Innovation Energie Développement (IED)

CAP-REDEO project

Capacity & institutional strengthening for rural electrification and development - Decentralised Energy Option (CAP-REDEO)

HYDRO AND BIOMASS POTENTIAL REPORT

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Spatial Analysis Report

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ABBREVIATION/ACRONYM

Cambodia

CDEC	Local Cambodian engineering firm
DIME	Department of Industry, Mines and Energy (Province)
EAC	Electricity Authority of Cambodia
EDC	Electricité du Cambodge
HC	Health Centre
HP	Health Post
JICA	Japan International Cooperation Agency
MIME	Ministry of Industry, Mines and Energy
MoEYS	Ministry of Education, Youth and Sport
MoH	Ministry of Health
MoP	Ministry of Planning, National Institute of Statistic
MPWT	Ministry of Public Works and Transport
OD	Operational district (administration office)
PPP	Public Private Partnership
REF	Rural Electrification Fund
RH	Referral Hospital
UoA	University of Agriculture, Department of Geographical System

Lao PDR

DOE	Department of Energy/MEM
EDL	Electricité du Laos
MEM	Ministry of Energy and Mines
NUOL	National University of Laos
PDEM	Provincial Department of Energy and Mines
NGD	National Geographical Department, Office of Prime Minister
MoE	Ministry of Education
MoH	Ministry of Health
MIC	Ministry of Industry and Commerce

Commonly used

DP	Development Pole
IPD	Indicator for Potential Development
HDI	Human Development Index
GIS	Geographical Information System
GPS	Global Position System

Table of contents

Introduction

In the framework of the CAP REDEO project, a detailed study on biomass and mini hydropower projects (in the range of 10 to 1,000kW) has been conducted in the two pilot provinces, namely KampongCham in Cambodia and Khammuon in Lao PDR.

This report summarizes the results of this study. In addition to the potential sites identified for rural electrification projects from hydro and biomass sources, and as part of the capacity building task of the project, some elements of methodology are provided to allow identification of other potential sites in the two pilot provinces, and even replication of the CAP REDEO planning approach to other provinces.

1 Hydro potential

1.1 KampongCham

1.1.1 Site preselection

A list of 5 potential sites for mini hydropower had been proposed by MIME in KampongCham province:

- Svay Lmeat
- Preak Lpeak
- Chroch Takok (A)
- Chom Ta Hing (B)
- Preak Chor / Preak Kampraeus (C)

The 2 first sites have been previously visited by JICA and afterwards rejected because the absence of head makes those old irrigation channels not suitable to generate electrical power on a larger scale than mere picohydro.

In February 2008, the IED hydro and rural electrification expert has visited 2 other sites (Chroch Tatok and Preak Kampraeus). A third one (Chom Ta Hing) has been investigated without field visit based on interview and map study. Eventually site Preak Kampraeus has been ruled out, due to insufficient head.

1.1.2 Preliminary data

No flow measurement data from gauging station have been made available for the surveyor, therefore no analysis of the hydro availability and the flow duration curve (FDC). However rainfall data have been collected for 4 years as given below and clearly indicates the seasonal variation with a dry season between November and April. January and February are the driest months. Moreover the field survey was conducted during the dry season allowing the surveyor to check the minimum flow conditions and to assess the potential of mini hydropower.

Table 1 Rainfall data and flow measurement (from KampongCham Meteorological Station)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Annual
2003			153.9	27.3	288.8	137.2	164	142.2	292.7	199.8	15.8	0.7	**1422.4**
2004	1.4	0	0.5	104	103.3	249	128.6	190.6	210.3	162.4	32.2	0	**1182.3**
2005	6.8	0	31.9	80.7	83.6	122.6	323.9	101.7	361.3	188.6	104	41.3	**1446.4**
2006	0	35.9	84.9	138.2	154.8	181.5	162.7	281.2	246	218.1	12.7	13.8	**1529.8**
Aver.	**2.7**	**12.0**	**67.8**	**87.6**	**157.6**	**172.6**	**194.8**	**178.9**	**277.6**	**192.2**	**41.2**	**14.0**	**1395.2**

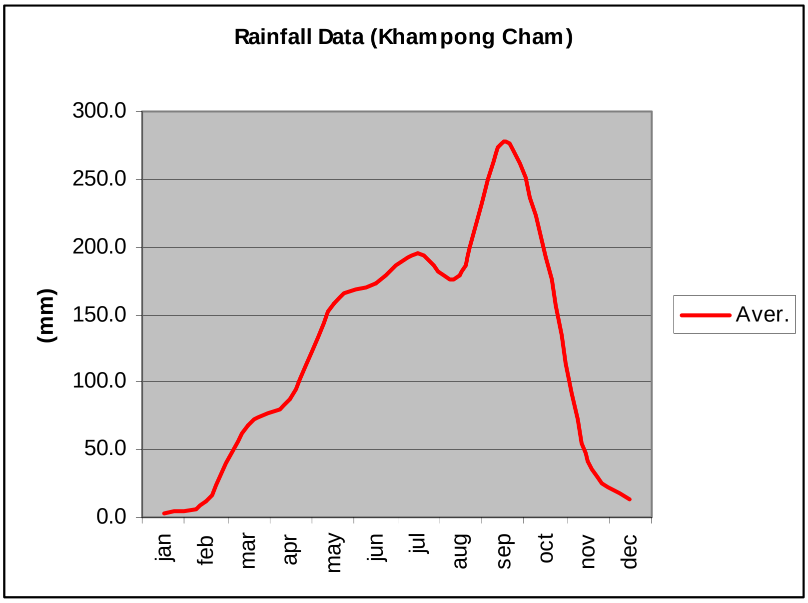

Figure 1 Rainfall data (KampongCham)

1.1.3 Selected sites

The following sites have been selected:

Table 2 Hydro potentials

Site	A	B
Site name	Chroch Takok	Chom Ta Hing
District	Stueng Trang	Dambae
Long. (dec)	105.6131	105.9526
Lat. (dec)	12.3357	11.9203
River name	Châmbâk Méas	Stoeng Thom
Head (m)	40	10 to 20m
Flow (m3/s)	0,02	0,02 (dry) – 0,2 (av.)
Power (kW)	4	20
Availability (%)	100%	50%
Village(s)	Sre Sankai (1km)	Srâmâr (<1km)
Households	36	300
Comments	2 other nearby villages	2 other nearby villages

Figure 2 Map of selected hydro potentials

1.1.3.1 Site A: Chroch Takok

The first site is located on the Châmbâk Méas river, a small tributary of the Mekong river, and has few villages in the vicinity. The site is at about 50km from the provincial town KampongCham and is accessible by track road (only 10 minutes walk). The narrow and rather steep valley has a small and short stream flowing from an upper plateau down to a field area as shown in the below map.

The main gross head is roughly estimated to 20m over 1km. It is nevertheless possible to increase the head up to 40 meters but at a reduced flow.

The river flow at the time of the site visit was estimated to be around 40 liters per second at the powerhouse location but is progressively reduced once going up in the valley. Two main tributaries are flowing to the main stream but the permeable/seepage nature of the soil affects significantly the flow at the potential intake location. At that location, the flow is estimated to be less than 20 liters/sec. Therefore the calculated hydropower is maximum 4kW[1]. The catchment area could hardly be estimated from the topographical maps.

The river flow is said to be rather constant all the year round, except after heavy rains.

The potential power demand in the vicinity comes from 3 villages (Sre Sankai). One of them (Sre Sankai) is close (1km) and small (36 households) being a better target for such small hydropower scheme.

[1] 0.02 m3/s x 40 m x 5 = 4 kW

Figure 3 Detailed map of the site (1:50.000)

Figure 4 Collection tank for water supply – potential location for powerhouse

1.1.3.2 Site B: Chom Ta Hing

This site has not been visited but has been deeply discussed with the district chief in KampongCham. According to his information and map study, a large dam (5 meter high x 2741m long) has been recently rehabilitated by the Ministry of Agriculture (2006) for irrigation purpose (not used during dry season because rice crop only). The tank is about 20.000 to 30.000m^3 and located in the upper part of a large plain. The catchment area is very limited (estimated 15 km^2) but some head can be used by bringing a penstock from the reservoir down to 1 or 2 km away. The contour lines from the topographical maps indicate a possible gross head of 10m over 1.5km and 20m over 3km.

Three villages are located nearby and are insisting to get power. Phum Srâmâr is the closest with 300 households. Phum Phâav and Phum Kouk Srâlau are about the same size (300 to 400 households each).

Some time has been spent with the district chief to explain the limitation of the reservoir for hydropower generation.

If only one village is considered (the smallest and nearest one), the required power can be roughly calculated as follow:

Power demand: 300 households x 200W/household = 60kW

Flow required: $P = Q \times H \times 5 \rightarrow Q = 60 / 20 / 5 = 0{,}6\ m^3/sec = 2160\ m^3/h$

As the reservoir has a capacity of 20.000 m^3 it will be emptied in less than 10 hours at designed flow. Even with energy saving measures and awareness of customers, the tank is expected to be emptied in less than 2 days for 1 village only.

When considering a mean specific flow of 0,013 $m^3/sec/km^2$ (assuming that 70% of the annual rainfall water is lost before reaching the reservoir), the estimated 15km^2 catchment area will produce an average flow of 0,2 m^3/sec; a third of what is required by one village.

The situation in dry season is much more critical as the specific flow goes down to 0,001 $m^3/sec/km^2$ and the river flow is estimated to be less than 0,02 m^3/sec, i.e. 280 hours or 12 days to refill the reservoir.

Furthermore the power grid should come to the main road (N7) in 2009.

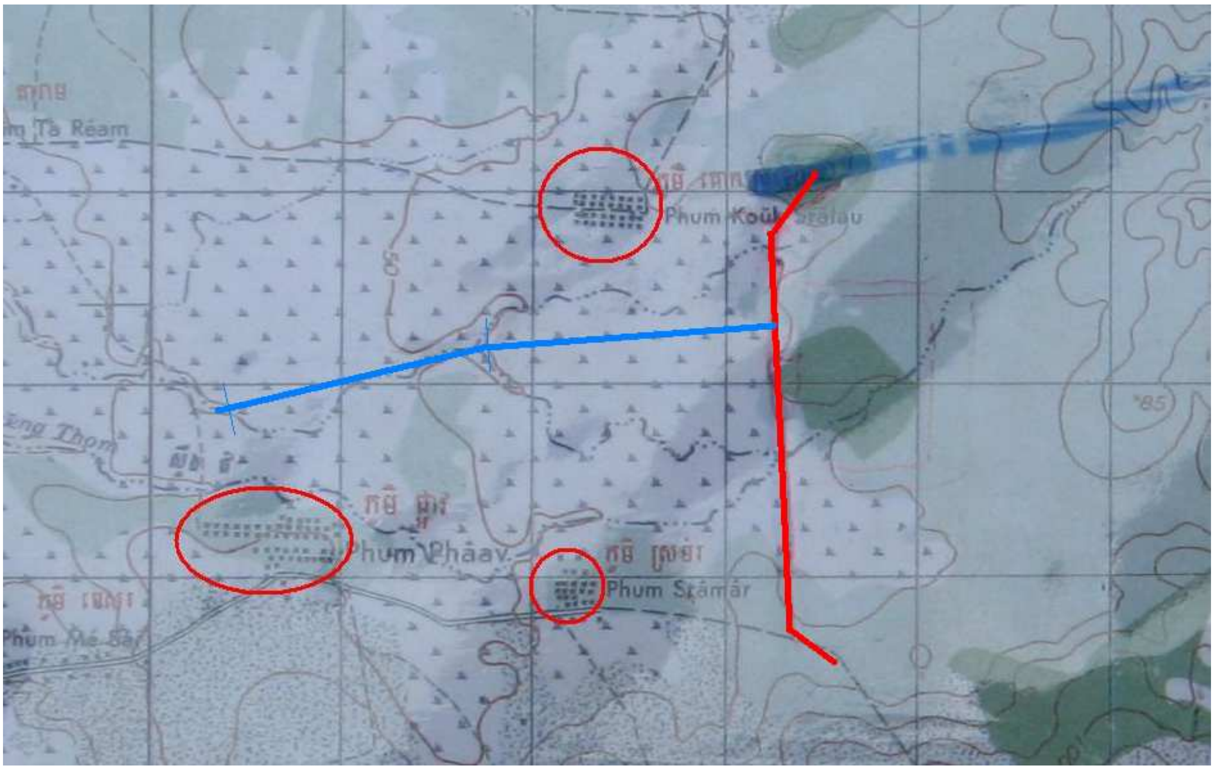

Figure 5 Detailed map of the site (1:50.000)

1.1.4 Conclusion

Despite strong local interest for hydropower generation, no site suitable for deeper investigation was found in the proposed area. Proposed irrigation channels and large reservoirs are not appropriate to produce large amounts of electricity and will probably not be an interesting option for rural electrification in KampongCham.

1.2 Khammuon

1.2.1 Methodology

14 topographical maps (1:100.000) have been screened in detail to find potential hydro sites based on the gross head **H** obtained between contour lines (either 20m or 40m equidistance) and the roughly estimated catchment area (km²). Without hydrological or rainfall data for the area, the river flows **Q** have been estimated in first approximation assuming a specific dry flow rate of 3.0 litres/sec/km². And a factor of 5 has been used to calculate approximately the potential power **P**:

$$P = 5 \times Q \times H$$

Low head hydro sites (below 30m) can be found only with field surveys or with more accurate maps. Therefore they are not included in the present investigation.

Then GIS databases from VOPS & PMU have been used to localize the existing grid and the non-electrified villages in the proximity of the potential hydro sites. The following table 1 lists the different hydro sites identified on the topographical maps with medium or high head; an assessment of some key features is given as location, canal length, distance to village(s), accessibility and connection to the grid. The maximum hydro potential varies from one site to another between 30 and 650kW.

1.2.2 Selected sites

After identification by the hydro expert and discussion during the workshop held in Vientiane on 4th of April, the following sites have been selected:

Table 3 Hydro potentials

Site	A	B	C	D	E
District	Nakai	Gnommalath	Boualapha	Boualapha	Boualapha
River name	Môn	On	Xe Bangfai	Xe-Noy	Kok
Access	+/- OK	no road	+/- OK	OK	OK
Gross head (m)	40	40	40	80	100
Catchment area (km²)	80	204	640	140	52
Dry flow (m3/s)	0.24	0.612	1.92	0.42	0.156
P (kW)	**48**	**122**	**384**	**168**	**78**
Channel	1,5	< 1	> 5	3	5
Long. (deg)	105°16'30"	105°41'20"	106°03'45"	105°46'15"	106°06'30"
Lat. (deg)	17°59'10"	17°37'40"	17°13'50"	17°06'30"	17°04'40"
Comments	1 cluster of villages downstream	All nearby villages are located along that road and many are already electrified.	2 villages down- and 1 cluster up-stream	2 clusters of villages: up- and down-stream. Alternative of 84 kW with 40m head and shorter canal	1 cluster of villages downstream. Alternative of 47 kW with 60m head and shorter canal (3km)

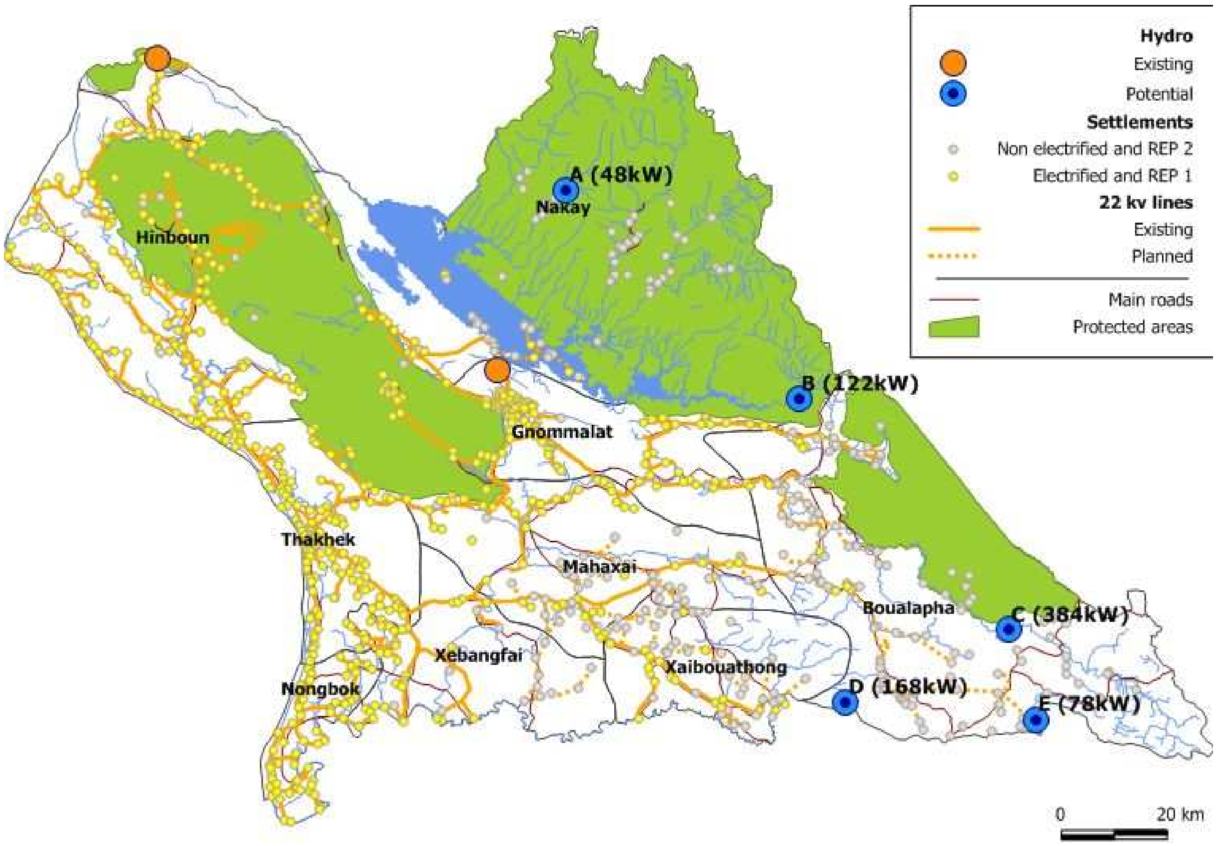

Figure 6 Map of hydro potentials

1.2.2.1 Hydro site A

This site has the smallest estimated capacity (48 kW) but benefits from an appropriate layout of 6 small villages gathered in the proximity of the hydro site (less than 11km).

1.2.2.2 Hydro site B

The site has good potential (122 kW) thanks to the Nam On river flow but the 40m head is located inside the forest beyond a mountain range at about 6km from the main road and less than 10km from the existing grid. All nearby villages are located along that road and many are already electrified.

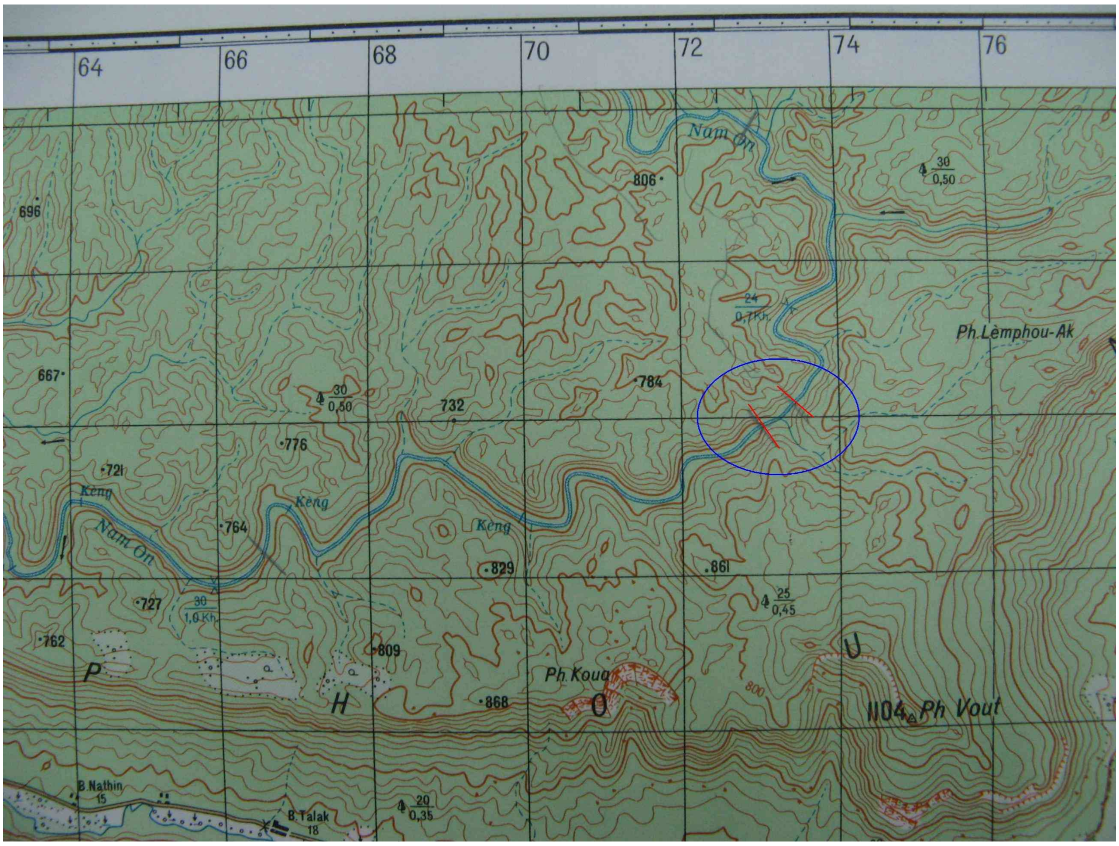

Figure 7 Detailed map of the site (1:100.000)

1.2.2.3 Hydro site C

The hydro potential of this site (384 kW) obtained with the good flow of Xe Bangfai river is attractive but only 5 villages can be found on the map in a radius of 15km, with an estimated total power demand of about 50kW.

1.2.2.4 Hydro site D

This site is easily accessible and has 5 small villages within 10km radius (upstream and downstream) with an estimated demand of 20kW. The hydropower potential estimated at 168 kW is largely above the demand.

1.2.2.5 Hydro site E

Despite an easy access and the proximity of 5 villages (within 5km radius), this hydro site requires a rather long canal to generate the full estimated power of 78kW. A smaller scheme of 50kW could be more cost-effective and could better match the local power demand level.

1.2.3 Recommendations

To assess more accurately the hydro potential of the selected sites, it is recommended to collect and analyze rainfall and/or hydrological data and to visit the rivers to measure the actual head available. An example of questionnaire is given in ANNEX 1, to show data needed to assess the suitability of the site for rural electrification and provide a first estimate of its capacity.

2 Biomass potential

2.1 Introduction

In this chapter, identified biomass potentials will be presented. There are many different types of technology to exploit energy from biomass and even more different biomass resources. Since biomass projects are currently not widespread in both Cambodia and Lao PDR, a brief overview of our hypotheses on the technology and targeted biomass resources will be given beforehand.

Although roughly estimated, potentials identified in this study are meant to open the way to deeper investigations and hopefully real projects. Nevertheless, because relevant data was not always readily available, the list of possible projects might not be as complete as possible. Therefore, some guidelines are provided to find more potentials in the pilot provinces and other provinces as well.

2.2 Targeted biomass resource

Studies on biomass resources generally divide them in three main categories:

- Natural resources (indigenous trees, bushes…)
- Energy plantations (fast growing trees, oil and sugar producing crops)
- Agricultural and industrial residues (all residues resulting from harvesting or transformation of agricultural products, e.g. rice husks, saw dust, wood chips, animal manure…)

The first category has been ruled out in our study, because of their unsustainable nature. Rural electrification planning should rely on sustainable scenarios and avoid encouraging overexploitation of natural resources.

Energy plantations will not be considered either, because they usually imply particular crop development scenarios and there are serious uncertainties concerning their environmental and social sustainability:

- Energy crops have a strong reputation of soil resource depletion and usually require large amounts of water, which might pose a problem especially in KampongCham where irrigation schemes are not widespread.
- In a context of low productivity and already high prices of food commodities, these plantations will compete with animal feeding and food uses, and therefore threaten the living conditions in rural areas.

In our planning approach, we prefer starting from existing and, if possible, unexploited potential. Therefore we will focus only on existing agri-businesses and plantations, which produce interesting residues for biomass-based electricity generation. This will be typically rice mills and wood processing industries (saw mills and furniture factories), which produce respectively:

- Husks and straw
- Saw dust, wood chips and off-cuts

While these two types of residues are commonly cited in biomass assessment studies in Cambodia and Lao PDR, they are not the only ones. A few others will be given for each province as suggestions for deeper investigation.

2.3 Technology

The technology used to convert residues to electricity will be biomass gasification. The overall process is summarized in the following diagram:

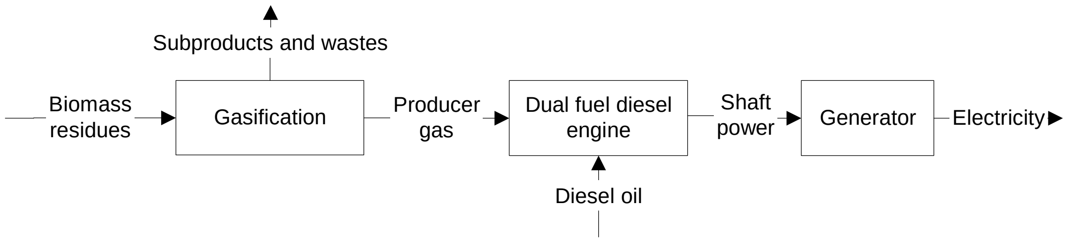

Figure 8 Gasification process

Biomass residues are first partly consumed in a gasifier, which controls the quantity of oxygen available so that residues do not consume completely but instead release “producer gas” or “poor gas” as a consequence of the high temperature. This gas contains mostly carbon dioxide, which is not useful for energy generation. But the remaining is methane (approx. 30% of the producer gas), which is the well known gas present in natural gas and even biogas, which should not be confused with producer gas. Biogas is obtained from anaerobic[2] digestion of organic matter, and its methane content is much higher, usually around 60%. Nevertheless, biomass gasification is a rather efficient conversion process, since it converts around 80% of the energy contained in the residue into gas.

The gas is then cleaned from impurities and burnt in a modified diesel engine. At this stage, there are two approaches: the diesel engine is either used in dual fuel mode (part diesel, part producer gas) or 100% gas. In the latter case, the engine needs some additional changes (spark plugs) to make it work without diesel. However, in this study we make the hypothesis that, even though diesel price is high, we will keep the option of dual fuel so that the quality of service can always be ensured even when the biomass supply is momentarily insufficient.

Another advantage of dual fuel systems is to guarantee the efficiency of gasification. The gas output of the gasifier can play the role of base generation, while fluctuations in demand can be addressed with diesel fuel. Indeed, the efficiency of gasifiers drops significantly below nominal capacity. It is thus better to keep their output steady.

The main advantages and issues of this technology are presented below:

Advantages

- Proven technology in other countries
- More efficient than direct combustion in a boiler coupled to a steam turbine.
- Different types of residues can be used at the same time, provided they have similar shapes and density, e.g. rice husk, peanut shells and saw dust or maize cobs, off-cuts and branches…

Issues

- Technology still not widespread in Cambodia and almost nonexistent in Laos
- Environmental hazards : wastewater and tar created during gasification. These substances pose some treatment and storage issues which are currently not really solved for rural electrification applications. However, tar production is minimized with downdraft designs (biomass is fed at the top of the gasified).

Finally, biomass gasification, as most biomass technologies, is more labor intensive than other supply options. Apart from the whole process of residue production, the residues must

[2] Without oxygen.

usually be preprocessed (trimmed and sometimes dried) before entering the gasifier. And biomass feeding is done by hand regularly throughout the day. This can be a disadvantage for the cost of production but it should be mainly regarded as an advantage for local employment opportunities.

Biogas production from animal manure would have been also an interesting option if there were large animal breeding facilities such as piggeries, unfortunately there is currently none in pilot provinces.

2.4 KampongCham

2.4.1 Sources of data

A first overview of the biomass potential has been taken from the JICA master plan on rural electrification from renewable energy[3]. Then several interviews have been conducted with different actors of the biomass sector in Cambodia, including:

- Department of Industry, Mines and Energy (DIME) in KampongCham province
- SME Renewable Energy Ltd
- Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)
- Ministry of Agriculture and Department of Agriculture (DOA) of KampongCham province

A field survey has also been conducted to identify interesting projects in KampongCham. The survey has been carried out among:

- 7 rice mills located in Cheung Prey, Prey Chhor and Tboung Khmum district, with production ranging from 130 to 10,000T rice per year
- 4 saw mills located in Ponhea Kraek, Chamkar Leu and Stueng Trang districts

[3] "The master plan study on rural electrification by renewable energy in the kingdom of Cambodia", JICA. 2006

Figure 9 Map of surveyed biomass potentials in KampongCham province

Several questions were asked to these mills, including their production, total residues, current use of residues and energy consumption of the mill.

According to indications from DIME, the above sites were among the largest in the province. However, the survey revealed that some other large rice mills and saw mills might still exist and we are expecting a more thorough list in the near future.

In addition, two existing gasification projects have been surveyed:

- REE in Prey Totueng
- Ice factory in KampongCham town

These two existing projects showed that the technology is viable in the area, and even more that technical know-how for construction and operation are available locally (both gasifiers were assembled by their owners).

2.4.2 Methodology

2.4.2.1 Rice husk

Significant potential has been found with rice mills for electricity generation from rice husks. In fact the largest ones had already been contacted by several suppliers of gasifiers (both local and foreign companies).

Even if most large rice mills are located in areas electrified by REEs, the tariff and quality of supply are such that all rice mills have their own diesel engines[4]. Gasification would then be an interesting option to decrease energy expenditures. According to our survey, about 40% of rice husks produced by the mill would be needed to replace entirely the diesel consumed. The remaining 60% would then be theoretically available for rural electrification, and most rice millers stated that they are willing to sell excess electricity to their surroundings.

[4] In most rice mills, no electricity is produced by the engine. Shaft power is only transmitted to different parts of the mill, through the use of drive belts. However, a rice mill in Tang Kouk (built in 2007) did generate electricity to power a very modern rice mill.

However, all large rice mills surveyed are already in areas electrified by REEs. Therefore, this kind of project is not in the focus of our project. Besides, investment costs are currently too high for rice millers (without access to adequate soft loans) and there are some organizational issues regarding electricity production from rice mills as this is not their core business, and association with private investors can be risky[5].

The suggested projects are thus not located inside surveyed rice mills, but instead near non electrified Development Poles[6]. Rice husks would then be collected from one or several rice mills in a 10 to 15km radius. Transportation of residues on even higher distances (20 to 25km) is proven to be feasible with the gasification plant of Mr. Kun Sambo (Prey Totueng).

Considering the existing non energy-related uses of rice husks (fertilizing, animal feeding, brick making…), we assume that only 50% of the available resource would be allocated to electricity generation.

2.4.2.2 Wood residues

The quantity of hevea (rubber tree) cultivated in KampongCham is supposed to by rather significant (around 300,000ha of industrial plantations according to CIRAD). However, the majority of it has been planted recently. Considering the relatively slow growth rate of hevea (around 30 years), the potential in terms of harvesting and thus residues will be low in the coming years. One of the surveyed saw mills was actually closing its businesses because of a shortage of supply.

Data on production and location of all large saw mills was not available, therefore we will only rely on the surveyed saw mill and their figures on residue production (off-cuts).

2.4.3 Site selected

The following projects have been selected:

Figure 10 Selected biomass potentials in KampongCham province

Site	A	B	C	D	E
District	Cheung Prey	Prey Chhor	Tboung Khmum	Stueng Trang	Stueng Trang
Long. (dec)	105.1085	105.2414	105.7165	105.5942	106.0040
Lat. (dec)	12.1385	12.1506	11.9710	12.3585	11.7845
Type of residue	Rice husks	Rice husks	Rice husks	Offcuts	Offcuts
Estimated residues available (T per year)	2000	1400	1300	120	630
Collected from	1 rice mill in Skon	2 rice mills in Doun Dei and Tang Kouk villages	3 rice mills in Tboung Khmum district	1 saw mill in Boeng Ket Leu	2 saw mills in Trapeang Phlong Pir
Energy output from biomass only (MWh per year)	1000	650	550	80	420

5 A recent dispute between a rice mill and a REE over the control of the generation equipment resulted in the closing of a gasification plant in KampongCham.
6 Cf. CAP REDEO Spatial Analysis report.

Site	A	B	C	D	E
Total energy output (MWh per year)	1400	950	850	120	630
Power (kW)	330	220	194	27	144

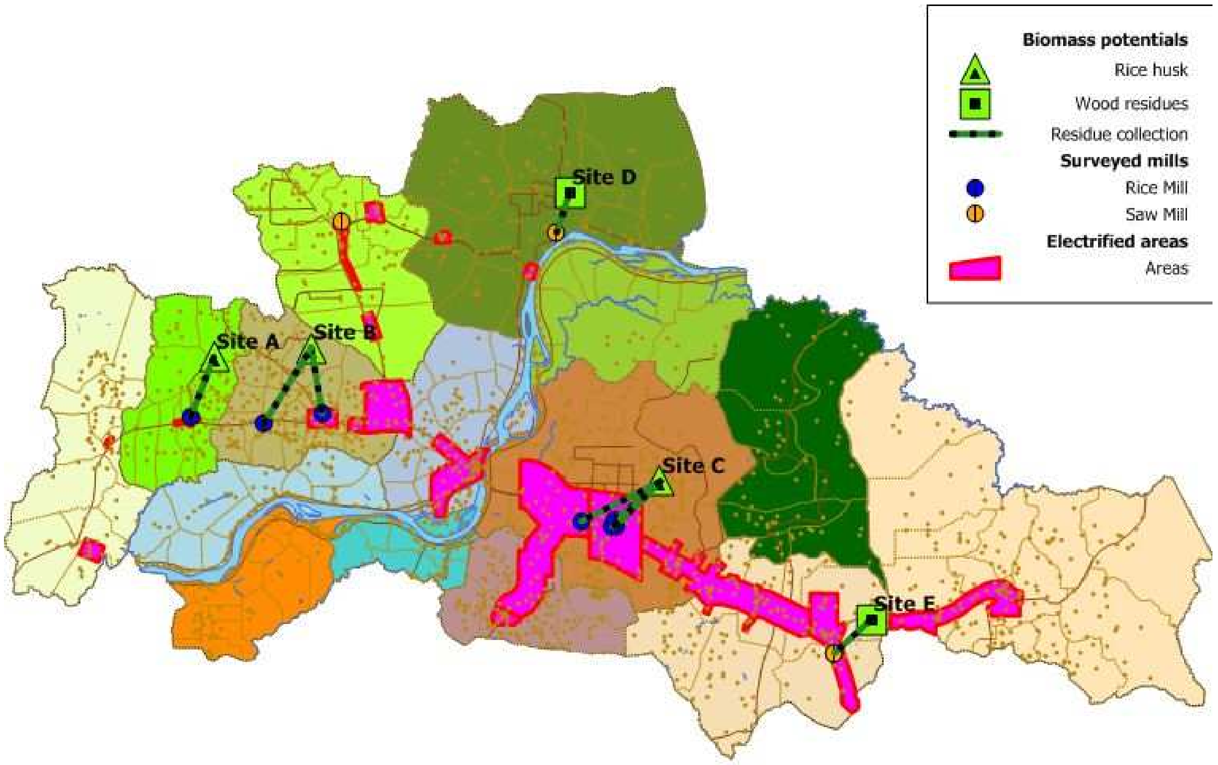

Figure 11 Map of biomass potentials for KampongCham province

Purchase price of residues is taken equal to 10 US$/T, including transportation costs[7]. Investment cost will be 1350 US$/kW, taken from the price of integrated systems sold by Ankur Scientific (Indian manufacturer).

2.4.4 Recommendations

It should be noted that the potentials mentioned above have been calculated from surveyed sites only. According to surveyed rice millers and an outdated list of rice mills in KampongCham, there are several other rice mills which could supply these projects or even new ones, especially in Cheung Prey, Prey Chhor and Tboung Khmum districts.

Likewise, other saw mills and furniture factories may be of interest. However, both their production capacity and the long term sustainability of their operation have to be carefully assessed.

To ease identification of additional potentials, an example of survey form as well as ratios to calculate the potential output are provided in annexes.

Apart from rice husks and wood residues, other biomass resources can be investigated:

- Despite 40,000ha of cashew nut plantations in the province, it seems that no processing unit is running in the area. The only existing one has been closed recently

[7] The REE in Prey Totueng buys its residues at around 8 US$/T, including transportation. In some areas rice husks are sold directly to villagers for cooking at around 4 US$/T.

according to DOA. Would any industrial collection or transformation factory be created, it would represent an interesting potential for residue production.

- Some sources believe that there are significant cassava and soy bean transformation units in the province. These factories might produce interesting residues as well.

2.5 Khammuon

2.5.1 Source of data

The main sources of data for Khammuon province used in this study are the following:

- Crop statistics for each district of Khammuon province (2006), from Department of Agriculture (DOA).
- List of all industries, kindly transmitted by Provincial Department of Energy and Mines (PDEM). This list includes all rice and saw mills, with a few figures on their total capital, number of employees, installed capacity etc., but no figure on production.
- Study of the Lao Institute for Renewable Energy (LIRE) on “biomass gasification in Lao PDR”
- Interview with the Science Technology and Environment Agency (STEA) in Vientiane.

The largest rice mill and saw mill of the province, located near Thakek town, have been surveyed to have an idea of competing uses in the area. However, they do not have any potential in terms of rural electrification since they are in an electrified area.

As experience in biomass projects is rather limited in Khammuon, some ratios taken from surveys and interviews in Cambodia have also been used.

A comprehensive report on biomass gasification in Lao PDR is due to be released by ESMAP, unfortunately it was not available at the time when this study has been done.

2.5.2 Methodology

We have used the following criteria to identify the site of potentials in Khammuon:

- The area should not be electrified and not belong to REP 1, which is assumed to be completed within 2 to 3 years. This criteria is critical, as most of the province is already electrified, or already under electrification projects.
- There should be significant residue sources (rice mills or saw mills) in a 10 to 15km radius.
- It should be close to main roads to allow easy transportation of residues, and close to Development Poles[8].

2.5.2.1 Rice husk

Survey on the largest rice mill in the province and data gathered during the socio-economic survey for the load forecast tend to show that the average production of rice mills in Khammuon is rather small (some village have up to 5 rice mills). Besides, the only industrial size mills are already in electrified areas[9]. Nevertheless, we believe that gasification projects might still be feasible through collection of rice from a large number of medium sized rice mills. Obviously, the cost an complexity of projects will be increased, and further analysis will be needed to assess their actual feasibility.

As data on the production of rice mills was not available, we made the following hypotheses to estimate it:

[8] Cf. CAP REDEO Spatial Analysis report.

[9] Contrary to the KampongCham case, the low electricity tariff make it possible for rice mills to connect to the grid.

- The rice cultivated in each district is processed by rice mills located in the same district[10].
- The quantity of rice processed is proportional to the total capital of the mill.

Then a collection area has been roughly drawn with a 10 to 15km radius, to assess the total quantity of rice husk available per year. As rice husks are currently used for other purposes (feeding, burning etc.), we assume that only 50% of residues would be available for electricity generation.

2.5.2.2 Wood residues

Accurate data on production of saw mills is very difficult to obtain in Khammuon, partly because of the significant illegal traffic. The reservoir of the large dam project of Nam Theun 2 will cover a large area of forest, and it is expected that a lot of wood will be processed in the coming years. However, this should not be considered as a regular supply of wood in our planning study.

Moreover, MEM does not want to encourage electricity production from wood residues, as it could eventually reinforce overexploitation of wood resources.

Therefore, gasification projects from wood residues will not be studied in Khammuon.

2.5.3 Sites selected

The following projects have been selected:

Table 4 Selected biomass potentials in Khammuon province

Site	A	B	C	D
District	Boualapha	Xaibouathong & Mahaxai	Xebangfai	Mahaxai
Long. (dec)	105.8232	105.4995	105.2165	105.2552
Lat. (dec)	17.2370	17.2635	17.1315	17.3389
Type of residue	Rice husks	Rice husks	Rice husks	Rice husks
Estimated residue production (T/year)	1250	850	240	400
Collected from	22 rice mills	57 rice mills	16 rice mills	20 rice mills
Energy output from biomass only (MWh/year)	550	350	110	180
Total energy output (MWh/year)	**850**	**600**	**165**	**270**
Power (kW)	**200**	**125**	**37**	**62**

[10] This assumption would be wrong in the example of large rice mills in KampongCham, which imported rice from neighbouring provinces. However, the capacity of rice mills in Khammuon is believed to be much smaller, and it is thus reasonable to state that they process only local rice production.

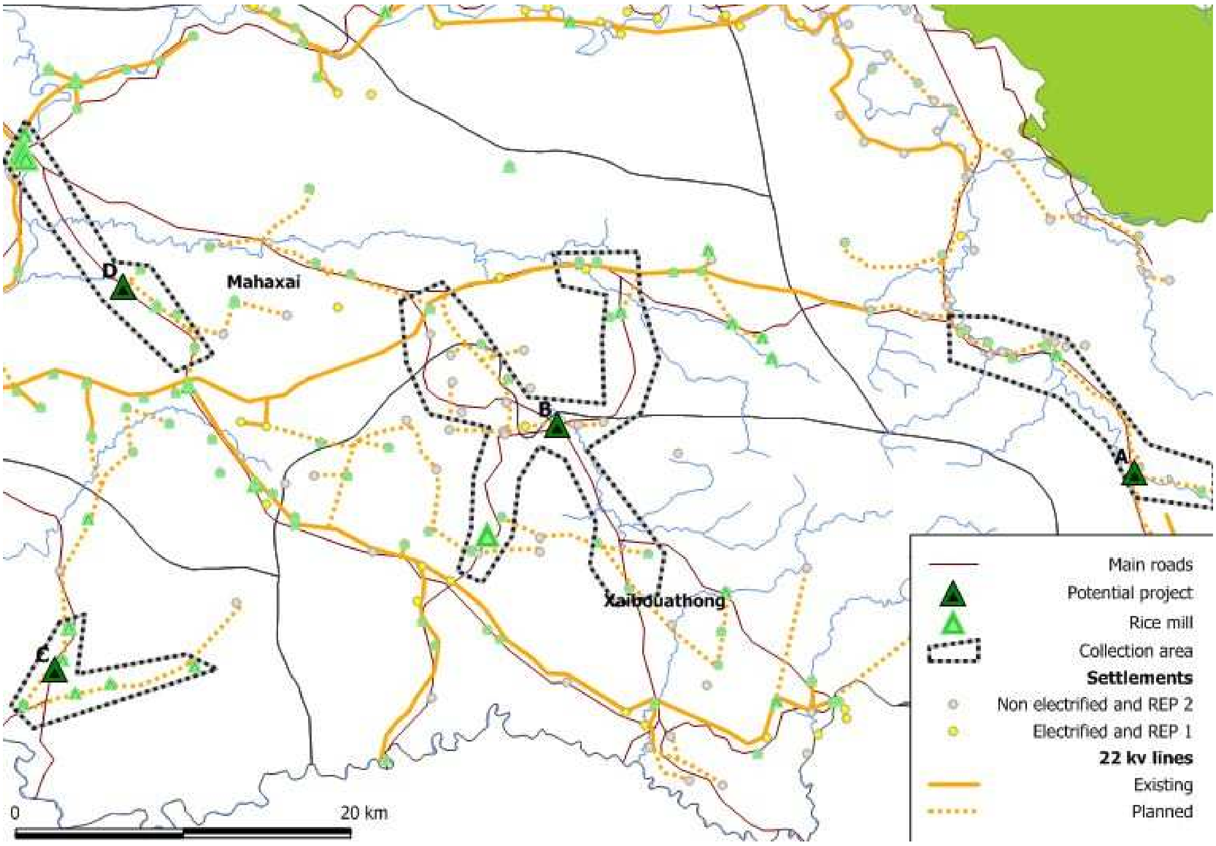

Figure 12 Map of biomass potentials for Khammuon province

Purchase price of residues is taken equal to 8 US$/T, including transportation costs[11]. Investment cost will be 1350 US$/kW, taken from the price of integrated systems sold by Ankur Scientific (Indian manufacturer).

[11] The LIRE study estimates the price at around 5US$/T, but it only accounts for transportation costs from close sources.

ANNEX 1 Example of Hydro questionnaire

1	**Latitude**	
2	**Longitude**	
3	**Altitude (m)**	
4	**District**	
5	**Name of River**	
6	**Gross Head (m)**	
7	**Catchment area (km)**	
8	**Mean annual flow (m3/s)**	
9	**Dry flow (m3/s)**	
10	**Site seasonality**	

Month	**Jan**	**Feb**	**March**	**April**	**May**	**June**
Mean Flow (m3/s)						
Month	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Mean Flow (m3/s)						

11	**SHP Availability (% of the year)**	
12	**Potential Installed Capacity (kW)**	
13	**Length of channel (m)**	
14	**Estimated Investment Cost (local currency)**	
15	**Distance to nearest village (km)**	
15	**Comments**	

ANNEX 2 Example of Biomass questionnaire

1. Area Identification

Date:	___/___/2007
Enumerator	

Village / Town:	
Commune:	
District:	
Longitude:	
Latitude:	

2. Activity Type

1	*Paddy*	*5*	*Furniture factory*
2	*Rice mill*	*6*	*Peanut*
3	*Saw mill*	*7*	*Cashew nut*
4	*Wood harvesting*	*8*	*Other:_______________*

Activity type**:**	

3. Activity Description

How many people does the activity employ?	
Who operates the activity ? 1=Government, 2= Private, 3=The Community, 4=other (please specify)	

4. Production

What is the average annual total production of the end product?		
Will the activity remain in operation for the next 10 to 20 years in the same location?	1=Yes 2=No	
What type of energy does the activity use 1=Electricity from the grid, 2=Diesel genset, 3=Other, please specify		
If the activity owns a diesel genset, how many liters are consumed per day ?		
Please describe the waste(s) produced: - Type of waste - Moisture (wet or dry) - Quantity produced per year		
Are the waste product used?	1=Yes 2=No	
If yes, for what purposes is it used for?		
If yes, for how much is it sold for?		
What percentage of the waste product could be used for energy purposes?		

5. Seasonality in Production

Is there a seasonal variation in production?	*1=Yes, 2=No*	

Months of Production: (Cross if applicable)

Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
What is the average monthly production											

ANNEX 3 Ratios used in potential identification for rice mills and saw mills

The first step is to assess the quantity of residues available for power generation. Sometimes the respondent has the exact figure, but very often they only have a rough idea of the total amount of residues produced and the units might not be very accurate[12]. It is thus advised to first estimate the average yearly production and then use the following average ratios:

Table 5 Residue ratios

Product	Residue
1T rice produced	0.42T rice husks
1T raw wood processed	0.5 residues, including 0.2 offcuts (suitable for gasification), 0.2 shavings and 0.1 sawdust

Again, production can be given directly by the owner or estimated from the capacity of the mill and its average load (e.g. used at 80% of its capacity for 8hours per day and 6 days per week).

Once the quantity of residues available is known, we can calculate the energy which can be produced with the following ratios:

Table 6 Quantity of residues to produce 1kWh of electricity

Residue	Quantity to produce 1KWh of electricity
Rice husks	1.8 to 2.3 (av. 2.17)
Off-cuts and other woody biomass	1.5

Then the total quantity of energy produced is calculated with the assumption that diesel would account for one third of the total consumption:

$$\text{Total Energy Produced} = \frac{\text{Energy Produced From Biomass}}{1 - \frac{1}{3}}$$

And finally, the capacity is derived from the total energy produced, assuming a plant factor of 50% (ratio between the average power and the peak power):

$$\text{Power} = \frac{\text{Total Energy Produced}}{8760 \times 50\%}$$

[12] rice bags, small carts, trucks etc. are often mentioned