data is difficult to obtain for small capacity generators, the following rates have been verified for comparison:

- 7 kW Generator (full load): 2.1 litres/hour
- 30 kW Generator (25 % to full load): 5-11 litres/hour

Based on previous experience, the above figures are representative of the average fuel consumption when running with SVO. These numbers have been used in previous sections to estimate the required supply of feedstock for both options. For a rough estimate of the required oil supply needed to deliver 4 hours of electricity per day for household use only, the simple calculation of: (approximate litres/hour peak) x (# of hours per day) x (# days per year) = 2.1 x 4 x 365 = ~3,000 litres per year. Although untested in the academic literature, this figure could reduce by as much as 25%, to 2,250 litres if the generator were run at a lower load.

Recalling the peak demand from scenarios 1 and 2 as 2.6 kW and 5.4 kW, it is apparent that a 7 kW generator running at the recommended 80 % load would allow for larger loads in the future. The ‘low demand’ scenario could increase by 3 kW while the ‘high demand’ scenario could increase by an additional 0.2 kW during their respective operating times.

Although difficult to predict future power demand in the future, the village could purchase a larger generator at a later date, integrating it easily into the electrical transmission system. This larger generator would result in a more reliable system, with the smaller generator acting as the backup supply.

As shown previously, if irrigation or industrial power were needed in the future, the fuel consumption of a larger generator would be substantially higher.

As a rule of thumb, a diesel generator will require replacement or a major overhaul every 30,000 hours. In this study, this number could decrease by up to a factor of 3 due to the use of SVO, ambient conditions, and increased number of start ups/shutdowns. Hence a scaled approach, commencing a pilot with a smaller generator and upgrading at a later date, anywhere between 5 and 15 years, is the preferred option.

The sourcing of a modified generator in Lao PDR has its challenges but there are various willing vendors in the capital. The most probable outcome for this pilot study would be the contracting of a foreign company to perform the minor modifications required, followed by importation of the generator through official vendor contacts such as RMA Laos. Based on a thorough analysis of the performance using SVO from various diesel generator manufacturers, it is currently recommended to select SDMO as the preferred manufacturer. A professional single-tank SVO system is recommended as there is no waiting or switching fuels as with two-tank SVO systems. The engine starts easily and burns cleanly from the start. Single-tank SVO systems are suitable for both Indirect Injection (IDI) and Direct Injection (DI, TDI, PDI) diesel engines. The modification includes specially made injector nozzles, increased injection pressure and stronger glow-plugs, in addition to fuel pre-heating. There are a number of companies that offer SVO conversion kits, including Elsbett technologies.

8 Economic analysis

8.1 Traditional energy sources

Currently, the majority of the villagers are using traditional energy sources. The most common sources are battery torches with 96 % saturation of the interviewed households. The households use these torches in order to visit friends in the village or to go hunting (mainly frogs) during the night. Villagers are currently spending about 12,000 kip per month on batteries. The approximate duration of hours used per day is two hours. Regarding the electrification plan, there is an option of installing street lamps to make village walks/visits more convenient for villagers. These lamps could be handled as common property from a joint fund.

The main traditional energy source for lighting the house is the kerosene lamp. 77 % of the interviewed households declared that they use them. Villagers are spending about 40,000 kip per month on fuel (the price for petrol is 10,000 kip in Phoukhoun, and 12,000 kip in the village). However, only 50 % of them spend currently 40,000 kip or more than that, the other half spends 20,000 kip or even less according to their statements. The approximate duration of hours used per day is about 4 ½ hours, about 1.5 hours in the morning and 3 hours in the evening. 30 % of the interviewees use candles for lighting in the evening. The cost of 3 hours of candle light is 2,000 kip per month for the purchase of candles.

In total, based on an energy audit, villagers are spending about 45,000 kip per month on traditional electricity sources. 41 % spend 45,000 kip or more, 26 % between 45,000 kip and 32,000 kip, 15 % between 32,000 kip and 20,000 kip, and then 19 % less than 20,000 kip.

Further investigations showed that 100 % of the interviewed villagers are interested in the connection to an electrical grid. Based on interviews, they are willing to pay a connection fee and a monthly bill of 15,000 kip.

8.2 Price analysis

The following price analysis is based on 27 individual interviews conducted in Ban Bouampoh:

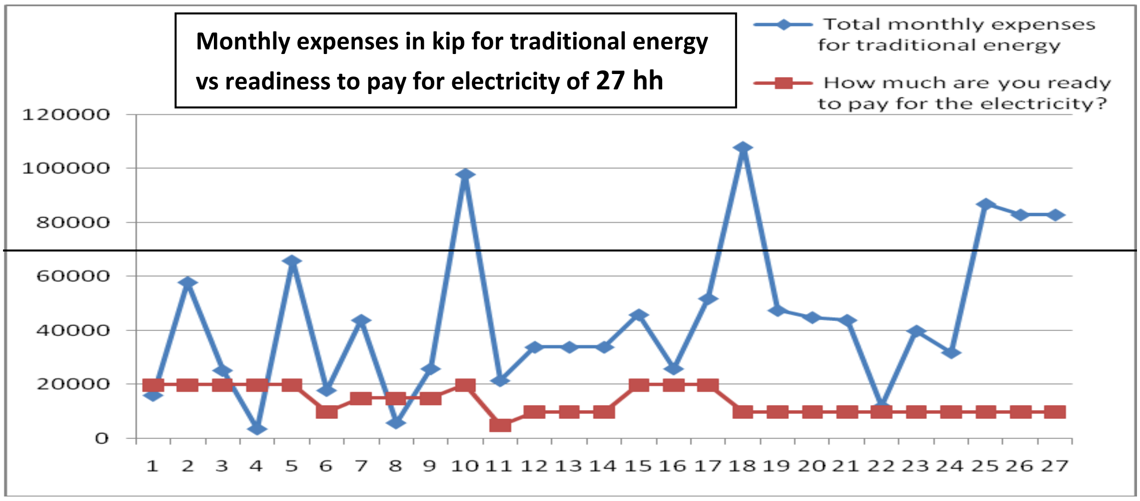


Figure 10: Monthly expenses for traditional energy vs readiness to pay for electricity

It appears that there is a difference between what villagers report paying each month for traditional energy sources and what they state they would be willing to pay each month for an electrical connection. In order to solve the tariff issue, the consultant team is presenting a choice between two options. These two options are:

- Option 1: The tariff is fixed based on what the households declare to be ready to pay for the electrification. According to the interview of the households, considering also that these households are a representative sample size of the village, and the connection rate based on the different scenarios, this tariff is 1.25 USD per month.

Table 13: Declaration of the households on their ability to pay the electricity

		How much are you ready to pay?		
		LAK	US$	US$/kWh
Scenario 1	20 hh (75%) able to pay at least:	10 000	1.25	0.36
Scenario 2	19 hh (70%) able to pay at least:	10 000	1.25	0.25

- Option 2: The tariff is fixed based on what the households pay every month for their current consumption of traditional energy. This tariff depends also of the connection rate reached. In this case, the tariff is 3.23 USD per month.

Table 14: Household ability to pay based on current lighting expenses

		Total monthly expenses for traditional energy		
		LAK	$	$/kWh
Scenario 1	20 hh (75 %) spend more than:	26,000	3.23	0.92
Scenario 2	19 hh (70 %) spend more than:	26,000	3.23	0.65

The team members chose the second option mainly because the purpose of the implementation of electricity in this village is to try to substitute the current use of the traditional energy sources by the use of this new source of energy. It seems also that the households are clearly underestimating their ability to pay for electricity.

In consequence, the study team will focus the rest of the survey on the delivery of **option 2.**

8.3 Investment costs

Numbers and prices for the equipment but also for the feedstock material and operational models were sourced from suppliers and manufacturers but also from companies and organizations. Different qualities for oil extraction and electricity generation are available on the market. Oil expellers from Europe with high quality can cost more than ten times of the price of a Chinese expeller. Similar relations are given with professional plant oil engines from Europe or locally modified diesel engines. For the calculation, the local and therefore cheaper options were chosen.

An important investment is the village grid itself. The costs for the grid was assumed to cost approximately 250 $ per household. This investment cannot be covered by villagers or operators and has to be funded by external sources. In the calculations a connection fee of 35 $ from the household to the village grid was used. The depreciation was assumed to 10 years.

Another important investment which is not considered in the calculations is the building for the oil extraction and power generation. This cost was estimated at 10,000 US$.

Table 15: Infrastructure cost

	Village grid (250 $/hh)	Building ($)
Ban Bouampoh	21,500	10,000

8.4 Operational costs

Table 16: Overview financial model

Number of Household		Hh	86
Connection rate scenario 1		rate	75%
Peak demand scenario 1		W/hh	40
Connection rate scenario 2		rate	70%
Peak demand scenario 2		W/hh	90
Electricity demand	Scenario 1	kWh/month/hh	3.5
	Scenario 2	kWh/month/hh	5
	Scenario 3	kWh/month/hh	4.4
	Hardware		
Oil pressing & electricity generating	Generator	$/kW	750
	Internal cache	$	100
	Oil press	$	1500
	Collecting vessel	$	1500
	Security vessel	$	1000
	Oil storage vessel (1000 l)	$	400
	Depreciation	years	10
	Connection grid	$/hh	35
	Feedstock		
Oil crop Jatropha	Price seeds	$/kg	0.16
	Net oil content	%	20
	Price of residue	$/kg	0.16
Oil crop cotton	Price seeds	$/kg	0.12
	Net oil content	%	15
	Price of residue	$/kg	0.12
	Running		
Operation	Energy content (based on a 7 kW generator)	kWh/liter	3.3
	Pressing capacity	Kg/h	15
	Operators salary	$/month	50
	Generator operating hours/day	hours	4
Maintenance	Gear oil	$/year	25
	Spare parts	$/year	200
	Miscellaneous	$/year	50

This model has already been presented in the previous report. The study team has just updated some figures regarding to the exchange rate, the oil yield (relatively conservative) and the choice of the generator (7 kW). Nevertheless, it is important to underline the uncertainty about the price of the cotton seeds and of its residue:

- The yield of the cotton seed is 15 %. In other words, 25 % less than the yield of Jatropha seeds. In consequence, the study team has decided to set the price at 0.12 US$/kg (25 % less than the price of the Jatropha seed) in order to ensure the sustainability of the model. This assumption does not seem unrealistic, given the fact that there are many other opportunities for the other components of the cotton (fiber, yarn).

- For the same reason, the study team estimated that the nutrient content is lower with respect to the cotton press cake relative to the Jatropha press cake.

The costs and calculation for the electrification system can be divided in the 4 following components:

1. Hardware: generator, equipment, connection from the grid to the house
2. Feedstock material: Jatropha and cotton seeds
3. Running operation: operator salary, maintenance
4. Sales: electricity, residue

8.4.1 Hardware

Table 17: Hardware costs in USD

	Scenario 1	Scenario 2
Generator (based on a 7 kW generator)	5250	5250
Other equipment	4600	4600
Connection from the grid to the house	2258	2107

8.4.2 Feedstock

Table 18: Potential Feedstock costs

	Scenario 1	Scenario 2
Total demand of vegetable oil (l)	3000	6000
Vegetable oil Jatropha (l)	2000	4500
Jatropha seeds (kg)	9091	20454
Jatropha seeds cost ($)	1455	3273
Vegetable oil cotton (l)	1000	1500
Cotton seeds (kg)	6061	9091
Cotton seeds cost ($)	727	1091
Seed costs total ($)	**2182**	**4364**

8.4.3 Running operation

Table 19: Running costs

	Scenario 1	Scenario 2
Operator yearly salary ($)	600	600
Yearly Maintenance ($)	275	275

8.4.4 Sales

Table 20: Sales performance

	Scenario 1		Scenario 2	
Electricity	0.92 $/kWh	3.23 $/month/hh	0.65 $/kWh	3.23 $/month/hh
Residue	0.16 $/kg Jatropha seeds	0.12 $/kg cotton seeds	0.16 $/kg Jatropha seeds	0.12 $/kg cotton seeds
Annual electricity sales	2492 $		2333 $	
Annual residue sales	1782 $		3545 $	

8.5 Conclusion Scenario 1

The graph below shows the economic analysis for Ban Bouampoh applied for a depreciation time of 10 years in scenario 1 (low-demand). The bars show that under the given parameters an economic viable operation is possible. Indeed, the income from the sales of the electricity and the residue (press-cake) cover all the costs.

The revenues from the electricity sales is approximately 2500 $ per year. The income generated by the selling of the Jatropha-Cotton presscake amounts to 1782 $ per year which is 41,5 % of the whole income. With this operational model, the situation is perfectly balanced.

However, there is an important limit at this model: the very strong dependence to the sales of the residue. Currently, we don't know if there is a market for by-products from the oil production. That is why it is very important for each considered oil crop to develop a strategy to identify niche markets for these residues. As can be seen with in the chart, the majority of the operating costs **are covered by the proposed income from the electrification tariff**. Even if no market exists during implementation for presscake residue, the revenue might still cover the anticipated operational costs.

To increase the potential revenue, farmers in other areas produce soap from the residue of cotton seeds. This may be an interesting opportunity to assess. Another problem is the toxicity of Jatropha. If Jatropha and cotton seeds are mixed during the process of production, it is difficult to use the residue for feeding the animals, for instance, which limits the possibilities and opportunities. The solution could be not to mix Jatropha and cotton seeds during the process of production.

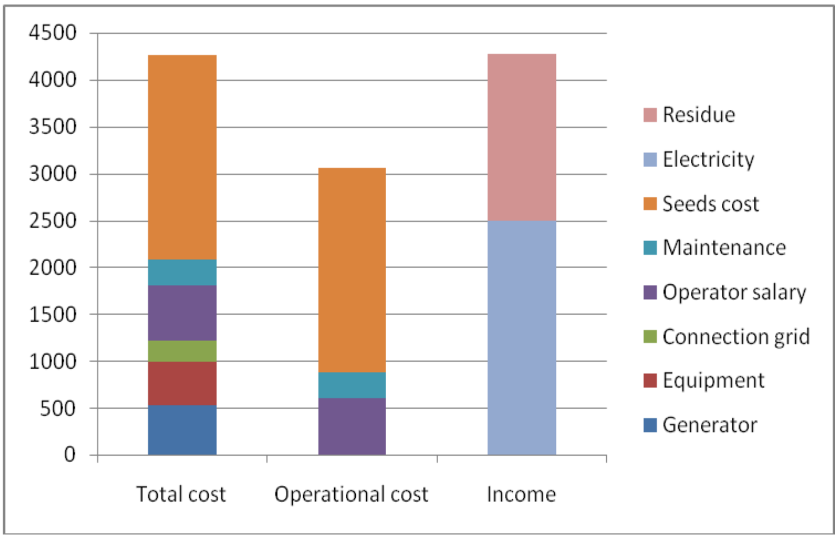


Figure 11: Economic analysis scenario 1 in USD per year

8.6 Conclusion Scenario 2

The graph below shows the economic analysis for Ban Bouampoh applied for scenario 2 (high-demand). The bars show that under the given parameters an economic viable operation is possible, only if the investment costs or total costs in the graphic (generator, equipment, grid connection) are excluded. With this operational model an annual deficit of 556 $ (income vs total costs) or respectively a surplus of 640 $ (income vs operational costs) is achieved. In this scenario, more than in the previous one, the dependence with the residue sales is extremely marked. This income represents 60.3 % of the whole income. Consequently, the reserves are the same as previously.

This report anticipates a small increase in income in the coming years, allowing the possibility of a higher monthly fee that could facilitate an increased number of hours of electricity per day.

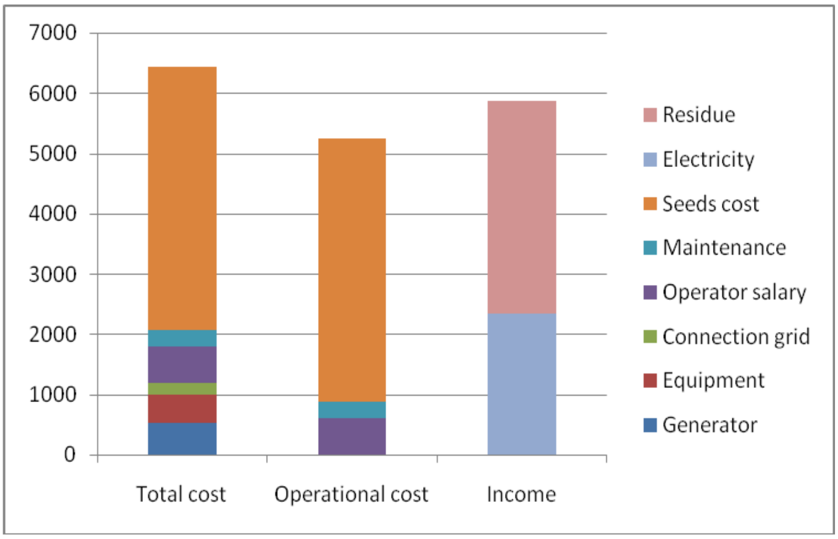


Figure 12: Economic analysis scenario 2 in US$ per year

9 Opportunities

The option of turning SVO into biodiesel is a technical option available to this project. In order to make Biodiesel from SVO, a biodiesel reactor is required and a processing facility established. The reactor takes in straight vegetable oil, mixes it with methanol, and heats it in the presence of a catalyst (normally Sodium or Potassium Hydroxide). Furthermore this has to be done in a facility with spark-proof extraction fans in order to ensure sufficient standards of safety are maintained. Methanol vapors are explosive and pose serious risks to human health, so robust handling protocols are required.

It is this report's opinion that the production of biodiesel in Ban Bouampoh poses unacceptable and unrealistic safety risks to the local population. That production of biodiesel in an off-grid setting would be intrinsically hazardous as guaranteeing methanol fume evacuation without reliable power would be hard to ensure. Furthermore methanol containers are more hazardous when they are empty than full, as the methanol-air mix is more explosive and to ensure safe disposal in Ban Bouampoh, some 2 ½ hours travel from the district centre, would be practically difficult.

Direct substitution of diesel consumption with SVO in **vehicles** is possible, but without proper engine modifications to the engines used, a typical diesel engine will only operate for around 100 hours before it needs repairing. LIRE's own internal studies show that the required modification kits for SVO operation of standard diesel engines are priced around $800-$2000 USD per engine used by a household which is assessed to be outside of the likely affordable price range of local villagers.

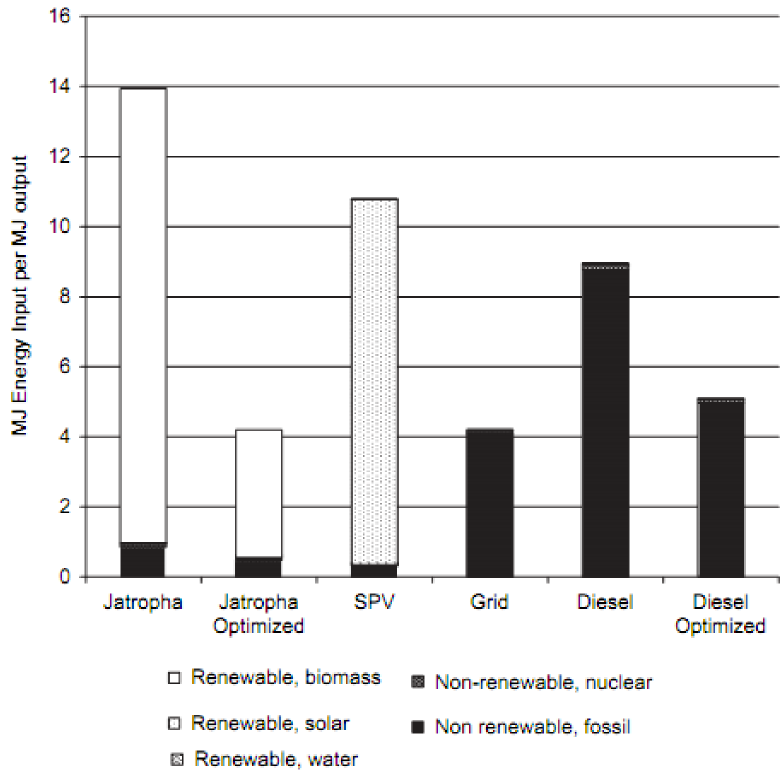
9.1 Greenhouse gas lifecycle analysis

Although an in depth study of greenhouse gas emissions was outside the scope of this work, a similar project using SVO for electrification has been implemented and analysed, of which an extract is produced below for reference.

The following information is referenced from the paper *Life cycle assessment of village electrification based on straight jatropha oil in Chhattisgarh, India,* Simon Michael Gmunder, Biomass and Bionenergy 34, 2010.

"A decentralized power generation plant fuelled by straight jatropha oil was implemented in 2006 in Ranidhera, Chhattisgarh, India. The goal of this study was to assess the environmental sustainability of that electrification project in order to provide a scientific basis for policy decisions on electrifying remote villages.

A full Life Cycle Assessment (LCA) was conducted on jatropha-based rural electrification.



In summary, the jatropha-based electrification in Ranidhera reduced greenhouse gas emissions over the whole life cycle by a ***factor of 7*** *compared to a diesel generator or to a grid connection. Nevertheless, environmental performance was improved only slightly, a fact due mainly the severe air pollution caused by pre-heating the jatropha seeds. Overall, the environmental performance of the PV system was superior in all aspects considered. Even though renewable energy systems show generally low environmental impacts and global warming potential, the impacts in certain categories are typically higher than the fossil reference. The jatropha system showed, for instance, a relatively large eutrophication effect, although only small amounts of fertilizer were applied. Furthermore, the release of photo-oxidants and particulates caused a relatively high impact on human health.*

This study has shown that rural electrification based on extensive jatropha cultivation is environmentally friendly compared to the usage of fossil diesel or to connection to the local grid. The optimization of the expelling process and the operation of the engine under full load might further improve environmental performance. However, significant environmental benefits can only be achieved if jatropha is cultivated on marginal land. Therefore, land suitability has to be assessed carefully before implementing jatropha-based electricity systems. Under these conditions, jatropha-based electricity generation may be a useful alternative to the renewable electrification options, as the technology is very sturdy and can be maintained even in remote and highly under-developed regions."

10 Conclusions

The following performance chart is based on the assessment found in previous sections and is displayed in the standard FONDEM template.

Following indicator items were used:

- ++ : very favorable,
- + : favorable,
- 0 : indifferent,
- - : unfavorable,
- -- : very unfavourable.

Table 21: Qualitative assessment – Summary of findings

	Electrification project Ban Bouampoh
Carbon performances:	
Savings in green house gas emissions	+
Impacts on the use of the land:	
No competition with supply and agriculture	+
No competition with other local uses of the biomass (for local constructions or traditional medicines)	++
Protection of biodiversity (cultivation of hedges, diversification, low amount of land)	++
Availability of unused land	+
Environment:	
Water management	+
Pollution (reduces kerosene use but increases engine emissions)	0
Land management, conservation of the quality of the land/soil (erosion)	+
Management of inputs (no chemical fertilizer)	0
Local development and equitable creation of income	+
Technical sustainability:	
Continuity of the supply (including cotton and external feedstock)	+
Quality of the delivered electricity (stability, etc.)	+
Equipment robustness (life expectancy, availability of parts, etc.)	+
Possible operator training	++
Economic sustainability and financial profitability:	
Economic sustainability	+ (scenario 1);- (scenario 2)
Purchase price of the biomass for the population can remain guaranteed	0
Diversity of income	++
Limited social impacts:	
Respect of the living conditions of the populations	+
Work conditions are respected or improved	-
Respect of the social cohesion of the village	+
No impact on health	++
Respect of the right ownership of the land	+
Labor intensity	- (plantation); ++ (hedges)
Enough labor available	+

According to this analysis, this report supports the implementation of electrification using SVO. The willingness of the villagers, local environmental conditions and the availability of unused land makes Bouampoh an ideal location for this pilot.

10.1 Short term feedstock supply

As highlighted earlier in the report, short term feedstock supply is one of the major hurdles to implementation. LIRE has identified three strategies that could overcome this problem:

1. Source additional feedstock from neighboring villages for the first three years while a future Jatropha crop is maturing. As stated more analysis is needed if this strategy is adopted. An estimated 235 kg of Jatropha seeds, costing 350,000 kip, would need to be sourced per week from these sources in order to adopt the 4 hour electricity scenario.
2. Diversification using both cotton and Jatropha. Cotton could be harvested after 4 months and used to produce the majority of SVO in the short term. This could be in addition to the first strategy.
3. Use both SVO and diesel fuel in the short term, increasing the amount of SVO as plants mature.

10.2 Long term feedstock supply

Based on the supply/demand analysis, it is apparent that additional oil crops are necessary to provide adequate SVO on a long term.

As stated previously, this report recommends adopting Scenario 1, 4 hours per day supply of electricity, with the potential for up scaling to 8 hours or more at a later date. Using the proposed 7 kW generator, this would allow a future increase in electricity demand during operating hours.

To provide the required additional 2,700 liters per year for this initial 4 hours per day scenario, Jatropha hedges should be the main focus for planting in order to ensure production under high environmental conditions.

- A total of 24 km of additional hedge planting around upland rice fields and other useful areas would provide the required additional supply within 3-5 years.

Although the price of SVO production is comparable to diesel fuel, it is important to note that these funds would be reinvested into the community, benefitting the economy and purchasing power of the community.

It is fundamental in the next stage to assess more sustainable opportunities for the use of the residue of the seeds in order to ensure several viable market outlets. Presently, in this survey, the price of the residue is based on the value of the fertilizer.

10.3 Economic viability

An important investment is the village grid itself. This investment cannot be covered by villagers or operators and needs to be funded by external sources. The establishment of a Public-Private Partnership (PPP) could be an option to overcome this constraint.

Focusing only on running cost of scenario 1, the project is economic viable. It assumes a quite ambitions price for the selling of residues. However, even without selling the residues the economic viability could be feasible.

At this stage of development, scenario 2 is not economically viable. However, if we assume future economic growth, a higher potential monthly tariff could be proposed in the future to cover the increased cost of feedstock supply.