Lao
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Biomass

Gasification

Technologies

Biomass Gasification in Lao PDR

Prospects of Biomass Gasification in Lairthong and Nyotphaire Villages in Phoukoud District, Xiengkouang Province

Report

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Vientiane

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About us

LIRE is a non-profit organisation dedicated to the sustainable development of a self sufficient renewable energy sector in 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.

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Abstract

Lairthong and Nyotphaire villages in Phoukoud district of Xiengkouang province endures an increasing electricity demand, which is inadequately met at present by inconsistent power supply from pico-hydro, and people there are willing to pay for additional electricity in any terms such as cash, kind (land for plantation) and human resource (work labour). As such, there is an opportunity for a hybrid village grid powered with hydropower as well as other energy sources, including biomass.

1. Introduction

In Lao PDR the demand for electricity is primarily for lighting. However, in the economically growing society of today, access to electricity comes with the provision for other energy services that can bring about changes in lifestyle and enable development. Therefore, electricity generation and supply can be considered as a starting point towards providing access of energy to the rural and geographically dispersed communities, thus enabling them further to be involved in productive activities.

A study by Smits and Rietzler (2008) entitled *Biomass gasification in Lao PDR: A feasibility study on biomass gasification at potential sites in Bokeo and Xiengkouang province for the Phitrust Foundation* was conducted earlier this year with the aim to identify possible sites for the implementation of biomass gasification unit in Lao PDR. The major criteria for selection of eligible villages in this study were that the settlements should be situated in off-grid areas that would not be connected to the national grid in next 5-10 years and that a sustainable supply of desirable biomass was present in the immediate vicinity. In that process, Lairthong and Nyotphaire villages in Phoukoud district of Xiengkouang province were selected jointly as a potential village electrification site for a 22 kW biomass gasifier.

The main conclusion of the feasibility study for eligible sites was that the demand for electricity is very low and investment costs are very high. As such, for a village site, commercial viability of a biomass gasifier is not valid. However, biomass gasification technology could contribute to a broader social objective of providing electrification in rural areas and promoting its productive usage. In the context of low energy demand as well as limited biomass resource for biomass gasification in the village site, there still remains an option for implementation of the technology in combination with other renewable energy technologies such as pico-hydro and solar as a part of a broader hybrid grid for village electrification.

This report presents the findings of a follow up study focused on the detailed investigation of Lairthong and Nyotphaire villages, and the prospects for a village electricity grid.

1.1. Objective

The overall objective of this study is to check the viability of biomass gasification technology in Phoukoud district of Xiengkouang province in Lao PDR by investigating the options concerning input supply to the technology with reference to the demand for energy in the selected site. Additionally the financial circumstances of the study area shall be studied by investigating the current pattern of electricity usage and lighting sources in the villages.

1.2. Research questions

The main research questions that would lead to attaining the study objectives are:

1. What is the ability and willingness of villagers to pay for the energy service?
2. What biomass supply is available at the location and what potential exists for the extension of this supply?

1.3. Study methodology

Three different steps, as given below, were taken to realize this study.

Step 1: Selecting the energy segments

Depending upon the end user, the primary beneficiaries selected were:

- Domestic energy end-users: individual households
- Communal energy agency: village leaders, community groups
- Energy entrepreneurs: mills, handicraft workshops

Step 2: Describing the energy segments

This involved collection of socio-economic data on the selected energy segments, mainly through survey and interviews, for the following points of interest:

- General information (physiographic and socio-economic features)
- Existing energy provision
- Energy demand (existing and desired demand)
- Affordability (capacity and willingness to pay)
- Potential for biomass gasification and other renewable energy technologies

Step 3: Analysing the energy segments

Data from surveys and interviews were analysed under each point of interest identified in step 2.

2. General Information on Study Area

2.1. Physio-graphic setting

Lairthong and Nyotphaire are neighbouring settlements; the distance between the two villages is approximately 4 kilometres. Although in close proximity to each other, the communities are connected by dirt road, and hence the route can be difficult during the height of the rainy season.

Table 1. Land coverage information of the villages

Type of land	Lairthong (ha)	Nyotphaire (ha)
Cultivated land	126.969	93.77
Forest land	2003	1312
Water logged land	1.60	6.10
Grazing land	not available	1,200

Source: Village Data, 2008

As illustrated in table 1, forest cover accounts for the majority of land belonging to both villages, which includes both forests with restricted access as well as forests for open use. Out of the total forest land available, in Lairthong 68% is conserved and the remaining 32% is available for use. In Nyotphaire, only 39% of the currently available forest land is secured and 61% can be used. The cultivated land listed in table 1 includes both agricultural land used for rice and cash crops, as well as garden land, where small scale vegetable and spice plantation was being practised, mostly for self consumption. Villagers reported that there was never any need to sell land in these communities, and everyone has some plot of land. A typical response was that "Land is plentiful", however the "human resource to work on the land is not enough".

River *Nam Phaire* is the main water source supplying both villages, with many of its smaller tributaries flowing across the cultivation areas.

2.2. Socio-economic setting

Household and population

In Table 2, general demographic information is summarised for the two villages. Out of the total population, 47% is male and 53% female. In the study site, on occasion more than one family were found to live at a single household (HH).

Table 2. General demographic information on the villages

	Lairthong	Nyotphaire	Total
Total population	534	841	1,375
Total female population	295	436	731
Total number of houses	79	145	224
Total number of families	113	190	303

Source: Population statistics of villages in Phoukoud district (District Administration Office, 2008)

Ethnic composition

There are two main ethnic groups in the site area, namely *Lao Loum* and *Mong* (ethnic minority of *Lao Soung*). All people in Lairthong village are from *Lao Loum* ethnicity. Nyotphaire is predominantly *Lao Loum* as well, with approximately 23% of the total village population belonging to the Mong community.

Economic Situation

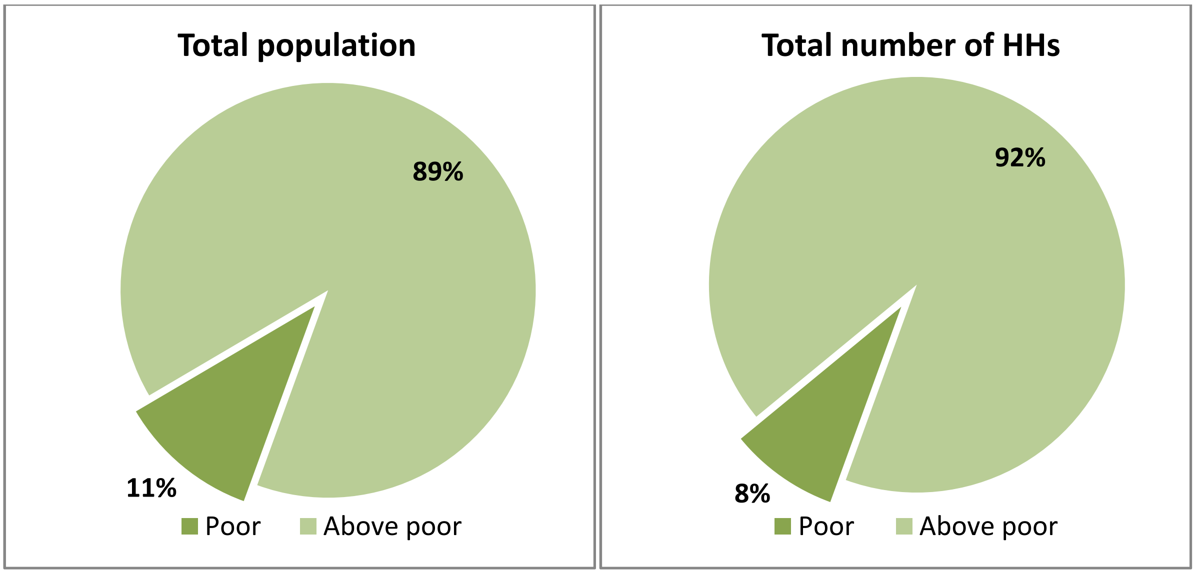

Figure 1. Overall economic situation in the study area

Figure 1 gives the overview of the economic situation in the study area. Out of a total population of 1,375 villagers, 151 (11%) are classed as poor. Likewise, from a total of 224 households in the two villages, 19 households (8%) are below the poverty line. Rural households in Lao PDR are considered poor if they have an income of less than 85,000[1] LAK (or the equivalent in kind) per person per month. Importantly, this amount is approximately equivalent to the price of 16 kilograms of rice per

[1] At year 2001 price rate

head per month, which is considered a minimum basic need (Lao People's Democratic Republic, 2004; Lao People's Democratic Republic, 2001). Therefore, it is insufficient to cover additional expenses such as clothing, shelter, education and health care.

Subsistence farming, including the cultivation of crops and livestock rearing, is the main economic activity of most households in Lairthong and Nyotphaire villages. Household economics very much follow the crop calendar. Hence, the annual income is concentrated in the harvesting season, which falls mostly on November and December of each year for rice.

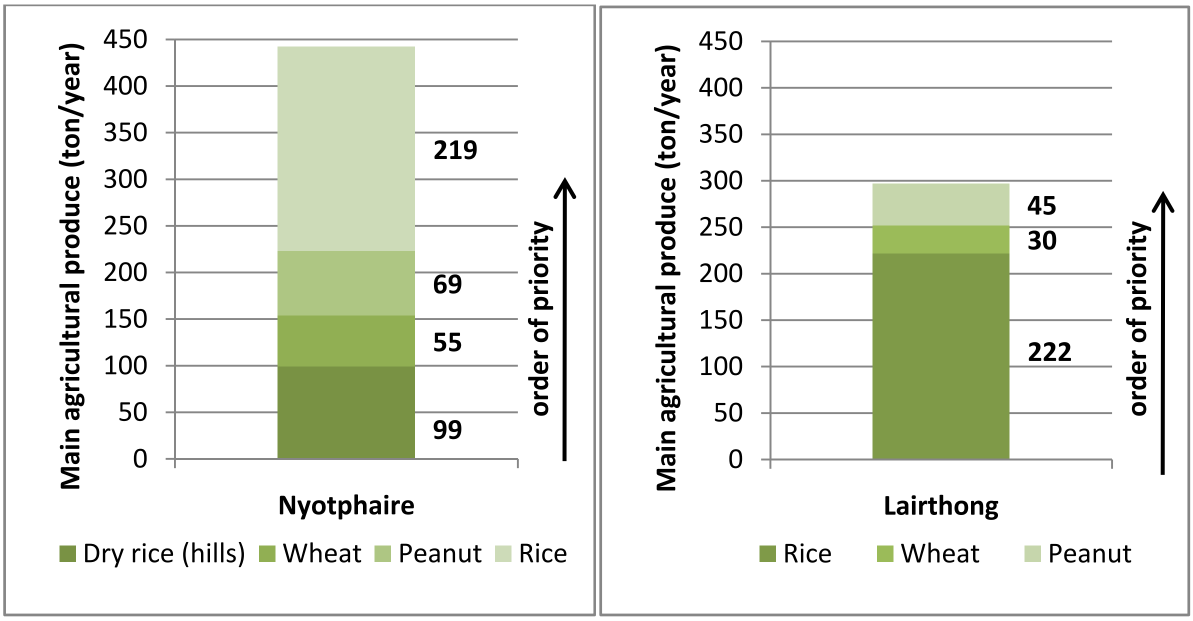

Figure 2. Amount of main agricultural produce in a year

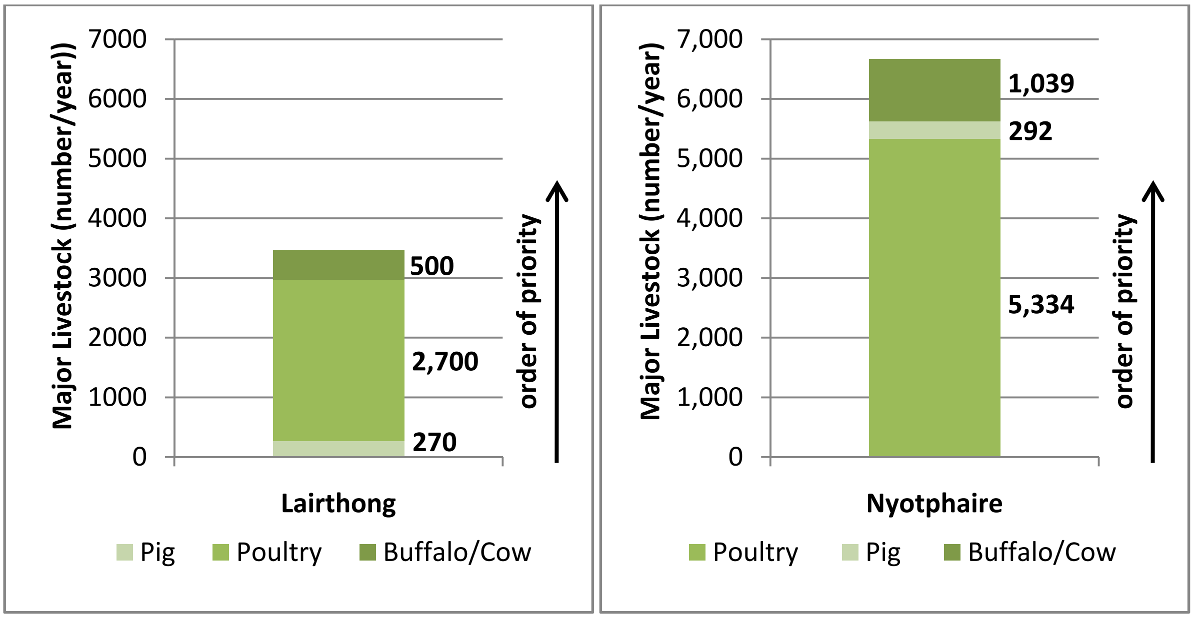

Figure 3. Number of major livestock produced in a year

In Figures 2 and 3, the main productions in crops and livestock are shown for the two villages as per their preference. Other important crops produced are given in the crop calendars of each village (Appendix 4; Appendix 5).

There are at present few economically productive activities in these villages, except from the income received by selling off excess agricultural produce remaining after putting aside the most part for their self consumption. Four households in Lairthong are currently involved in making umbrella stands/posts out of bamboo. A popular additional source of income was found to be the retrieval of pieces of UXO (unexploded ordnance) that have littered the area since the Secret War with USA (part of Vietnam War). Such items have small market value in the form of decorative items. The family property is directly transferred to the children. Small financing facilities such as banks, saving/credit, etc. are not available in the village.

3. Existing Energy Provision for Lighting

Information obtained from the Provincial Office of the Ministry of Energy and Mines at Phonsavan indicated that there are no immediate plans to reach Lairthong and Nyotphaire with the national grid. During the survey it was observed that, although villagers were familiar with the notion of voltage, the specifications of the lighting devices in use were generally unknown. When buying, people typically only enquired about the durability of the products. Details on the energy resources utilized for lighting in the study site are discussed below.

Pico-hydro

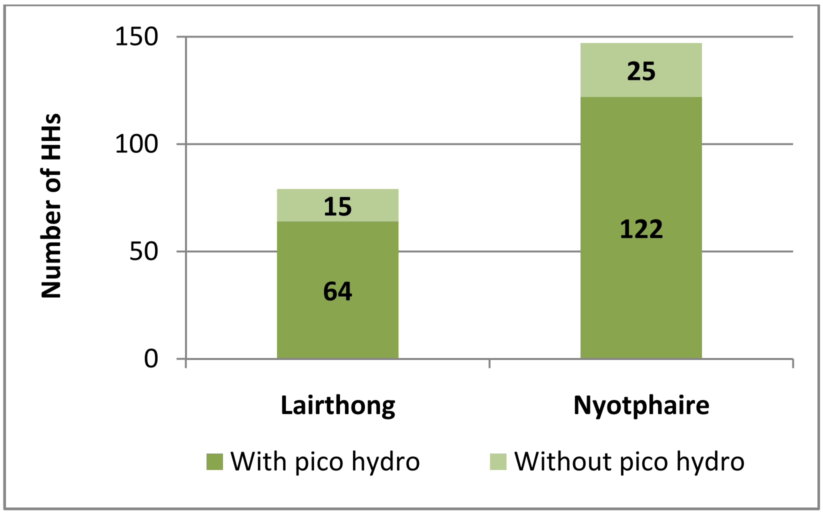

Figure 4. Number of households using pico-hydro for electricity

Most houses in Lairthong and Nyotphaire villages use pico-hydroelectricity (power ratings of up to a few kW) for elementary lighting. The scale of pico-hydro implemented in the villages is illustrated in Figure 4. Households electrified with pico-hydro account for 81% of the homes in Lairthong and 83% in Nyotphaire. Therefore, 82% of the totals HHs in the study site have adopted pico-hydro technology to meet their electrical needs. According to the district official, the typical size of pico-hydro used in the region is 2.5 kW. However, the turbines used in the study site ranged from 0.5 kW to 1 kW only.

For eight months of a typical year, the local water courses were reportedly sufficient to provide electricity for lighting as well as for other entertainment appliances such televisions and compact disc players. The remaining four months occur in the dry season (from December to March), when the water flow is much reduced and is largely diverted for irrigation. During the height of the rainy season the level of the main waterway, the *Nam Phaire* River, is typically too high for the pico-hydro units. In response to this seasonal variation, it was common practice for villagers to relocate pico-hydro turbines to smaller streams when necessary, which were adequate to meet the electricity demand during these times.

When asked about electricity consumption, respondents admitted that the 500 W turbines could not guarantee sufficient power for lighting and other appliances throughout the year. In the case of 1 kW pico-hydro units, under-loading was a major concern. Load control was typically afforded by including many lighting appliances around the house to use up the excess power. Villagers were familiar with faults occurring in their lighting devices or in the pico-hydro itself if this practice was not observed. Some houses have voltage stabilizers for their valuable electrical items such as television. Indeed, to ensure smooth operation of their pico-hydro units, villagers often left the pico-hydro in the stream overnight and kept their lights on overnight as well.

Diesel lamps and generators

Diesel lamps are used as the primary lighting source by households that do not have pico-hydro units of their own. As for the households with pico-hydro units, they still used diesel lamp on occasions, especially when problems occurred in their pico-hydro. Diesel lamps consisted of thick wicks inside small glass bottles filled with diesel fuel. A bottle/lamp with approximately 166 millilitres capacity could run adequately for around three days before refilling. The rate of use of diesel lamp ranged from two to five hours a day. The expense borne by the villagers in using diesel lamps for lighting has been analyzed in section 5 of this study.

As for productive energy use, there are 48 and 60 rice mills in operation in Lairthong and Nyotphaire respectively, all powered by diesel-electric generators. The rice mills vary in size and ownership (i.e. some rice mills belong to individual households, whereas others are shared between 2-4 households). These are used infrequently during the year, since the harvested rice is milled only when required for self consumption and/or selling. Additionally, there are two welding machines in each village, also powered by diesel generators.

Disposable Batteries

Disposable batteries are in widespread use for flashlights that are primarily used outdoors. The batteries are also utilized in radios, which were used from two to 12 hours per day. The households reported that they used from two to five sets of disposable batteries per month.

Candles

Wax candles are seldom used by the villagers for lighting.

Wood

Being without charge and easily available, wood is mostly used for short time lighting, especially during outdoor movements in the night.

4. Energy Demand Assessment

4.1. Household Load

The houses in the study site mostly consisted of one kitchen and one main common room with 2-4 partitions as sleeping areas, depending upon the total number of people living at the property. Hence the minimum lighting arrangement for a typical household was assumed to comprise two lighting points, to allow for one in each room. An assortment of lighting devices was found in the villages, ranging from filament bulbs to compact fluorescent lamps (CFL). The former were the more common type in use. In addition to lighting, most of the households with pico-hydro units also had television sets, typically of the black and white (B/W) variety.

When asked about their desired load, villagers often preferred to have at least four fluorescent lamps (as they are brighter than the conventional incandescent light bulbs) for lighting purposes, and possess a colour television as well as a CD/VCD player for entertainment and information reasons.

Table 3. Benchmark electricity demands per household

Type of demand	Appliances
Average demand	2 bulbs (20 watt each), 1 B/W TV (30 Watt)
Desired demand	4 fluorescent lamps (20 watt each), 1 colour TV (80 watt), 1 CD/VCD (50 watt)

Taking the average demand and desirable demand loads as benchmarks, and assuming a daily usage of five hours, the monthly electricity demand is estimated as shown in Table 4 below.

Table 4. Estimated monthly electricity demand

Type of demand	Total Power (watt)	HH Use (hr/day)	HH demand (wh/day)	HH demand (kWh/month)	Overall* demand (kWh/month)
Average demand	70	5	350	10.5	2,373
Desired demand	210	5	1,050	31.5	7,119

* Overall implies to the total number of households in the two villages (i.e. 226 households)

As Table 4 shows, an approximate monthly demand of 11 kWh per household is derived from the estimated average load. This amount would increase threefold to 32 kWh were the families in the study area to achieve their desired level of electrical load.

The actual electricity demand of households with pico-hydro generators is summarised for each village in Tables 5 and 6 below. The number of lighting points varied considerably among the 64 and 122 equipped households respectively in Lairthong and Nyotphaire villages, depending upon the wealth of the residents as well as the size of their pico-hydro unit. The village chiefs indicated that each household had at least one normal bulb and one fluorescent tube, and this estimate is used in the tables. Lighting devices were on average used for 12 hours per day, as the people left their pico-hydro units in the stream overnight. Most of the households with pico-hydro units had a television set and CD/VCD player. Although B/W televisions were more abundant, it appeared from the survey that up to 40% of the households instead owned a colour television. On average television were used for around four hours per day and CD/VCD players for two hours per day.

Table 5. Estimated current electricity use from pico-hydro per month in Lairthong

Appliances per household	No of HHs	Power (watt)	Total Load (kW)	Average use (hrs/day)	Daily load (kWh/day)	Monthly load (kWh/month)
Normal bulb	64	20	1.28	12	15.36	461
Fluorescent lamp	64	20	1.28	12	15.36	461
TV (B/W)	30	30	0.90	4	3.6	108
TV (Colour)	20	80	1.60	4	6.4	192
CD/VCD	40	50	2.00	2	4	120
Total			7.06			1,342*

* monthly load for the whole village

Table 6. Estimated current electricity use from pico-hydro per month in

Appliances per household	No of HHs	Power (watt)	Total Load (kW)	Average use (hrs/day)	Daily load (kWh/day)	Monthly load (kWh/month)
Normal bulb	122	20	2.44	12	29.28	878
Fluorescent lamp	122	20	2.44	12	29.28	878
TV (B/W)	32	30	0.95	4	3.816	114
TV (Colour)	21	80	1.70	4	6.784	204
CD/VCD	45	50	2.25	2	4.5	135
Total			9.78			2,210*

* monthly load for the whole village

From the estimates given in Tables 5 and 6, the peak load for both villages combined due to household consumption alone is approximately 17 kW. This is at present fulfilled by the personal pico-hydro units alone. The total monthly energy demand from households is similarly derived to be approximately 3,552 kWh. The peak load equates to approximately 91 W per household, which is in close agreement to the initial estimated average demand of 70 W given in Table 4.

4.2. Community Load

Both of the villages in the study area had a few communal buildings that also used electricity, including schools, a health centre and temples. At present the only electrical demand was a single light in one village temple, however the communities both expressed a desire to install electrical lighting in these communal buildings. In response to this request, an inventory of desired electrical appliances is given in table 6 below. This list was generated from the following assumptions.

A regular primary school in rural Lao PDR typically contains around four classrooms. It is estimated that at least two filament bulbs are required in each classroom for proper lighting. Likewise, at least two fluorescent tubes are necessary in health centres. One normal bulb would be enough for lighting up the *wat* (temple).

Table 7. Community electricity load

Communal facility	Number of facility	Number of connections
Primary School	Lairthong (1), Nyotphaire (1)	8 bulbs (20 W each) in 1 school
Health centre	Lairthong (0), Nyotphaire (1)	2 fluorescent lamps (20 W each) in 1 health centre
Temple	Lairthong (1), Nyotphaire (1)	1 bulb (20 W)

From this, the monthly electricity demand of communal facilities is estimated in Table 8 below. The average use per day was estimated by the village chiefs. It can be seen from this estimate that the peak load for overall communal facilities including both Lairthong and Nyotphaire villages is small compared to household consumption.

Table 8. Estimated monthly electricity demand of communal facilities

Communal facilities	No of lighting connections	Power (watt)	Total load (kW)	Average use (hrs/day)	Daily demand (kWh/day)	Monthly demand (kWh/month)
Primary school	16	20	0.32	4	1.28	38.4
Health centre	2	20	0.04	24	0.96	28.8
Temple	2	20	0.04	12	0.48	14.4
Total			0.40			82*

* monthly load for both villages in total

4.3. Overall Energy Demand and Prospects

For basic type of demand fulfilment for all 226 households in the study area, the peak load is approximately 16 kW. As for the desired type of demand, the peak load for all households in the study area amounts to nearly 48 kW.

The energy consumption assessment undertaken in this survey provides both a current and projected energy demand in the study area. Of the 226 households in the two villages, 186 currently use pico-hydro turbines to meet their electricity demands. This subset of the population demands approximately 17 kW peak load already, but aspires to a 48kW load given sufficient disposable income. Indeed, if the basic demand per household were to remain at approximately 91W, but all households in the village were to become connected to a village grid, then the additional 40 households (those currently without pico-hydro) would increase this demand to approximately 20.5 kW. Therefore, any village grid system for this settlement should be designed with a large margin for expansion included.

Another form of energy consumption that was not considered in this study was the productive energy demand largely due to rice mills. These could represent a large increase to the peak load of a village grid. Therefore a further study would be warranted if these energy demands were to be met by a central electrical energy generator in the study area.

5. Ability and Willingness to Pay

The cost of lighting sources currently in use can give an indication of the ability and willingness of households to pay for electricity. At present, villagers incur two principal expenses for lighting: the purchasing of pico-hydro units and/or buying diesel for wick lamps. The typical household expense in candles and flashlight batteries was found to be negligible.

As mentioned in section 3, the pico-hydro units used in both Lairthong and Nyotphaire ranged from 0.5 kW to 1 kW in output. The lowest price mentioned for a 0.5 kW pico-hydro unit during the household survey was 150,000 LAK (≈17 USD[2]) and the highest for a 1 kW unit was 1.2 million LAK (≈140 USD). According to the respondents, the pico-hydro units had expected lifetimes of around three years, with some need for intermittent maintenance during this time. The maintenance expense for pico-hydro units could amount to 300,000 LAK/ year (≈34 USD). Since, this is comparable to the price of a new unit, villagers would often chose to buy a replacement instead of paying for repairs, or switch to diesel lamps if unable to afford a new unit.

Considering households with and without pico-hydro electricity as two separate subgroups of the village population, the individual household expense in diesel was estimated as shown in Table 9. For households without access to pico-hydro electricity, diesel lamps were used all year round. In the case of households with pico-hydro units, diesel lamps would be used infrequently during the eight months of wet season when the pico-hydro energy is generally available. However during the dry season, people would resort to diesel lamps and follow the same general pattern of usage as those using the lamps throughout the year.

Table 9. Expense in diesel lamp per household

Type of household	No of months used	Rate of diesel use in lamp (litre/month)*	Total expense (LAK/month)**	Total expense (LAK/year)
HH without pico-hydro	12	1.5	21,000	252,000
HH with pico-hydro	4			84,000

* Rate of fuel use = 0.05 lit/day (Estimation: 150ml diesel lamp last for 3 days)

** Local diesel price was 14,000 LAK/litre at the time of this study

As shown in Table 9, the monthly household expense on diesel lamp was estimated to be around 21,000 LAK. This amounts to 252,000 LAK/year for households that use the lamps all year round. In case of households with pico-hydro, the rare use of diesel lamps during the eight wetter months of the year was ignored. Instead an annual expense was derived by only considering the four months of

[2] 1 USD ≈ 8,700 LAK, source: Banque Pour Le Commerce Extérieur Laos (BCEL), http://bcellaos.com/, accessed July 2008

dry season when households are entirely dependent upon the diesel lamps. This gave an appropriately smaller estimate than for households not equipped with pico-hydro generators of around 84,000 LAK/year.

When asked about the additional ability and willingness to pay for electricity above the current level of expense, respondents were generally prepared to pay for electricity from another (more reliable) source provided that the expense was reasonable and that the tariff could be paid in instalments (as their income is not stable throughout the year). The survey indicated an average additional sum of 20,000 LAK/month was reasonable for both villages.

The overall price villagers are able to pay per household per month was estimated as shown in Table 10. These figures were calculated by combining the expense due to pico-hydro units and diesel lamps, and the additional willingness to pay for electricity from another source. As indicated in the table villagers in the study area are able and willing to pay up to 41,000 LAK/month (≈5 USD) for the electricity utility.

Table 10. Overall ability of household to pay for electricity per month

Type of household	Expense in pico-hydro (LAK/month)	Expense in diesel lamp (LAK/month)	Additional sum willing to pay (LAK/month)	Total price able to pay (LAK/month)
HH without pico-hydro	0	21,000	20,000	41,000
HH with pico-hydro	4,167*	7,000	20,000	31,167

* Using the lowest quoted value of 150,000 LAK for a 0.5 kW pico-hydro unit that lasts for 3 years

6. Energy Potential Assessment

Household pico-hydro units form the major energy source currently used to meet the electricity needs of the people in the villages of Lairthong and Nyotphaire. However, this survey has found that this source is neither available for all months of the year, nor is it well regulated nor reliable. Combined with an expected increase in demand, there is a need to consider other energy solutions. The present survey was dedicated to assessing the potential for biomass gasification in the study area. Thus in this section, particular emphasis shall be attributed to this energy source. In order to provide a more complete assessment of the potential, a discussion of other renewable energy technologies has also been included at the end of this section.

6.1. Potential for Biomass Gasification

A sustainable supply of input feedstock is required to ensure a reliable and efficient output from a biomass gasifier. For a given system, a certain amount of biomass should be available on demand during each load. For instance, the wood[3] consumption rate of a 22 kW gasifier of 100% gas mode is 36 kg per hour; that is 1.5 kg of cut and dried woody biomass is required per unit kilowatt of electricity generation[4].

Agricultural residues

At present, rice husks, straw and peanut shells are the main varieties of agricultural residue generated each year in Lairthong and Nyotphaire. These are summarised in figure 5. Approximately 2 tons of rice husks are obtained each month from the two villages. Likewise, roughly 0.5 tons shells of peanut are generated from the overall study site. Although agricultural produce is seasonal (refer to the crop calendars in Appendix 4 and Appendix 5), they are generally stored and gradually processed/milled for regular use, mostly for self consumption all along the year.

Ignoring the technical issues of compatibility for feedstock and gasifier configuration, the amount of rice husks required for per unit kilowatt of electricity generation from a 22 kW biomass gasifier is higher than if using woody biomass. Around 1.8 kg of air-dry rice husk is required for per kWh electricity generation (Smits & Rietzler, 2008). Taking this figure into account, from a monthly production of around 2 tons of rice husks, not even 1,200 kWh of electricity can be generated in total. This is considerably below even the average demand estimated for the 226 households in the study area (refer to Table 4 in Section 4). Similarly peanut shells also represent a relatively low potential.

However, biomass gasification does represent a realistic option when considered as part of a village hybrid grid. If the entire annual rice husk stock is stored and used for electricity production via a biomass gasifier just for the four months when pico-hydro electricity is unavailable in these two villages (refer to section 3), approximately 5,838 kg of feedstock can be spent per month. This translates to 3,243 kWh of electricity production per month, which is comparable to the estimated current demand from households with pico-hydro units. However, if the predicted increase in

[3] Wood should be of proper size, good quality, low moisture (<20%) biomass and under ideal operating conditions (with cooling water temperature of less than 30^{0}C) (Source: Ankur/SME, January 2008)

[4] From specifications provided by SME Renewable Energy Co. Ltd. (January 2008)

demand is also taken into account (refer to Table 4 in Section 4), then it can be seen that biomass gasification using rice husk alone would be inadequate.

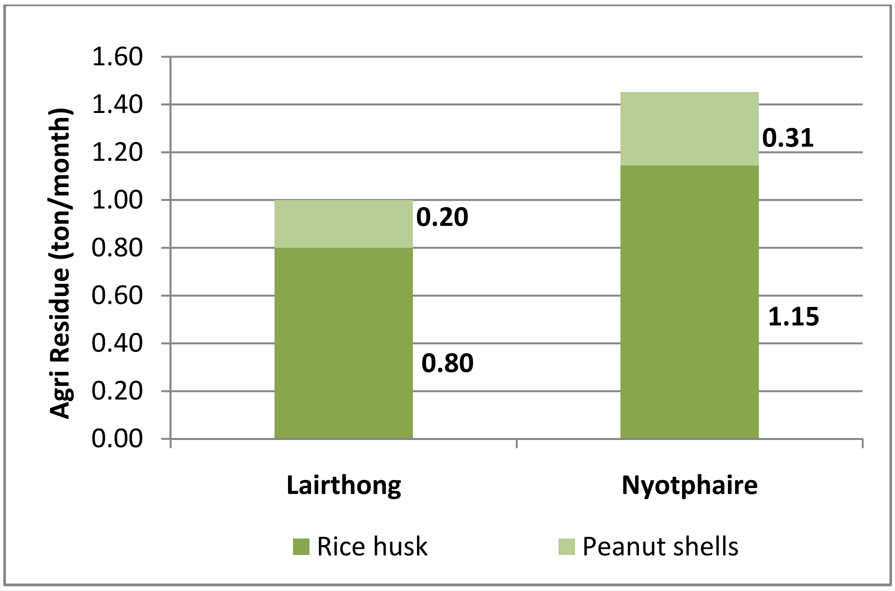

Figure 5. Amount of major agricultural residue generated per month

Other challenges can also be foreseen regarding the use of existing agricultural residue. Previous initiatives have cited technical difficulties in combining rice husks with other woody biomass. It should also be noted that these residues are not currently without use. A major fraction forms an input to other farming activities, for example, in the form of feed for livestock, cover and/or nutrient input for agriculture land, etc.

Intentional plantations

Given the concerns over the availability of existing biomass for running a gasifier, the idea of conducting sufficiently-sized energy plantations as a supplementary biomass source for the gasifier have been proposed. These plantation sites would not only provide wood for running the gasifier, but could also offer additional benefits such as providing animal fodder for livestock farmers. For this specific site, fast growing trees such as Acacias, Glyricidia and Leucaena have been proposed for initiating intentional plantations (Smits & Rietzler, 2008). However, prior to introducing any such species, it would be necessary to analyse to suitability of the available land in terms of soil and climatic conditions.

Naturally growing bamboo is abundant but not redundant in Lao PDR. Its consumption ranges from use as a construction material for houses to making household utensils and handicrafts. Depending upon the need and frequency of use, some households have cultivated bamboo in their lands as well, especially for domestic purposes. A study conducted by Boupha & Phimmavong (2006) concluded that on an average, a farmer can expect to harvest 2,832 culms[5] of bamboo per hectare. In total 1,337 ha of pure bamboo forest containing approximately 5.4 million bamboo culms exist in

[5] above-ground or aerial stems

the whole of Xiengkouang province. In order to translate this figure into a weight of avaiable biomass, it is necessary to make some assumption of the average culm size.

During the field work of this study, all respondents expressed willingness for involvement in intentional plantation projects, provided that they would gain some benefit from in addition to the production of biomass for a gasifier. On average, most people were able to set aside at least one hectare of land for intentional plantations and were willing to set aside around 200,000 LAK for possible expenses, along with providing labour for plantation management. At the community level, the village chiefs of both villages were confident of being able to set aside at least 2 ha of communal land for energy plantations as well as coordinate a village level committee for the necessary management of the plantation site.

6.2. Potential for Other Renewable Energy Technology

Solar technology

Currently, many village level meetings are being held at regular intervals to discuss specifically the options available to expanding their use of energy sources for lighting. Solar technology has been well advertised as an alternative technology. However, some concerns have been raised in the communities. Firstly the higher installation cost of solar technology compared to a pico-hydro unit makes the option less attractive. Villagers are also cautious due to the need for expertise to handle the equipment, the limited energy output.

Another option that was not under discussion in the village would be a central hydro-electric facility. Although in this study the head and flow of the main water course was not analysed, based on the current usage of pico-hydro systems, it would appear sufficient at least for part of the year. Moreover, a single communal hydro-electric system would be more efficient and more reliable that the individual units installed in the village at the time of the study.

In general, it was apparent that there is a lack of access to knowledge in the villages regarding the various energy services that could be availed from these technologies. Therefore it is clear that villages would benefit from promotional information to assist them in evaluating their options.

7. Conclusion and Recommendations

7.1. Findings of energy demand survey

A real demand for electricity was observed in the villages, with a strong indication of a growing trend as the community becomes more affluent and aware of amenities and entertainment that electricity can engender. Low cost of pico-hydro units makes them popular among the rural people. More than 80% of the total population from Lairthong and Nyotphaire villages have opted to this technology to meet their basic electricity demand. In general the population in the study area are keen to adopt any available means to fulfil their increasing energy needs. The remaining 20% of the population is still dependent on conventional sources such as wood and fossil fuel for energy, mainly due to economic limitations.

There are not yet any significant sections of the community engaged in economically productive applications of energy; a majority of the population remain subsistence farmers. Nevertheless, there still exists a sizeable demand for energy just for basic purposes such as lighting and entertainment. Looking into the current trend of electricity utilization in the study area, the load of providing basic electricity of same share to all 226 households is approximately 20.5 kW. Provided all households have adequate income, the aspired electricity demand would reach 48 kW. This also implies that any grid system developed for this village cluster should have the provision of load expansion in case of increased demand.

The present cost for household lighting, which in this case study comprises the price of pico-hydro units and diesel fuel for wick lamps, gave an indication of their ability to pay for energy. Households that completely relied on diesel lamps for primary lighting were spending approximately 252,000 LAK/year. In the case of households with pico-hydro units, a lower estimate of around 84,000 LAK/year for diesel was derived, due to the four months of dry season when the local water courses run too low to operate pico-hydro units, and therefore, villagers have to switch back to diesel lamps. The willingness to pay for electricity above the current level of expense was estimated as 20,000 LAK/month. Combining all these expenses, villagers in the study area are able and willing to pay up to 41,000 LAK/month for electricity.

7.2. Biomass potential

Considering the existing availability of biomass as input material for running a 22 kW biomass gasifier, locally generated rice husk was insufficient to produce electricity throughout the year. If rice husks produced all year round is stored and used up to produce electricity from the gasifier for only four month in dry season (when pico-hydro electricity is unavailable), it can fulfil the current demand supplied with pico-hydro units. However, if the electricity demand is to increase, electricity production from gasification of rice husk is not enough. Another challenge to using agricultural residues as input in a gasifier is the common application of this waste in existing farming activities.

Intentional plantation remains a promising alternative solution to meet the biomass requirement. The villagers have shown an interest to participate in this project and would be willing to provide 1-2 ha of land for plantation and looking after its management. A follow up study would be required to check land and climatic parameters, and identify suitable plant species for plantation. Bamboo is a promising option, being a woody type of biomass and with some history of domestic cultivation by farmers in that area.

7.3. Outstanding issues and threats

Regarding the implementation of a biomass gasifier, there remains some outstanding uncertainties that the present study was unable to elucidate either due to unavailability of reliable data or because of being out of scope of the study objective. The followings should be tackled in any future study of these villages.

1. The costs associated to the transportation of biomass from where it is produced or harvested to the community gasifier site remain unknown. Biomass transportation costs could be substantial, considering the dispersed nature of the settlements and poor conditions of the roads.
2. Electricity needs of rice mills currently operating on diesel generators. Were these to be connected to a village grid, then even if the use of these facilities is very infrequent, the increase to peak load could be substantial.
3. The potential to use a biomass gasifier to run irrigation pumps as replacing replacement to diesel. This is a recommendation drawn from the earlier feasibility study (Smits & Rietzler, 2008). Un-powered (canal) irrigation was present in the study area during the time of the current study, and hence respondents were unwilling to consider questions regarding pumping systems. However, it was uncertain whether this was the case throughout the year, and whether a real need for irrigation pumps remains in the dry season.

Finally, a possible threat to any electrification project for these villages is that a company called Phubia is currently undertaking a mining survey at Nyotphaire. Villagers are aware that, were a large-scale mining operation to be established near to these communities, then there would be some possibility that the national grid could be extended to their region.

7.4. Outlook

To summarize the above conclusions, a collective system with existing pico-hydro system in combination with a 22 kW biomass gasifier could work towards fulfilling the energy demand of this village site. Although pico-hydro units come for a comparatively lower price, electricity from this source is currently unreliable. Therefore, in the context of inconsistent supply of electricity from pico-hydro, increasing demand for additional electricity and people's willingness to pay for it, and possibility of specified quantities of biomass supply, these communities appear well suited applicator for the implementation of a hybrid village grid powered with hydropower as well as biomass and other energy sources.

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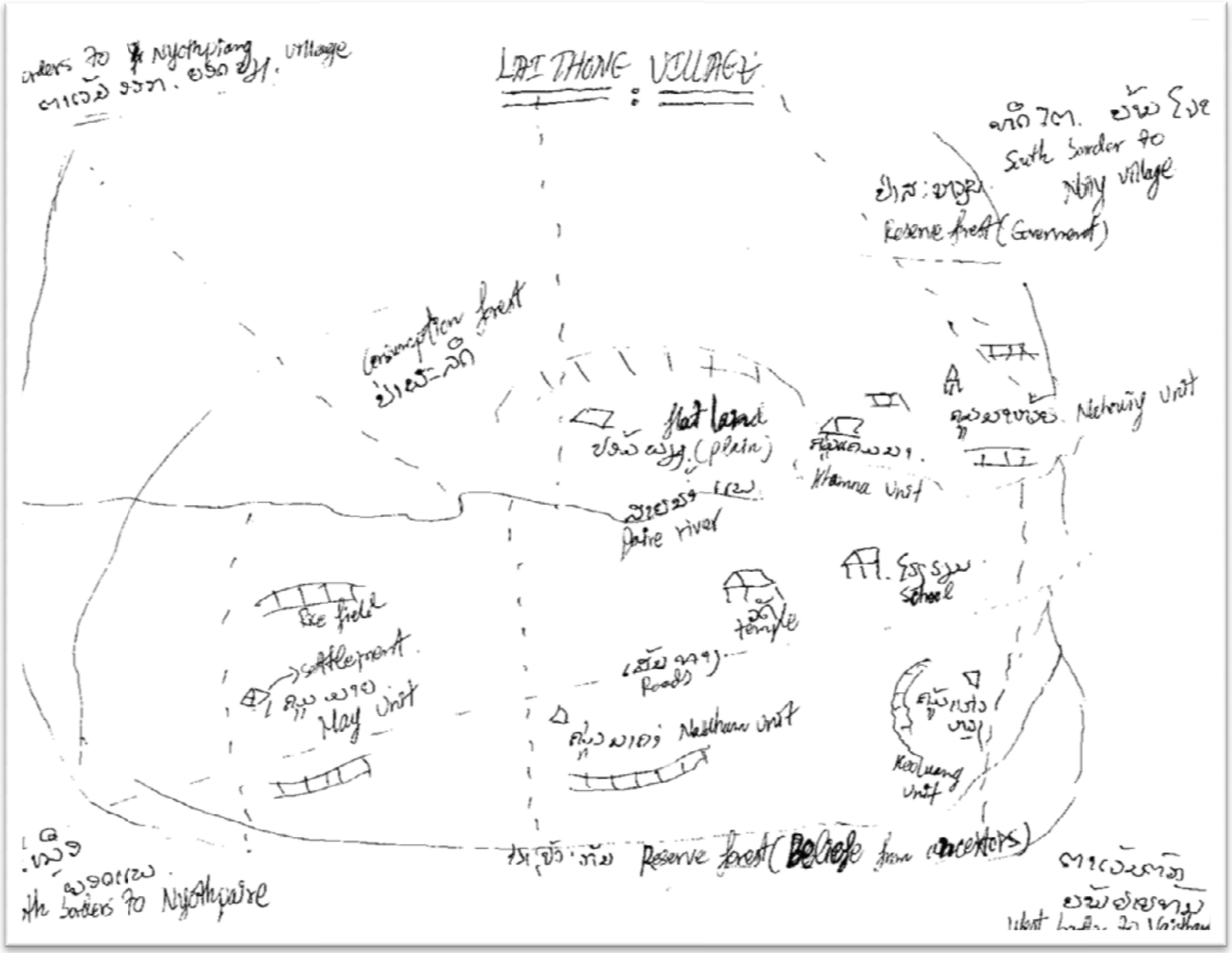
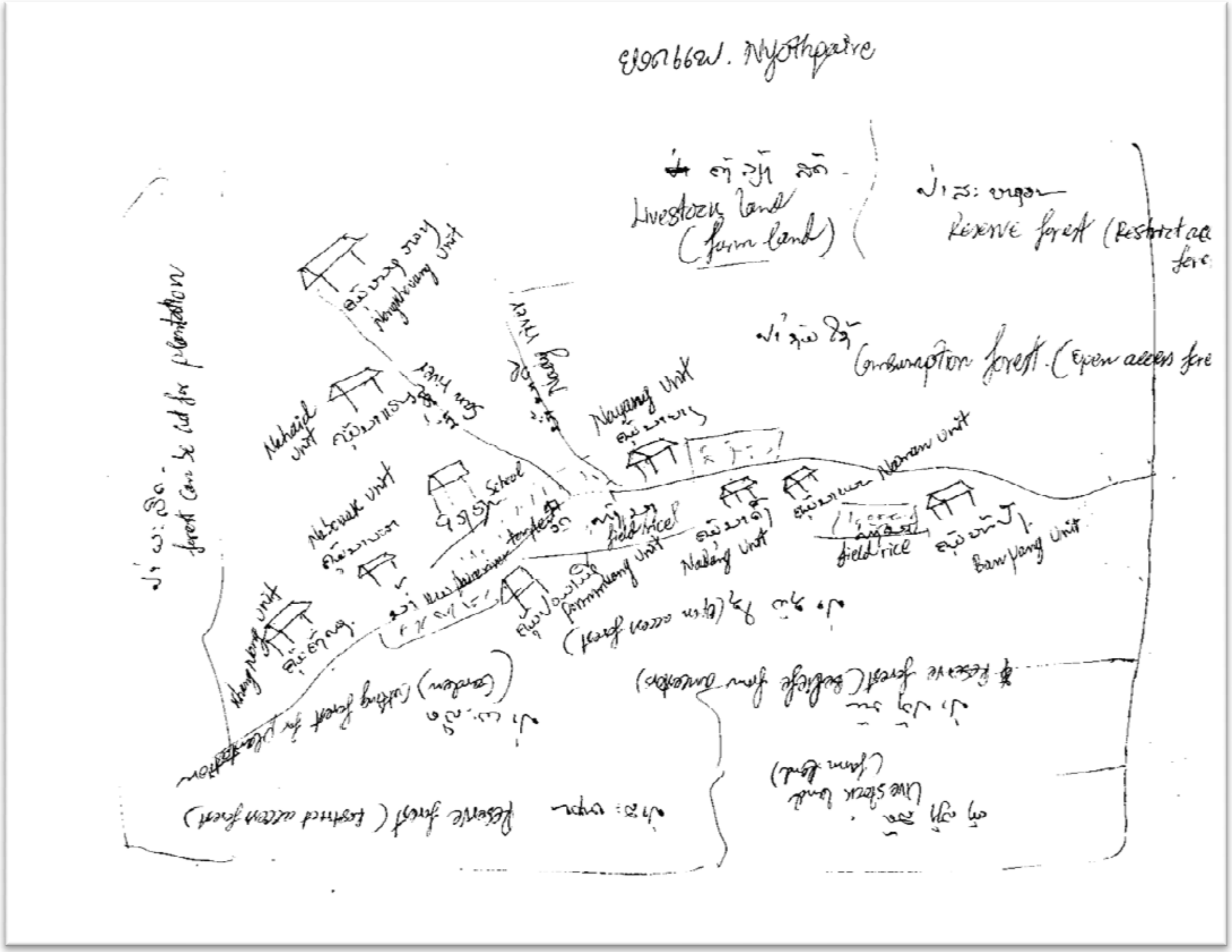
Appendix 1: List of people interviewed

SN	Name	Address
1	Saisamone Lathammavong	MoEM, Phonsavan Province
2	Khamphet Udumsuk	DAO, Phokoud District
3	Khamkeo Phanthabhom	Lairthong Village
4	Bophan Phanthabhom	Lairthong Village
5	Oma	Lairthong Village
6	Bounmmy Inthaseng	Lairthong Village
7	Bounpan Phanthabhom	Lairthong Village
8	Noyduongsee	Lairthong Village
9	Sitha Soulingthong	Lairthong Village
10	Soun Siiphawan	Lairthong Village
11	Wansii	Nyotphaire Village
12	Wanna Udonsouk	Nyotphaire Village
13	Bunphong	Nyotphaire Village
14	Odumshook Bounthan	Nyotphaire Village
15	Siamphet	Nyotphaire Village
16	Saidongta Phommawongsaw	Nyotphaire Village
17	Siambokham	Nyotphaire Village
18	Buddi Syangpochyan	Nyotphaire Village
19	Boaphan	Nyotphaire Village
20	Phon	Nyotphaire Village

Appendix 2: Resource mapping of Lairthong village



Appendix 3: Resource mapping of Nyotphaire village



Appendix 4: Crop calendar of Lairthong village

Agri Products	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Wet (field) rice	○	○	○	○	→	✓	✓	↑	↑	↑	×	×
Dry/highland rice												
Corn				→	✓	↑	↑	↑	↑	↑	↑	×
Peanut					→	✓	↑	↑	↑	×		
Garlic	↑	×							→	✓	↑	↑
Chilli				→	✓	↑	×					
Cassava	↑	↑	↑	↑	×	→	↑	↑	↑	↑	↑	↑

<u>Note:</u>

→ for land preparation

✓ for plantation/sowing

× for harvesting

↑ for the growth period

○ when land is left fallow/uncultivated

Appendix 5: Crop calendar of Nyotphaire village

Agri Products	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Wet (field) rice					→	✓	✓	↑	↑	↑	×	×
Dry/highland rice		slash and burn		→	✓	✓	↑	↑	↑	×		
Corn				→	✓	↑	↑	↑	↑	↑	×	
Peanut					→	✓	↑	↑	↑	×		
Garlic	↑	×							→	✓	↑	↑
Chilli				→✓	↑	↑	×					

<u>Note:</u>

→ for land preparation

✓ for plantation/sowing

× for harvesting

↑ for the growth period

○ when land is left fallow/uncultivated