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

CAP-REDEO

Innovation Energie Développement (IED)

CAP-REDEO RESULTS REPORT

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IED

Intelligent Energy Europe

PROJECT REFERENCES

Contractual References :

IED : 06/013/CAP REDEO
IEEA : EIE/06/265/SI2.447980

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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 Center
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

Common used

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

1 Introduction

1.1 Presentation

Title:	Capacity and Institutional strengthening for rural electrification and development – decentralised energy options
Acronym:	CAP-REDEO
Programme area:	COOPENER
Target countries:	Cambodia and Laos PDR
Status:	Completed
Coordinator:	Innovation Energie Développement (IED) France E-mail: ied@ied-sa.fr Tel:+33-4 72 59 13 20
Partners:	ETC foundations, the Netherlands
Subcontractors:	Cambodian Development and Engineering Company (CDEC), Cambodia; SV company, Laos PDR
Associates	Ministry of Industry and Mines (MIME, Cambodia), Electricité du Cambodge (EDC), Electricity Authority of Cambodia (EAC); Rural Electrification Funds (REF, Cambodia), Ministry of Energy and Mines (MEM, Laos PDR), Electricité du Laos (EDL)
Website:	www.cap-redeo.com
Objective:	Improve the impacts of rural electrification on poverty alleviation by establishing effective multi-sectoral investment and planning capacities and instruments using GIS as the convening factor. Formulate appropriate policies and instruments to reach this goal.
Benefits:	- National level rural electrification and development tool - Provincial level rural electrification and development programmes - Operational groups familiar with rural electrification planning as an input to rural development, planning approaches and the proposed tools - Replicable training programmes
Keywords:	Rural electrification, GIS database, multi-criteria planning
Duration:	12/2006 – 12/2009
Budget:	€ 690,322 (EU contribution: 50%)
Contract number:	EIE/06/265/SI2.447980

1.2 Context

Rural electricity services play a key role in rural development because the access to affordable, reliable and safe electricity can greatly improve food, education and health services, as well as improving opportunities for income generation. This is particularly true for Cambodia and Lao PDR, after decades of destructive war.

Cambodia has a population of about 13.5 millions, of which 84% live in rural area. In the rural areas of Cambodia, the generation and distribution of electricity is mainly left to small private entrepreneurs because the governments need to focus limited resources on urban areas. Consequently this important rural service is usually provided by small family businesses (commonly used name of Rural Electrification Enterprise REE in Cambodia) with very limited technical and managerial capacity, with no access to support services or advice, and with very limited access to financial services needed to upgrade their operations. The environment in which these small businesses operate is increasingly difficult due to rising fuel prices (imported diesel fuel), and increasing pressure from government to improve standards, quality and reduce tariff.

The Royal government of Cambodia has formulated its policy in term of rural electrification as a part of Cambodia's wider rural transformation and poverty alleviation goals. It put a high target for rural electrification to reach 70% of Cambodia rural population within 30 years from now.

Lao PDR has a population of 5.61 million people in 2005. There are over 72% of population live in rural areas and are engaged in rice-based agriculture. It has significant natural resources like forestry, minerals and hydroelectric power. The government of Laos has formulated it objective to attain 70% of electrification by the year 2010 and 90% by the year 2030.

In the short term, Laos is embarking on its Rural Electrification Programme with the support of World Bank and GEF: the off-grid component is now launched and the grid extension component under way. Cambodia is launching a World Bank supported Rural Electrification project (as of July 2006, the Rural Electrification fund has been established) and has completed a renewable energy resource assessment supported by JICA and is currently formulated the master plan for Renewable. There is an urgent need in both countries to develop technical capacity and to be endowed

with hands on tools to direct investments and decide between off grid and on grid options, renewable or fossil fuel based off grid production – and priority areas from the perspective of maximizing development impact of scarce resources.
To meet this challenge, this project will analysis the options and perspectives: its supply sources, its main actors and its rural energy market, to show that with the mobilization of all means and resources, this target is achievable.

1.3 Objectives

The global objective of the project in Laos and Cambodia is to improve the impact of rural electrification on sustainable development and poverty alleviation by establishing effective cross sectoral investment and planning capacities and instruments using Geographical Information Systems as the convening factor. The ultimate objective of the present action is that the developed tools outputs provide the required tangible elements for the formulation of appropriate policies and instruments to reach this goal. Hence, the project will:

- Raise awareness among high level decision makers of the important role energy can play in poverty eradication, through fostering of multisectoral working groups;
- Strengthen local energy expertise of the central planners – Ministry, power utility, regulator and of local Provincial authorities in planning methods;
- Demonstrate the energy services for poverty reduction linkages through providing basic infrastructure services and affordable modern income generation opportunities;
- Develop an alternative planning approach for electricity service delivery by emphasizing the socio-economic impact of energy service extension, instead of only relying technical-economic considerations.

In the short term, both countries will develop technical capacity and be endowed with hands on tools to direct investments and decide between off grid and on grid options, renewable or fossil fuel based off grid production – and priority areas from the perspective of maximizing development impact of scarce resources.

In the medium term, the regional plans will help to develop electrification projects, from which the local population will benefit. A more integrated approach will contribute to bring additional investments in the sector in synergy with the recently established Rural Electrification Fund in Cambodia. There are several possibilities for replication and extension of the project outcomes in the other Provinces of Cambodia and Laos and to other countries in the region.

This can only be achieved through a hands-on “learning by doing” approach wherein a focus group will be formed at the national level, and at the Provincial levels and will be hands on involved in implementing of the project. Specific training sessions at Provincial and National level will be organized. Regular meetings of the working groups as open workshops will ensure sharing of exchanges and ownership building.

The global objective of the project in Laos and Cambodia is to improve the impact of rural electrification on sustainable development and poverty alleviation by establishing effective cross-sectoral investment and planning capacities using Geographical Information Systems (GIS) as the convening factor. Both countries will develop technical capacity and be endowed

with hands on tools to direct investments and decide between off grid and on grid options, renewable or fossil fuel based off grid production – and priority areas from the perspective of maximising development impact of scarce resources.
This can only be achieved through a hands-on "learning by doing" approach wherein a focus group will be formed at the National level, and at the Provincial levels. Specific training sessions will be organised. Regular meetings of the working groups will ensure sharing of exchanges and ownership building.

The project is essentially articulated through the following activities:

- Establishment of a national level multisector working group which will work on rural electrification planning issues, articulating multi-sector development, formulate planning objectives and comment on scenario results, provide inputs for developing a national level convening tool;
- Development of a concrete Provincial level rural electrification development programme using the GEOSIM tool and suggest implementation modalities;
- Establishment of Provincial level working groups to validate the Provincial-level rural electrification plans;
- Trained focus groups amongst the associates on:
    - Data base structuring, use of Geographical Information Systems; establishment, use and maintenance of a multi-sector national level data base for rural electrification and development planning
    - Techno-economic aspects of grid, off grid and renewable energy projects; Load forecasting; financial and economic analysis;
    - Energy and development links, impacts and indicators; participatory planning and validation of investment plans;
    - The GIS tool for rural electrification planning

1.4 Calendar and key events

Project Phase	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Multisectoral approach																																				
Review																																				
Establishement of working group																																				
Creation of project website																																				
RE planning																																				
Data collection national and provincial level																																				
Spatial analysis																																				
Load forecast																																				
Hydro and Biomass potential identification																																				
Network options																																				
Business opportunities																																				
Trainings																																				
Stakeholders meeting and workshops																																				
Newsletters																																				

2 A new approach of Rural Electrification with GEOSIM

The proposed methodology consists of 4 main steps:

- ➔ **Spatial analysis and planning**
- ➔ **Load forecasting**
- ➔ **Optimisation of supply options**
- ➔ **Standalone systems**

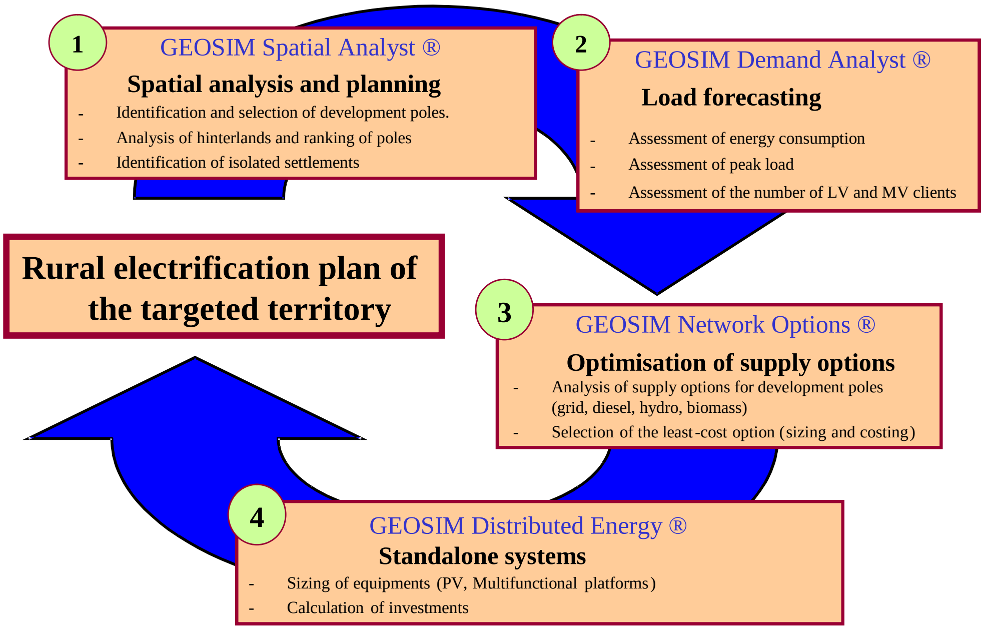


Figure 1 planning process

As shown in the diagram above, each module operates in a logical sequence. While they can mostly be used independently from the others, it is strongly recommended to follow the order indicated above to prepare rural electrification plans.

2.1 Spatial Analysis

2.1.1 Maximizing the impact of rural electrification on social and economic development

The main objective of our spatial analysis approach is to anticipate the impact of rural electrification projects on social and economic development, in order to maximise it at the planning stage. In other words, cost per kWh or number of connections achieved will no longer be the only criteria to identify promising projects, contrary to orthodox planning methods.

This novel approach is motivated by the following paradox: modern forms of energy such as electricity have in theory a significant potential for social and economic development and yet rural electrification projects until now have had very often a low impact on development according to many evaluation studies[1].

[1] E.g. "Impact of solar photovoltaic systems on rural development: FAO study for rural electrification in the 21st century", B.V. Campen, D. Guidi, G. Best, Environment and Natural Resources Service (SDRN), November 1999, www.fao.org

2.1.1.1 Definition of "impact"

First of all, we are to define the concept of "impact" of rural electrification (on social and economic development). The concept used here is very different from the concept of direct results, which are for example the number of households and businesses benefiting from electricity, avoided costs in energy purchase etc.

Contrary to results, impact takes into account long lasting changes provoked by electrification, possibly interacting with changes in other sectors (typically health, education and economy), cf. Figure 2. For example, the impact of a rural electrification project on a target area where there are only households will be significantly lower than that of a project targeting villages with many productive activities, hospitals and schools, even if these factors are (supposedly) independent from the electrification project itself.

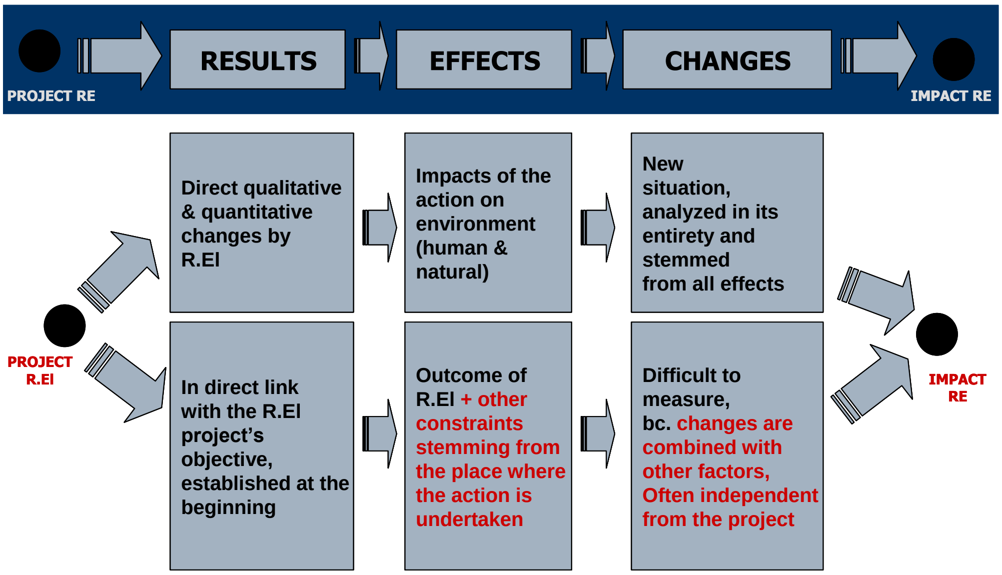


Figure 2 Results, effects and changes

2.1.1.2 Taking into account impact in the planning process

While impact of rural electrification can be taken into account at many different stages of the project development process, here we will focus on the following problem: how to maximize this potential impact at the very early stage of regional or even national planning.

The CAP REDEO approach suggests to anticipate impact upstream of the planning process, as shown in **Error! Reference source not found.**.

Spatial analysis will allow us to identify the most relevant places (settlements) to electrify and then rank (prioritize) them, according to their rated potential for development. More classical tools such as load forecasting and least-cost sizing of powerplants will then be used to optimise the projects technically, economically and financially, which will provide power to these high ranked settlements.

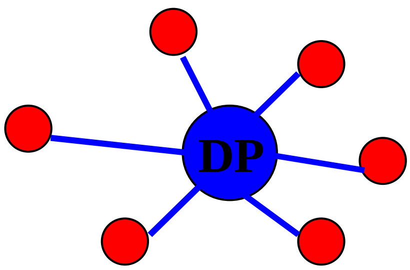


Figure 3 Minigrid from Development Pole

The rationale behind this is the following reasoning: rural electrification is usually not profitable, therefore it requires public subsidies which are available in very limited quantities, and these limited resources should be allocated to places with the highest potential for development, even if they are not necessarily the most profitable, nor administratively the most important. Naturally, once these places are identified, the planning model strives to find the cheapest solution to electrify them and possibly their nearby settlements, creating a minigrid (cf. figure on the left). Technical and economic aspects of electricity generation do not play a role in the choice of settlements to electrify first.

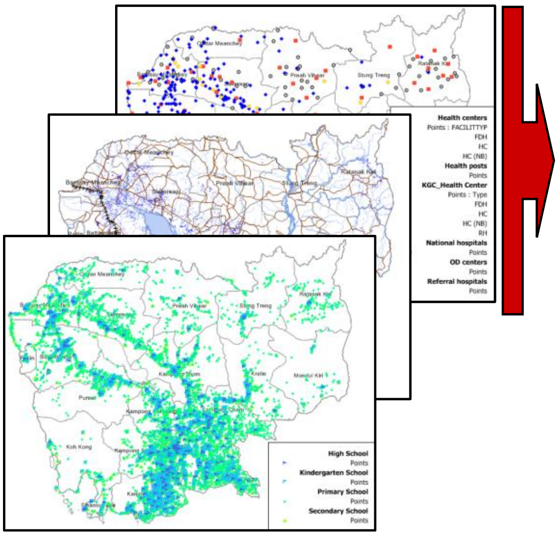
These settlements with relatively more potential impact on the development of their surroundings (or **hinterland**) than other settlements of the area are called **Development Poles** (DP). The methods to identify and rank these DPs is explained is the next chapters.

2.1.2 Identification of Development Poles

2.1.2.1 Method

The method used to identify DPs draws its inspiration from the Human Development Index (HDI) developed by the UNDP. The overall idea is to calculate a composite index, similar to the HDI, but for each settlement of the area (and not only at the macro scale). This index, called the Indicator for Potential Development (IPD), is calculated from multisector data[2] and ranges from 0 (no potential for development) to 1 (highest potential). Settlements with the highest IPD will be simply selected as DPs. The list of DPs can then be validated or changed manually by decision makers.

Multisector data



Evaluation grid

PART	WEIGHT [0,1]	Examples of CRITERIA	WEIGHT [0,1]
HEALTH	1/3	Health posts	1/2
		Access to drinking water	1/2
EDUCATION	1/3	Adult literacy	2/3
		Enrolment ratio	1/3
LOCAL ECONOMY	1/3	Population of the settlement	1/4
		Market	1/4
		Savings and credit organization	1/4
		Distance to the nearest road	1/4

IPD for all settlements

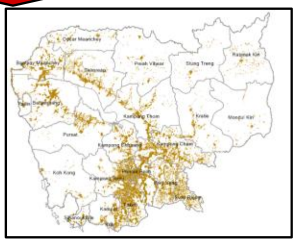


Figure 4 IPD calculation process

The evaluation grid of the HDI consists of 3 main components (health, education and economy), each subdivided in different criteria.

Likewise, IPD has an analytical grid featuring the same components (health, education and local economy), which will have an equal weight in the final result. The score for each component is calculated from a weighted set of criteria: not all criteria will have the same importance in the final result. The score for each criteria is itself defined by indicators (for example the score for the "Access to healthcare" criteria can be defined by the "Type of best hospital in settlement" indicator). Criteria, their weights and indicators must be established and accepted by the different planners and stakeholders[3]. Rules of thumb to define them are explained below.

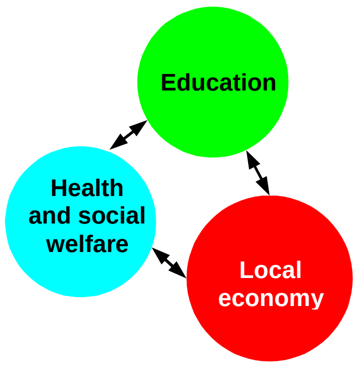


Figure 5 Components of IPD

Criteria must take into account the following constraints:

- The criteria must be a measure of the potential impact of the

[2] Data from different sectors such as health, education, economy, transport…

[3] Ministries of energy, regulation, health, education, transport, rural electrification agencies, electricity utilities…

electrification of the settlement, on the development of the area comprising this particular settlement and its "hinterland" (or surrounding area, see 2.1.3.1). That is to say, only aspects of development potentially benefiting directly or indirectly from electrification should be considered.

- Good quality data must be available throughout the studied area

This last point is critical, as the refinement of the analysis will depend on the data available and its quantity. In cases where data available at national and provincial levels are not the same, IPD analytical grids will have to be different from one context to another.

Weights are usually defined according to the following rules:

- Access to health is twice as important as access to water for the health component.
- Primary, Secondary and High school education are respectively two, three and four times as important as kindergarten education for the education component.
- Size of population is of the same importance than access to markets, roads and credit services for the local economy component.

And for indicators:

- The score returned by indicators ranges from 0 (no potential for development) to 1 (highest potential for development throughout the study area).
- Depending on available data, criteria concerning access to social and economic services are measured by one or two indicators: best type of service present in the settlement and/or the number of people benefiting from the service (students, patients, clients…). When both are available, they are given the same weight (importance) in the result.
- When intervals are involved (e.g. for the population criteria), interval boundaries are calculated so that a similar number of settlements will fall in each interval.

2.1.3 Ranking of selected Development Poles

2.1.3.1 Method: inner potential and hinterland

A quick and easy way of ranking DPs would be to use again their IPD. However, IPD is only an estimate of the inner potential of the settlement on the development of its hinterland. Even if a DP has an IPD of 1 (the highest value), but is located in a very remote area for some reason, the electrification of this particular DP will benefit only to the people living inside it, and nobody will benefit indirectly from the electrification (for example electrified hospitals and schools), simply because it is too far from any other settlement.

That is why ranking of DPs is done using a sophisticated gravitational model[4] combining the IPD score and the distance of each DP to other settlements. The main outcome of this calculation is the estimated total population covered by a DP, i.e. the population potentially benefiting directly or indirectly from the electrification of the DP. DPs are then ranked by their population covered (higher population covered means higher priority). With this model, it happens very often that a DP with a slightly lower IPD has a very high priority of electrification simply because it is located in a very populated area.

Another interesting outcome of the calculation is the identification of "remote settlements", located outside an "accessibility limit". These are the settlements which are very far from all DPs and are thus suitable for pre-electrification strategies such as solar energy and multifunctional platforms. Please bear in mind however that the isolated status of settlements does not necessarily mean that they will not be electrified before the end of the planning period and vice versa: not all settlements inside the

[4] The model, which will not be explained in detail here, is the "Huff" model with the attractivity parameter equal to the IPD.

accessibility limit will be electrified. Isolated settlements will only have lower chances of being electrified by conventional means since priority is given to DPs, which are by nature far from these settlements and thus less likely to include them in their clusters.

2.1.3.2 Results – Pole selection

IPD has been calculated for each settlement at provincial and national levels in both countries, using the analytical grids mentioned above. The settlements with the highest IPD score in each case has been selected as DPs.

Naturally planners are most welcome to suggest different figures at provincial levels.

The choice is a matter of spatial planning and depends on both financial resources available, because DPs are meant to be electrified eventually, and development policy (“centralised” vs. “decentralised”). It should be a compromise between the following constraints:

- There should be enough DPs to cover uniformly the study area and be able to reach, at least indirectly, very remote areas.
- There should not be too many DPs, so that available funds are sufficient to electrify all of them in the near future. Besides, too many DPs will result in some of them being very close to each other and they will compete for the same “hinterland”, thus lowering their potential impact on the development of their hinterland (see 2.1.3.1).

To help assess the level of “centralisation” (or “decentralisation”) for each study area, 3 ratios have been calculated:

- Number of inhabitants/Number of Poles
- Number of villages/Number of Poles
- Area/Number of Poles

2.2 Load forecast

Results of the load forecast module are critical in the planning process, since they provide least-cost algorithms with data on demand (peak, consumption, number of clients…) for each village of the study area.

2.2.1 Village scale and « bottom-up »

There are two main categories of load forecasting models:

- Top-down forecasts are based on macro-level (regional or national scale) econometric data. They assess statistical dependencies between indicators to better anticipate the trend of demand. This approach is usually used by utilities for large scale power generation & grid extension development plans.
- The approach used here belongs to the “bottom-up” type: demand is calculated from the number and average consumption profiles of each type of end-user (households, schools, shops, other productive activities etc.), determined by socio-economic surveys. This method is best suited for small-scale projects.

We will compare our bottom-up results to figures of top-down forecasts to check the orders of magnitude, but it is normal to have discrepancies between the two approaches. Top-down forecasts strive to be accurate at the macro-level, while bottom-up forecasts focus on the village level.

2.2.2 Willingness to pay and market segmentation

The distribution of domestic users among different classes, called market segmentation, is an important step of load forecasting. While most approaches to market segmentation are based on income only, we recommend to define classes of clients according to two more reliable criteria if possible :

- Level of service expected
- Willingness to pay

Level of service expected is usually defined simply by intended installed capacity.

Willingness to pay is a very delicate indicator to estimate. A good method is to calculate the substitutable energy bill of would-be electrified households, using substitution ratios. But this method works only with large and well sampled surveys[5].

2.2.3 Regions

Consumption of electricity can vary significantly from one region to another, depending on living standards, local habits, agri-ecological zones etc. Thus, GEOSIM Demand Analyst® lets the user define some parameters specifically for different regions.

This feature has not been used in this study (the whole study area has been treated as the same region), but may be used later on.

2.2.4 Special demands

In our model, the load forecast of a village is mainly determined by its population and average consumption profiles for different populations. This assumption is usually valid, unless the village features a very large end-user which creates an unusually high demand.

These end-users, usually industries and agri-businesses, are called *"special demands"*. There are two types of special demands:

- Small special demands ("particular demands") : these are located inside settlements. Their power consumption is of the same order of magnitude than the rest of the settlement. Typically these small special demands would be SMEs.
- Large special demands ("specific demands") : these can be located inside or outside settlements. Their power consumption significantly outweighs the consumption of a single settlement and can be of the same order of magnitude than a small cluster of settlements, thus justifying electrification projects dedicated to them and possibly neighbouring villages. Typically these large special demands would be large agribusinesses, factories or mines.

2.2.5 Outputs

For each village of the study area, each year of the planning period and each scenario (24h, 10h and 5h supply), the following outputs are created by GEOSIM Demand Analyst®:

- Number of low and medium voltage clients
- Peak demand (in kW)
- Yearly consumption (in MWh)
- Load duration curves

In addition, typical daily load curves can be produced for a specific village, in order to test the validity of input data and hypotheses.

2.3 Network options

The overall planning process adopted in CAP-REDEO project was to successively answer the following questions:

➢ **Which villages should be electrified first to optimise the socio-economic development within the provinces?**

[5] In this study, the surveys were not sufficient to have sound estimates. Nevertheless, other project references provided averages.

GEOSIM Spatial Analyst® ➔ *identification of Development Poles at the Province level*

➢ **What is and what will be energy consumption in provinces villages?**

GEOSIM Load Forecast® ➔ *assessment of consumption growth over the planning period*

➢ **Which technical options would be the most appropriate to supply the electric clusters built on the Development Poles?**

➢ ***GEOSIM Network Options®*** ***➔identification of Network Options to fulfil various scenarios objectives***

The Network Options® model is therefore the core module of the GEOSIM® package. It analyses the different technical options to supply electricity to the Development Poles identified by the Spatial Analyst® model, on the basis of the demand forecast assessed with the Demand Analyst®[6] model.

2.3.1 Approach main features

2.3.1.1 Overall process

Given the Development Poles previously identified by Spatial Analyst®, the objective of the Network Options® module is to:

1. Define those of these Development Poles which will be considered "off-grid", i.e. not likely to be connected to the utility grid in the near future
2. Find the lowest cost technical options to supply them, using conventional technico-economic calculations

At the end of the planning exercise, all targeted Development Poles will have been allocated a supply option, whether grid extension or decentralized option.

Before actually undertaking least-cost sizing of decentralised supply options, the Network Options® module first defines the areas not likely to be connected to the utility grid in the near future.

This planning of the national grid network is done by either entering directly the forecasted grid extensions as input data, or by simulating the extension of the national grid, taking into account several possible constraints (investment budgets, available energy on the grid, number of villages to be electrified per year…).

In CAP-REDEO project, the grid extension model was used only for Kampong Cham province, where MV grid is to date poorly developed. Regarding Khammuane province, the MV network is covering most of the province territory and no extension had to be simulated as the network development was known when the study started.

When simulating grid extension, a crucial issue is to specify an ending year for this simulation; this time limit will be considered as a threshold date beyond which all localities that will not have been connected to the grid will be candidates for off-grid electrification.

Grid extension can be simulated at different scales (country, province, district, specific zone…) and for different purposes:

- in the perspective of developing a private network in a specific zone, the planner has the possibility to specify the area within which the extension should be simulated, and to indicate whether (a) the localities that should be connected or (b) the investment limit for the project.

[6] Results on Spatial Analysis and Load Forecast were presented in March 2008

- In the same way, if a planner wishes to extend the utility network from existing grid in a restricted specific area, this can be done by demarcating the zone concerned.

The module then identifies the best decentralised options to supply electricity to previously identified Development Poles (cf. glossary) and the settlements included within the same electric cluster, using one of the following methods:

- Comparison of different supply options: selected projects are those with the lowest electricity levelized cost among projects using different technologies (diesel, small hydro and biomass[7]). At this level, for a given project, all technologies are therefore competing.
- Technologies are ranked by preference. For example, if hydropower is deemed more important than diesel and biomass, then settlements located near potential sites of hydropower will be supplied by this technology, even if diesel or biomass would have been cheaper.

In any case, projects using each type of technology optimise the levelized cost of electricity, i.e. the cluster of settlements supplied matches the production of the power source (hydro, biomass or diesel), so that adding or removing a settlement would result in an increase of the levelized cost of kWh. The cost calculation follows a detailed structure, taking into account many technical and non technical parameters which can be modified by the planner.

2.3.1.2 Main steps : overview

2.3.1.2.1 Off-grid area identification - Grid extension simulation

Given the timescale of rural electrification planning (usually ranging from 10 to 20 years), it is recommended to anticipate future evolutions of the national grid network. Indeed, some non electrified areas located near existing lines might be connected in the next few years, and any decentralised option project in these areas would be of low interest.

Therefore, the Network Options® module offers different possibilities to simulate this grid extension, to make sure identified projects will remain “off-grid” long enough to make them relevant.

Ideally this is already planned by the Power Utility, and the user would only have to integrate it in the Geographic Information System (GIS) database. If this is not the case, GEOSIM® can simulate this extension with basic financial cost-benefit analysis.

A set of different criteria and parameters can be defined to run the simulation:

- Distance to the grid
- Investment budgets
- Available energy on the grid
- Maximum number of settlements to be electrified per year

According to these different constraints, the algorithm will strive to connect in priority settlements with the highest Net Present Value (NPV), typically those located near the grid and with significant demand. The formula is the following, with “Benefits” being the number of kWh sold multiplied by an average tariff of customers, and r the financial discount rate:

$$NPV = \sum_{i=1}^{horizon} \frac{Benefits\,(i) - Costs(i)}{(1+r)^i}$$

Equation 1 Net Present Value

[7] The model supports direct biomass combustion (in a boiler) with or without cogeneration, gasification and anaerobic digestion (biogas).

2.3.1.3 Off-grid projects identification

The basic "unit" of the off-grid rural electrification planning is the "project". These projects are defined by the following components:

- A settlement or a list of settlements
- A mini-grid connecting these settlements if there are more than one
- A technical supply option (diesel, hydro, biomass, hybrids…)

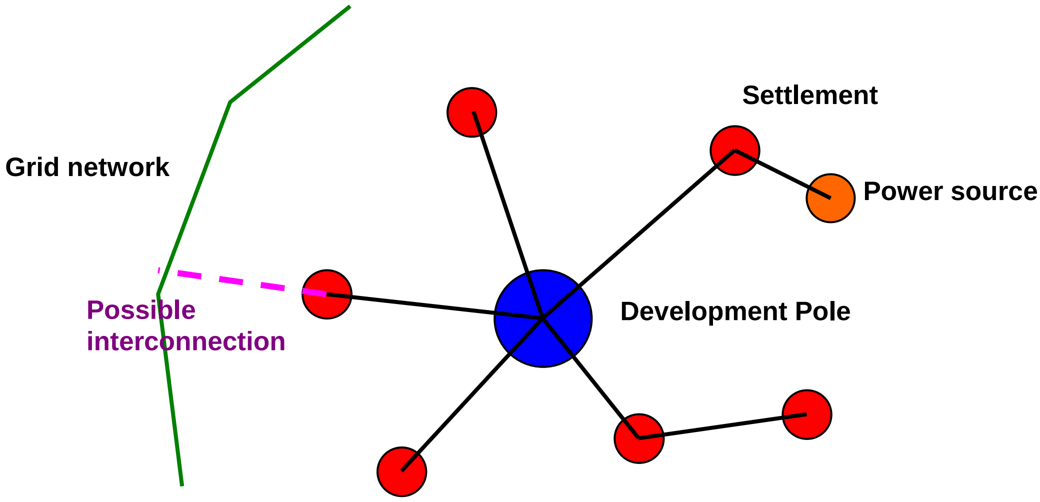


Figure 6: Project definition

They have the following characteristics:

- They often include one or more Development Poles which are not yet electrified
- They are small-scale, i.e. they will usually involve not more than about fifteen settlements and their total capacity will range from about ten kW to a few MW for the largest
- They are usually isolated from the grid but the planner may chose to also study interconnection with the forecasted grid
- In the case of the development of a private grid, a project will be a group of localities whose number will be set by the planner or will be depending on financial constraints.

2.3.1.3.1 Least-cost sizing and economic analysis

Since rural electrification projects are not profit oriented, least-cost sizing of projects is based purely on an economic analysis, which means that the profitability of projects will not be assessed in any way[8]. Therefore, the only criteria will be the levelized cost of the kWh, symbolizing the cost of supplying electricity borne by the community as a whole. Its formula is:

$$\text{Levelized cost of kWh} = \frac{\sum_{i=1}^{horizon} \frac{Costs(i)}{(1+r)^i}}{\sum_{i=1}^{horizon} \frac{Energy\ placed\ (i)}{(1+r)^i}}$$

Equation 2 Levelized cost of kWh

With:

[8] Of course, this will have to be done later on during feasibility studies.

- **Costs(i)** the costs in year i of the planning period, including investments and operating and maintenance costs
- **Energy placed (i)** the quantity of kWh sold in year i
- **r** the economic discount rate

Both benefits and costs depend on the demand in electricity, since the supply option is sized according to it and benefits are the number of kWh sold. Therefore the list of settlements supplied by the project will have a direct consequence on cost of kWh. The algorithm will thus find the optimal configuration by starting with a Development Pole and adding new nearby settlements to the project, until the NPV of kWh stops decreasing.

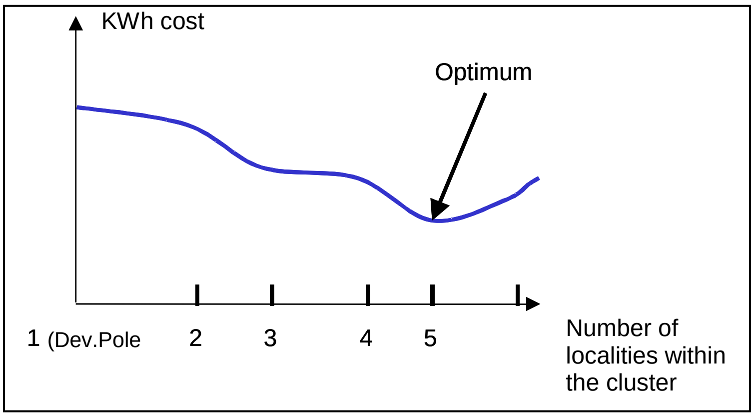


Figure 7: Construction of an electric cluster

2.4 Distributed Energy

Distributed Energy (DE) strategies generally aim at improving access to modern forms of energy (electricity but also mechanical power for productive uses) in areas where accessibility, lack of available financing and other socio-economic constraints render electrification through grid extension or isolated mini-grids impossible in the near future. Such standalone solutions may involve domestic equipments such as solar home systems (SHS) or community equipments (PV for schools and hospitals, multifunctional platforms).

Targeted areas are those which are not likely to be electrified soon: all settlements already electrified or included in the rural electrification plan drafted by the Network Options® module are automatically removed from the list of candidates. All or part of the remaining settlements will be considered candidates, depending on the user's targets and budget constraints.

Contrary to the Network Options® module, Distributed Energy® does not perform sophisticated economic and financial analysis over the planning period, only investment costs are computed on the basis of simple hypotheses (type of community equipments, type of domestic equipments and coverage rate…) without comparing different options.

3 Capacity Building & Pilot studies

3.1 Multisectorial working group at national and provincial level and pilot province selection

It was decided at the beginning of the project to have an informal multisector stakeholder group to discuss the objectives, criteria to be taken into rural electrification development program in each country – and collect existing data

With local subcontractors and focal points, the project team was able to identify and contact concerned institutions in each country to form multistakeholder groups at national and provincial level. They are representative from ministries of education, health, planning, statistics, energy utilities and regulators, private companies and entrepreneurs which participate to workshops and sometimes to data collection, a fundamental step to start the project and its multisectoral approach and have an update for the rural electrification status within each country.

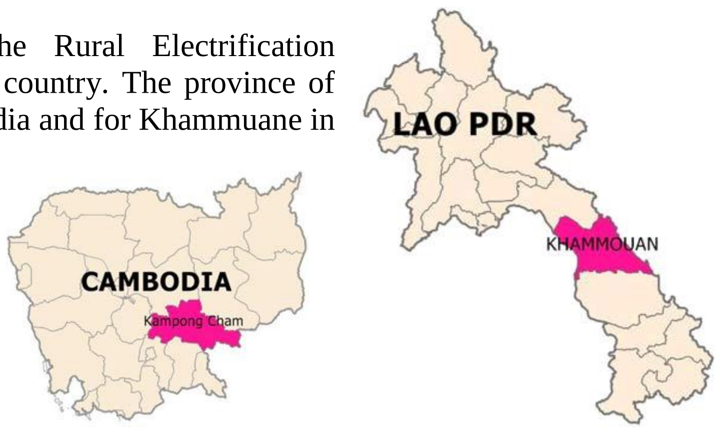
MIME in Cambodia and **MEM** in Laos were leaders (chairs) in these working groups and IED local subcontractors were liaison officers to animate (stimulate) the discussion.

Potential stakeholders to invite into Informal Multisector stakeholder group:

- Ministry of Energy
- Under planning : National Statistics
- Ministry of Transport
- Power Utility
- EAC
- Rural Electrification Fund
- Health
- Education
- Commerce and Industry / MIME
- Min Rural Development / PM Office
- Agriculture and Forests

Provincial level stakeholder group will be set up in the pilot Province with the support of the national level group, with the objective to facilitate data collection, surveys and to validate the results of the planning exercise as well as priority investment projects identified.

The group decided to implement the Rural Electrification methodology for one pilot province per country. The province of Kampong Cham was selected for Cambodia and for Khammuane in Lao PDR.



3.2 Data collection

To ensure that those ministries be well cooperated on providing those needed data, corresponding counterpart MIME in Cambodia and MEM in Lao PDR have issued data collection letters to those ministries to ask for well cooperation and introduction letter for local subcontractor as data collection agency on behalf of the project partners.

Various types of data were finally collected. They represented health centres by types, schools and number of students, market and financial services, access to roads, number of population and households, power system & networks…from many sectors such as health, education, agriculture and energy and water supply sectors. The status of these GIS data are presented and analysis at the annex.

At provincial level, macro-economic and technical data, provincial maps have been collected during the mission to the province on October 2007. Additionally, a test survey has been conducted by IED and ETC in two countries in order to adapt these questionnaires to real situations and contexts of Cambodia and Lao PDR. The updated list of villages in the provinces with statistic information such as population, number of households, location coordinates etc. have been collected:

- The list of electrified and non-electrified village
- The list of markets and village names
- The list of factories, rice mills, sawmills and furniture workshops
- The list of hospitals, clinics and health care centres including dispensaries and its locations.
- The list of primary, secondary schools and educational centres and its locations, list pf pagodas.

3.2.1 National and provincial level GIS database

As the RE planning will be developed using a GIS-based software a.k.a. GEOSIM(, some geo-referenced data were strongly required. These data were supposed to be in GIS format (GIS coordinates) and updated. The proposed list hereafter includes the required data. Some data were needed to calculate “Potential Development Indicator – IPD”, to classify development centres (DC) by electrification covering population. Other data (optional) are needed to represent in the maps the physical features and information for policy makers in energy planning formulation and decisions.

ADMINISTRATIVE ➔ *from previous survey & census, PM office*

- Provinces and district limits – GIS data
- Settlements at villages level: population, electrified or not, census codes, GIS coordinates (updated longitude and latitude);

INFRASTRUCTURE ➔ *from previous surveys, ministry of transport, MIME, MEM*

- Road networks: existing and planned; asphalt (if possible permanent or not) – GIS
- Water supply and sanitation: type of schemes (network, permanent, well…) - GIS

RESOURCES ➔ *from water resources Ministry, MIME, MEM*

- Rivers and basin in GIS

- Hydro potential in general, location map of minihydro sites identified (GIS coordination, potential power, production, operation or planned, discharges)
- Biomass potential (rice husk production, agriculture residues such as sugarcane, coconut husks, cassava stem…, biomass and tree farming), Location map of biomass sites (operational and/or planned with GIS coordination, potential power and production).

ENERGY SECTOR ➔ *contact and collect from EDC, EDL, MIME, MEM, EAC*

- Grid network existing and planned: updated: 230 kV, 115kV, 35kV, 22kV; existing and planned substations with installed capacities and exact location (GIS coordinates)
- Generation (including IPP): existing and planned; potential; including renewable, actual availability? PPA rate?
- Private as much as possible (REEs, PESCos, battery charging…) : capacity, number of costumers, type of business.
- Electrification rate % for each village (if possible) or for each district.

MULTISECTOR DATA: Health, Education, Religious centres (these data are used to calculate "Potential Development Indicator" to measure the socio-economic impacts of the potential rural electrification programs.

- Type of centre, following the national classification (high school, secondary school, primary school, training centre…; hospital, maternity, health point….;) with GIS coordinates, electrified or not, number of staff, teachers, number of students,
- Existing and planned centres

LOCAL ECONOMY ➔ Ministry of commerce, of industry

- Small scale and other industries; industrial zones
- Commercial centres / markets, bank outlets (permanent, weekly…,) with GIS coordinates

OTHER STUDIES, REVIEW, DATA

- Collect other available data and information from previous studies and projects

All existing databases

The collected GIS data have been checked and reprocessed, then integrated into the Manifold software by the IT staff and classified into 5 different folders following different types of data[9] – (1) Administrative folder, (2) Energy sector folder, (3) Infrastructures folder, (4) Multi-sector data folder and (5) Water resources folder.

These GIS data then have been presented in thematic maps such as spatial distribution of electrification by provinces, districts, villages, population density, energy systems…

3.2.2 Indicator of Potential Development (IPD) and Development Poles (DP)

These collected data from main economic sectors are considered for determining IPD and DC – Health, Education and Local Economy in process of rural electrification planning, in a multi-criteria approach developed by IED. An indicators grid allowing the IPD to be

[9] The final structure of the GIS national database may vary, depending on the data availability and contexts (REE in Cambodia and PESCO in Laos, for example)

calculated has been prepared and circulated with local project stakeholders in order to ensure that those IPD coefficients will be adapted to the Cambodian and Lao context and adopted by energy policy makers. The project stakeholders have sent back their comments and suggestions on the proposed coefficients values to the IED expert. The final analytical grid for each country has been adopted at the multistakeholder meeting held in Phnom Penh October 1st 2007 and in Vientiane October 11th 2007.

3.2.3 Survey at provincial level and questionnaires forms

There was a discussion about the target villages to be visited by the team of IED and ETC. The team proposed to name different villages electrified and non-electrified so that the interview will be more adapted.

PDEM’s head has identified 4 villages located at Hinboun district to visit on the 6th October. Each team will visit two villages, one electrified and one non-electrified

The villages in Khammuon province to visit are **Donhoy and Danhi** for the team of IED and Sonhong and Laokha villages for the team of ETC. PDEM has also provided their two staff members (Mr. Khamphou and Mr. Bounma) to accompany each team. In addition, there would be another staff member from Hinboun district authority to join one of the teams so that these staff member could introduce the survey team the target village head men.

Two villages in Kampong Cham have been selected for test-survey in consultation with DIME : **Spean Thmei and Roang Leo**

Before the beginning of the survey in few selected settlements, the manipulation of the GPS kit has been taught to staffs that are going to conduct the survey so that they would be able to use it to identify their surveyed localities and some potential bioenergy and micro-hydropower sites in the province. Moreover, a test of questionnaires has been carried out by the project teams – IED and ETC accompanied by sub-contractor (CDEC and Sensavanh Co. Ltd.) who will be responsible to implement such a kind of survey. It was found that some modifications were required at the end of the surveyed test.

After these test-surveys, questionnaires forms have been adapted for Cambodia and Laos and finalized with local consultants. The templates of these 4 questionnaires are provided in the annexe. The survey was then carried out during October- November 2007 by local consultants with 65 households in those 4 villages (3 non-electrified and 1 electrified), 4 heads of villages, 8 businesses (commerces) and also for assessments of minihydro and biomass potential for the provinces Kampong Cham and Khammuon.

3.3 Hydro and Biomass potentials identification

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.

3.3.1 Hydro potential

3.3.1.1 KampongCham

3.3.1.1.1 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.

3.3.1.1.2 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**

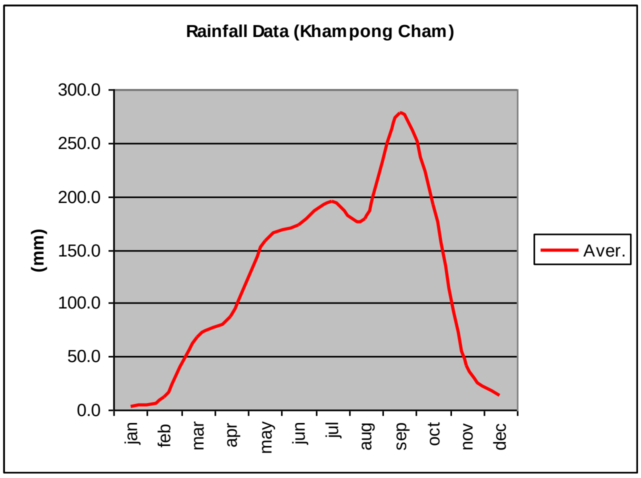


Figure 8 Rainfall data (KampongCham)

3.3.1.1.3 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 9 Map of selected hydro potentials

3.3.1.1.4 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.

3.3.1.2 Khammuon

3.3.1.2.1 *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.

3.3.1.2.2 *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)

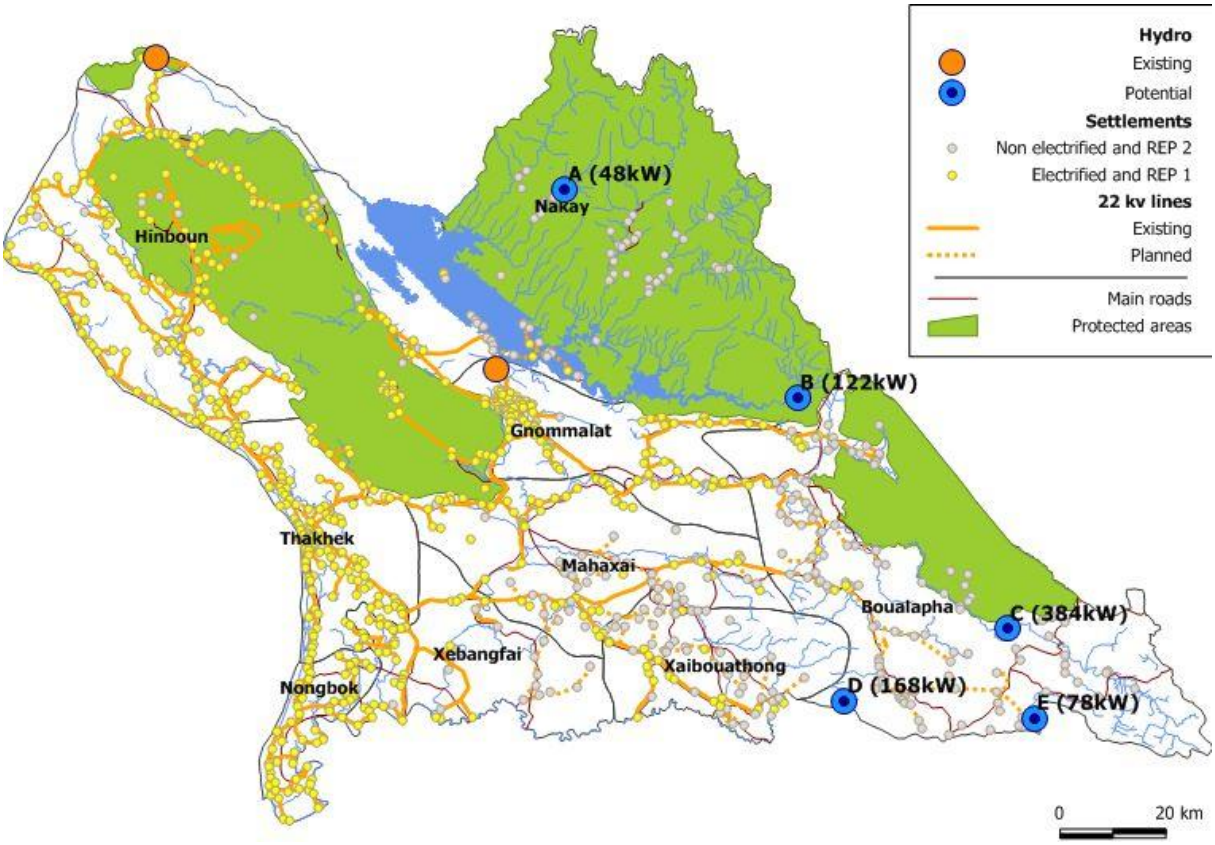


Figure 10 Map of hydro potentials

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3.3.1.2.3 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.

3.3.2 Biomass potential

3.3.2.1 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.

3.3.2.2 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.

3.3.2.3 Technology

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

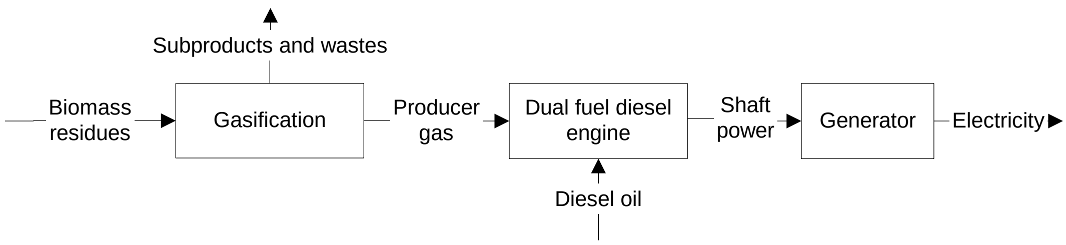


Figure 11 Gasification process

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[10] 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,

[10] Without oxygen.

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 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.

3.3.2.4 KampongCham

3.3.2.4.1 Sources of data

A first overview of the biomass potential has been taken from the JICA master plan on rural electrification from renewable energy[11]. 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

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

Figure 12 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).

3.3.2.4.2 Methodology

3.3.2.4.2.1 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[12]. 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.

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

[12] 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.

electricity production from rice mills as this is not their core business, and association with private investors can be risky[13].

The suggested projects are thus not located inside surveyed rice mills, but instead near non electrified Development Poles[14]. 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.

3.3.2.4.2.2 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).

3.3.2.4.3 Site selected

The following projects have been selected:

Figure 13 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
Total energy output (MWh per year)	**1400**	**950**	**850**	**120**	**630**
Power (kW)	**330**	**220**	**194**	**27**	**144**

[13] 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.
[14] Cf. CAP REDEO Spatial Analysis report.

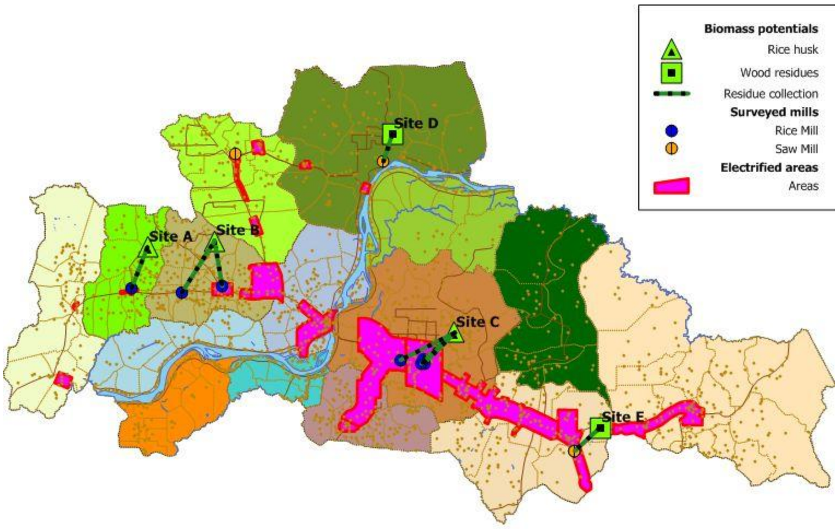


Figure 14 Map of biomass potentials for KampongCham province

Purchase price of residues is taken equal to 10 US$/T, including transportation costs[15]. Investment cost will be 1350 US$/kW, taken from the price of integrated systems sold by Ankur Scientific (Indian manufacturer).

3.3.3 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 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.

3.3.3.1 Khammuon

3.3.3.1.1 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).

[15] 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.

- 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.

3.3.3.1.2 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[16].

3.3.3.1.2.1 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[17]. 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:

- The rice cultivated in each district is processed by rice mills located in the same district[18].
- 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.

3.3.3.1.2.2 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

[16] Cf. CAP REDEO Spatial Analysis report.

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

[18] 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.

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.

3.3.3.1.3 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**

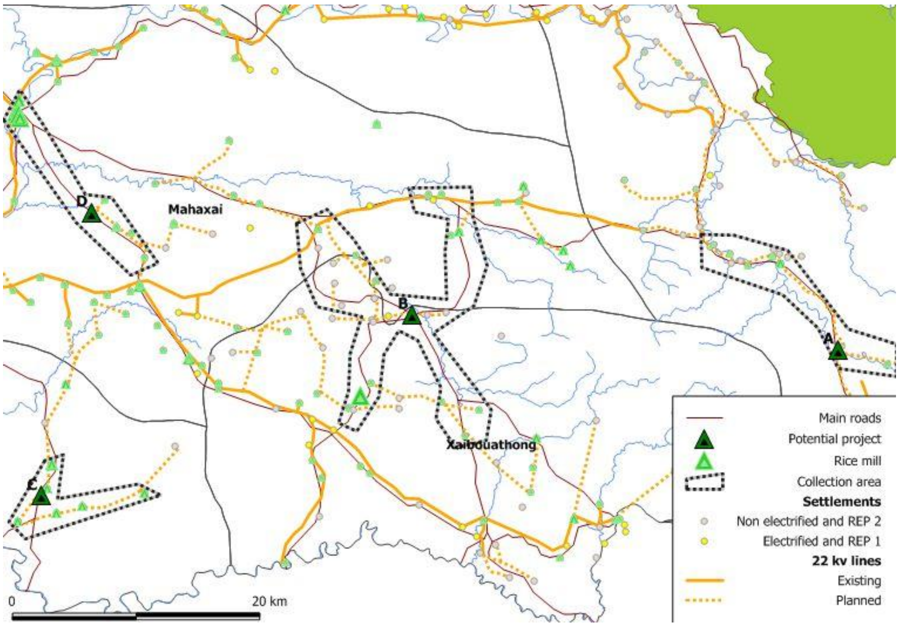


Figure 15 Map of biomass potentials for Khammuon province

Purchase price of residues is taken equal to 8 US$/T, including transportation costs[19]. Investment cost will be 1350 US$/kW, taken from the price of integrated systems sold by Ankur Scientific (Indian manufacturer).

3.4 GEOSIM deployment and trainings

The development plans and policy elaboration is based on the methodology applied with the GEOSIM® software developed by IED. This methodology initiated and improved through past projects (REDEO, IMPROVES...) can be divided into 3 main inter dependant modules

- Spatial Analysis
- Load Forecast
- Spatial Analysis

Twelve licences were finally deployed for Lao and Cambodian institutions as described below. Those versions were used for trainings and CAP-REDEO simulations but may also be used for others planning purposes than for CAP-REDEO planning

List of Manifold® and GEOSIM® licences installed

Institution	***Country***	***Number of licences***
MoEM (+ PDEM)	Laos	4
EDL	Laos	1
MIME (+DIME)	Cambodia	3
EAC	Cambodia	1
EDC	Cambodia	2
REF	Cambodia	1

The GEOSIM® software was delivered within a package including a **user guide** for each module. A copy of each training presentations, exercises and user guides also were distributed to each training attendant.

Four progressive training sessions were organized in the same time in order to insure the software takeover by national institutions. Trainings focused on both Manifold (GIS software) and GEOSIM and its methodology.

- **April 2007**
  - Built and update GIS Database (Manifold)
  - Energy & development links, impacts & indicators
- **September 2007**
  - Essentials for GIS use (Manifold)
  - Spatial Analyst® training (GEOSIM)
- **March 2008**
  - GIS Advanced techniques (Manifold)
  - Load Forecast® training (GEOSIM)
- **June 2008**
  - Supply options® training (GEOSIM)

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

3.5 Two Study cases: Kampong Cham (Cambodia) and Khammuane (Lao PDR)

3.5.1 Spatial Analysis

3.5.1.1 IPD analytical grids

Analytical grids which have been used in this study are presented below. The criteria used to calculated each component are shown, as well as their relative weights and the indicators used to give them a score between 0 and 1.

Provisional analytical grids have already been presented to stakeholders and discussed in national and provincial meetings[20]. Following these discussions and recent updates of the multisector databases, analytical grids have been adjusted (see **Error! Reference source not found.** and **Error! Reference source not found.**).

3.5.1.1.1 Cambodia

The same analytical grid has been used at national and provincial levels.

Element	Criteria	weight	indicators	value
Health	Best hospital	2/3	Health Post (Non building)	0.1
			Health Center (Non Building) & Health Post	0.3
			Former District Hospital & Health Center	0.5
			Referral Hospital	0.8
			National Hospital	1
	Quality of access to water (best available in the village)	1/3	Piped water (>50 hh)	1
			Piped water (<50 hh)	0.7
			Well	0.6
			Other	0.2
			None	0
Education	Kindergarten students	1/8	1-49	0.2
			50-99	0.5
			100-149	0.8
			>=150	1
	Primary schools students	2/8	1-349	0.2
			350-599	0.5
			600-999	0.8
			>=1000	1
	Secondary schools students	3/8	1-299	0.2
			300-499	0.5
			500-699	0.8
			>=700	1
	High schools students	4/8	1-999	0.2
			1000-1799	0.5
			1800-2499	0.8
			>=2500	1

Table 5 IPD analytical grid for Cambodia (health and education components)

[20] Phnom Penh 01/10/07, Kampong Cham 28/09/07, Vientiane 11/10/07, Khammuon 05/10/07

Element	Criteria	weight	indicators	value
Local Economy	Population	2/8	1-699	0.1
			700-1399	0.5
			1400-2099	0.7
			>=2100	1
	Travel time to closest market (minutes)	2/8	0	1
			1-74	0.6
			75-149	0.4
			150-299	0.1
			>=300	0
	Distance to closest road (km)	1/8	0	1
			1-4	0.6
			5-9	0.2
			>=10	0
	Travel time to closest road (minutes)	1/8	0	1
			1-49	0.6
			50-99	0.4
			100-199	0.1
			>=200	0
	Credit & saving points	2/8	ACLEDA PLC bank & Amret (micro-finance)	1
			ACLEDA PLC bank	0.7
			Amret (micro-finance)	0.5
			No service	0

Table 6 IPD analytical grid for Cambodia (local economy component)

3.5.1.1.2 Lao PDR

As explained above, multisector data with geographical coordinates was lacking at the national level. Therefore, we had to define two analytical grids: a simplified one at the national level (featuring only the local economy component) and a more complete one for Khammuon Province.

Element	criteria	weight	indicators	value
Health	Best hospital	1	Provincial Hospital	1
			District Hospital	0.8
			Health Center Type A	0.6
			Health Center Type B	0.5
			Drug Kit Type A	0.3
			Drug Kit Type B	0.2
			No Hospital	0
Education	Kindergarten	2/12	Exists	1
			None	0
	Number of years covered by primary schools	2/12	1	0.2
			2	0.4
			3	0.6
			4	0.8
			5	1
	Primary schools students	2/12	1-29	0.2
			30-99	0.5

			100-199	0.8
			>=200	1
	Number of years covered by secondary schools	3/12	1	0.1
			2	0.2
			3	0.4
			4	0.6
			5	0.8
			6	1
	Secondary schools students	3/12	1-59	0.2
			60-199	0.5
			200-499	0.8
			>=500	1
Local Economy	Population of the locality	4/10	1-199	0.2
			200-349	0.5
			350-599	0.8
			>=600	1
	MARKET nearby	3/10	Permanent	1
			Half Permanent	0.7
			Rural Market	0.3
			International Check Point	0.6
			Traditional Check Point	0.3
			Planned	1
	Distance to road, m	3/10	0-149	1
			150-999	0.5
			>=1000	0.1

Table 7 IPD analytical grid for Lao PDR (provincial level)

3.5.1.2 Results – Pole selection

3.5.1.2.1 Cambodia

90 DPs have been selected at national and provincial levels. The lists of DPs can be found in annexes 2 and 3, and maps are shown in **Error! Reference source not found.** and **Error! Reference source not found.** in the next chapter.

Zone	No of inhabitants	Inhabitants per DP	No of villages	Villages per DP	Area (km²)	km² per DP
Cambodia	12,9 M	**143 400**	13 860	**154**	180 000	**2000**
KampongCham	1,75 M	**19 500**	1 800	**20**	9 450	**105**

Table 8 Ratios for the number of DPs

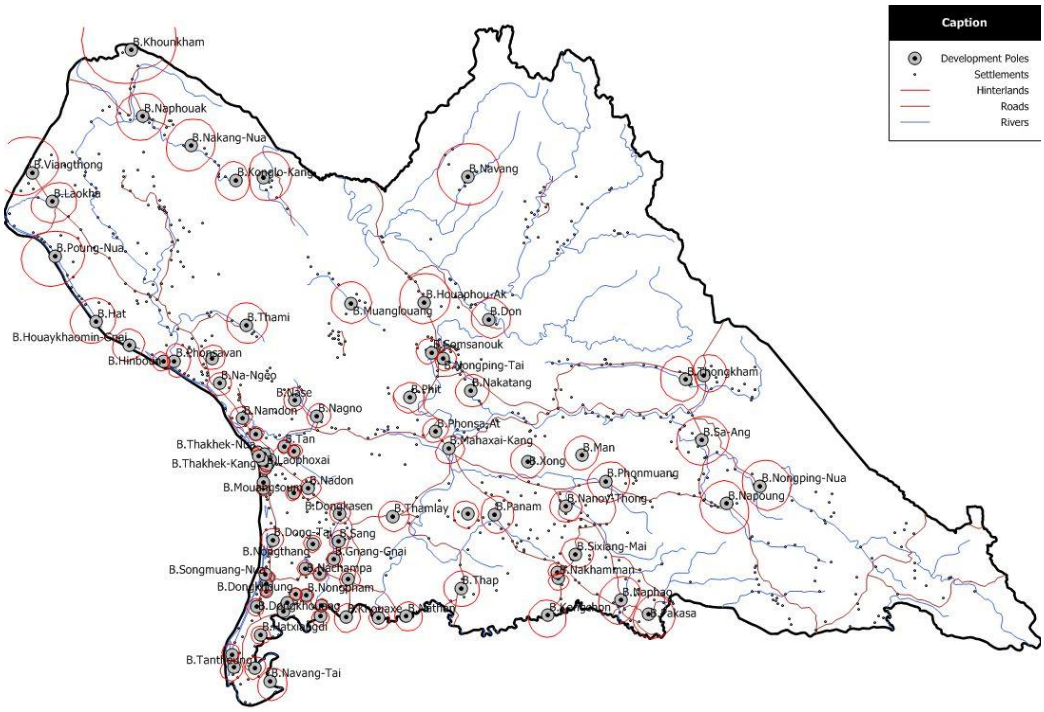
Since the same number of DPs have been selected at national and provincial levels, obviously ratios are much higher at the national level. In other words, DPs at the national level are much larger than DPs at the provincial level. In fact, only 15 DPs at national level are located in KampongCham province.

3.5.1.2.2 Lao PDR

417 DPs have been selected at the national level and 90 in Khammuon province. The lists of DPs can be found in annexes 5 and, and maps are shown in **Error! Reference source not found.** and **Error! Reference source not found.** in the next chapter.

A rather large number of DPs had to be selected at the national level because large centres like Vientiane, Thakek and Champasak contain almost all higher ranked DPs, therefore large areas would have been extremely far from any DP if we had selected only 90 DPs. This is partly due to the administrative definition of villages: large cities are divided into many small villages in the database (the largest village has a population of around 4000 inhabitants).

Zone	No of inhabitants	Inhabitants per DP	No of villages	Villages per DP	Area (km²)	km² per DP
Lao PDR	4,17 M	**10 000**	11 676	**10**	230 000	**186**
Khammuon	0,36 M	**4 000**	900	**28**	16 700	**551**



3.5.2 Load Forecast

3.5.2.1 Kampong Cham

3.5.2.1.1 Available data

Load forecast parameters have been designed with the help of previous studies, a field socio-economic survey and the GIS multisectoral database created by the CAP REDEO project.

3.5.2.1.1.1 Previous studies

The main sources of data from previous studies are the following:

- "The master plan study on rural electrification by renewable energy in the kingdom of Cambodia", JICA. 2006 0
- "Rural Electrification in Cambodia", presentation at CAP REDEO multistakeholder meeting, Heng KunLeang (MIME). 2007 **Error! Reference source not found.**
- "Energy and Electricity Outlook of Cambodia", H.E. Tun Lean (MIME). 2001 **Error! Reference source not found.**
- "Annual Report", EDC. 2002 **Error! Reference source not found.**
- "RE Strategy & Programme", Meritec & KCEC. 2001 **Error! Reference source not found.**
- "Review and assessment of water resources for hydropower and identification of priority projects", CPEC & ACT. 1995 **Error! Reference source not found.**

The first study is a comprehensive rural electrification master plan at the national level. It features recent aggregated consumption data from EDC and independent producers (REEs), as well as estimates of demand for off-grid areas. Figures are usually given at the national level, but data from a pre-feasibility study in Kratie province (neighbouring Kampong Cham) can also be used.

3.5.2.1.1.2 Socio-economic survey

In addition to the data from previous studies mentioned above, we conducted a field survey in a few villages of Kampong Cham province. In total 6 villages have been visited:

- Roang Leo in Kampong Siem district

- Spean Thmei in Kampong Siem district
- Svay Tbong in Srei Santhor district
- Ruessei Srok in Srei Santhor district
- Lpeak in Kampong Siem district
- Prey Totueng in Prey Chhor district (electrified)

Both non electrified and one electrified villages have been surveyed, to allow comparison of results. The first two villages have only been surveyed to test the questionnaires. After a few tests, questionnaires have been changed and used in the other villages.

Village selection was made among Development Poles in the province (cf. spatial analysis report). In consultation with PDIME of Kampong Cham province (Mr. Pou Run), 4 villages (3 non electrified and 1 electrified) spread over 3 districts have been selected. The electrified village is located along the national road NR6 from Phnom Penh to Kampong town, and non electrified villages are located somewhat far from the asphalt road – 1 is located around 20 km from the Kampong Cham town, and 2 others are located along the Mekong River in a frequently flooded area. The time taken to reach these non-electrified villages is about 3 hours from the asphalt road due to the fact that the access roads are laterite roads (local roads) being in very bad condition.

In each village, the village representative has been interviewed to provide a broad picture of the village.

Then around 2 different businesses or social services have been interviewed in each village to estimate their demand for electricity. In total 10 businesses and services have been interviewed.

Between 15 and 20 households have also been interviewed in each village to better understand their need for electricity and other forms of energy. In total 67 households have been interviewed.

Finally, 4 sites with significant potential for biomass production (rice mills and saw mills) have been interviewed. The results will not be used directly by the load forecast model but will allow us to estimate the potential of similar activities for biomass residue production and thus electricity generation, when we move to the next steps of assessing the production options for rural electrification planning

3.5.2.1.2 Load forecast parameters

In this chapter, main assumptions relating to the load forecast will be listed along with their references, so that relevant stakeholders can validate them or make suggestions of improvements.

3.5.2.1.2.1 Technical losses

Technical losses[21] are set equal to 20%, as suggested by EAC at the national stakeholder meeting in Phnom Penh **Error! Reference source not found.**.

3.5.2.1.2.2 Socio-economic data

- Villages are considered not scattered (the coefficient of not scattered households is equal to 100%), i.e. all households of a village are eligible for connection if the village is electrified.
- The population growth rate is 2.5% per year 0
- On average there are 5.7 people per household according to the GIS database **Error! Reference source not found.** (5.0 according to the survey **Error! Reference source not found.**)

3.5.2.1.2.3 Market segmentation (household classes)

Relative weights of household classes have been taken as 60% for the lower class, 30% for the middle class and 10% for the higher class in the first year of the planning period, as suggested during the stakeholder meeting **Error! Reference source not found.**.

[21] Taking into account transmission and distribution losses.

	Class 1	Class 2	Class 3
Year 1	60%	30%	10%
Year 20	50%	35%	15%

Figure 16 Relative weight of classes

3.5.2.1.2.4 Domestic demand

Ownership of appliances has been calculated from the survey **Error! Reference source not found.** and completed with data from the pre-feasibility study in 0.

Appliance	Class 1	Class 2	Class 3
Lighting	1.44	3.73	3.90
TV & Video-recorder	0.95	2.11	2.19
Radio-cassette	0.50	1.00	1.00
Rice cooker	0.06	0.12	0.12
Iron	0.05	0.20	0.45
Fan	0.21	0.86	1.73
Refrigerator	0.03	0.10	0.24

Table 9 Ownership of appliances (average number per household)

Consumption load curves of appliances have been designed from survey **Error! Reference source not found.** and calibrated to match the figures of average consumption per household taken from 0 and **Error! Reference source not found.**. Nominal power ratings[22] are indicated below:

Appliance	Power rating (W)
Lighting	16[23]
TV & Video-recorder	100
Radio-cassette	20
Rice cooker	300
Iron	800
Fan	100
Refrigerator	150

Resulting demand of each household class for the 24h supply scenario is presented in the following table:

	Class 1	Class 2	Class 3
Consumption (kWh/month)	13	43	68
Peak demand (W)	176	288	427

Table 10 Specific demand of one household for each class, not including distribution losses

3.5.2.1.2.5 Willingness to pay of households

Survey data wasn't consistent nor complete enough to provide an accurate estimate of willingness to pay and level of service expected. In fact, willingness to pay is usually measured by comparing expenditure in each form of energy between households in electrified and non electrified villages. However, the following indicative figures could be compiled: when asked directly how much they

[22] Please note that load curves of a given appliance do not necessarily reach the nominal power rating since these curves show the average power demand of an appliance and it often happens that the appliance is used only in a fraction of households at a given time of the day.

[23] This is the average power rating in the survey **Error! Reference source not found.**.

would be willing to pay for electricity, households answered 23600 Riels/month (6.12 US$) on average, which is higher than the figures provided by the JICA team 0 (between 2 and 4 US$). Surveyed electrified households spend even more (72500 Riels/month on average) but again, this village is not necessarily representative of remote areas. Therefore, 5 US$ per month appears to be a rather conservative yet realistic estimate of the willingness to pay.

3.5.2.1.2.6 Public services

- Number of health centres have been defined the GIS multisector database **Error! Reference source not found.**. According to discussions at the national stakeholder meeting **Error! Reference source not found.**, schools should not be considered as potential clients for an electricity service.
- Number of clients for water pumping, public lighting and meeting halls has been taken equal to 1 for all villages. However, their specific consumption is proportional to the population of the village.

Population range[24]	Health centres & health posts	Water pumping	Public lighting	Meeting hall/Pagoda
0-700	0.0	1.0	1.0	1.0
700-1400	0.0	1.0	1.0	1.0
1400-2100	0.1	1.0	1.0	1.0
>2100	0.3	1.0	1.0	1.0

Table 11 Average number of connections for public services for different population ranges

	Health centres & health posts	Water pumping	Public lighting	Meeting hall/Pagoda
Monthly consumption	72 kWh/connection	1200 kWh/1000p	1080 kWh/1000p	72 kWh/1000p
Peak demand	150 W/connection	4000 W/1000p	4000 W/1000p	400 W/1000p

Table 12 Specific demand of public services, not including distribution losses

3.5.2.1.2.7 Productive uses and small businesses

- Number of connections for different population ranges have been defined from survey **Error! Reference source not found.** (shops & restaurants) and the GIS multisector database **Error! Reference source not found.** for small industries[25].
- Rice mills above 20HP have been treated as particular demands (cf. chapter 2.2.4). Other medium to large industries exist in the GIS database **Error! Reference source not found.**, but reliable data is lacking about their demand for electricity and thus are not included in the forecast.
- Consumption load curves of infrastructures have been designed from survey **Error! Reference source not found.** and GIS database **Error! Reference source not found.** (for peak power of small industries, which is around 10kW), as well as data from Khammuon (cf. 3.5.2.2.2) because detailed good quality data on consumption of infrastructures and services was lacking.

Population range	Small industry (small mills, carpentry, metal works)	Misc. shops and tourism activities (hotels, restaurants)
0-700	0.9	1.0
700-1400	1.5	3.0
1400-2100	2.5	5.0
>2100	2.8	10.0

Table 13 Average number of connections for productive uses for different population ranges

[24] Population thresholds have been defined according to the ones chosen to calculate IPD (cf. spatial analysis report), i.e. a similar number of villages fall in each population range.
[25] Only small industries with engines below 20HP (15kW) have been selected. Bigger industries will be considered “particular” or “specific” demands.

	Small industry (small mills, carpentry, metal works)	Misc. shops and tourism activities (hotels, restaurants)	Rice mill above 20HP
Consumption (kWh/month)	540	146	3240
Peak demand (W)	2 000	300	12 000[26]

Table 14 Specific demand of productive uses, not including distribution losses

3.5.2.1.2.8 Growth hypotheses

Main assumptions for connection rates and consumption growth rate have been discussed during the stakeholder meeting in Phnom Penh **Error! Reference source not found.**. They are summarized in the following table:

Years	1	1-10	10	10-20	20
Connection rates					
Households	35%		98%		98%
Infrastructures and services	80%		100%		100%
Consumption growth rates					
Households		5.00%		0.00%	
Infrastructures and services		5.00%		5.00%	

Table 15 Growth hypotheses

3.5.2.1.3 Load forecast results

3.5.2.1.3.1 Example for a particular village

The results of the load forecast for a typical 500 inhabitants village are presented in detail below. Only results of the 24h supply scenario are shown.

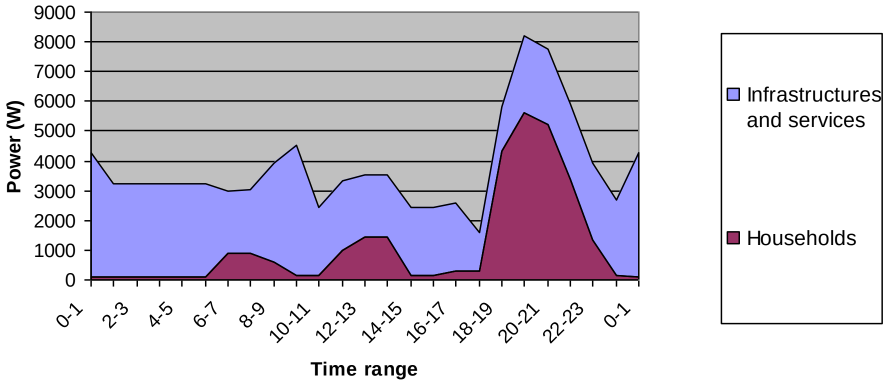


Figure 17 Average daily load curve in W for the first year (without technical losses)

[26] Peak demand of rice mills above 20HP is actually below 20HP (15kVA) because it is assumed that not all rice mills would run at the same time.

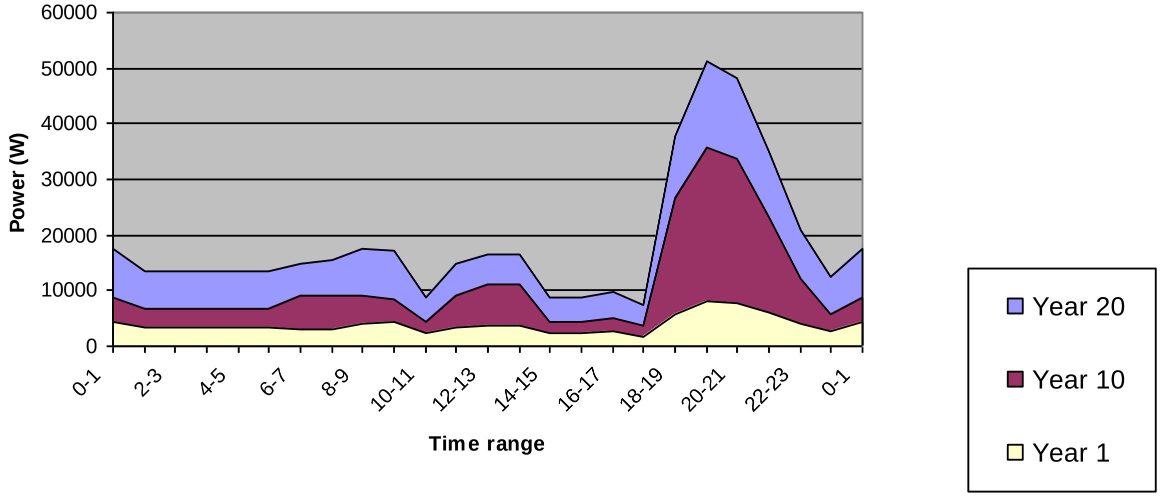


Figure 18 Average daily load curves for the first, 10th and 20th year (without technical losses)

Peak demand occurs roughly between 8pm and 9pm. It is mainly a consequence of household demand, while daytime demand is mostly non residential demand. A slight increase of the domestic share can be noticed between the first year and the last year of the planning period.

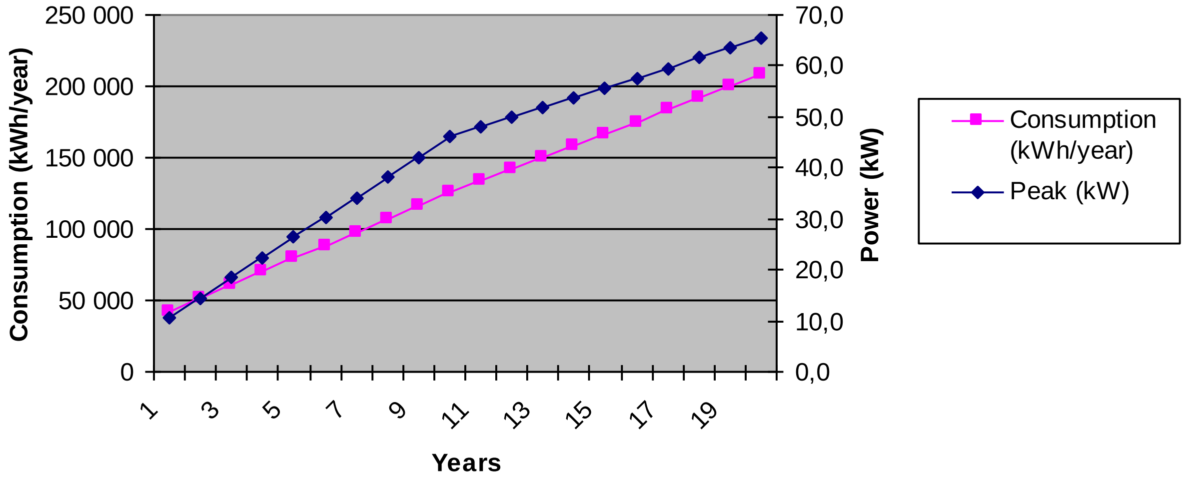


Figure 19 Evolution of yearly consumption and peak demand during the planning period (inc. technical losses)

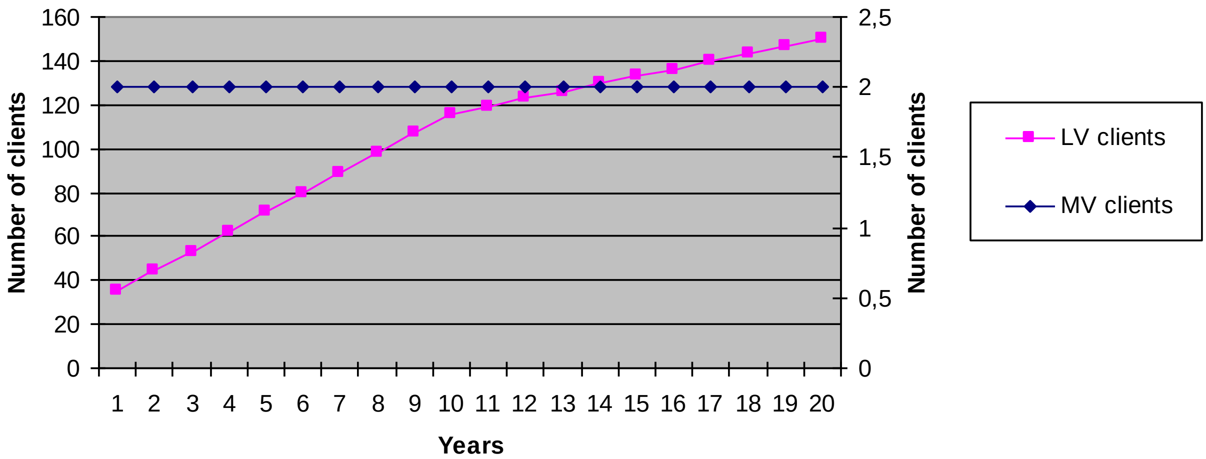


Figure 20 Evolution of LV and MV clients during the planning period (inc. technical losses)

Year	LV clients	MV clients	Yearly consumption (kWh)	Peak demand (kW)
1	35	2	42 481	10.5
2	44	2	51 684	14.5
3	53	2	60 887	18.4
4	62	2	70 090	22.4
5	71	2	79 292	26.3
6	80	2	88 495	30.3
7	89	2	97 698	34.2
8	98	2	106 901	38.2
9	107	2	116 104	42.1
10	116	2	125 306	46.1
11	119	2	133 580	48.0
12	123	2	141 853	49.9
13	126	2	150 127	51.9
14	130	2	158 400	53.8
15	133	2	166 674	55.7
16	136	2	174 947	57.6
17	140	2	183 220	59.6
18	143	2	191 494	61.5
19	147	2	199 767	63.4
20	150	2	208 041	65.4

Table 16 Summary of results (inc. technical losses)

3.5.2.1.3.2 GEOSIM results

The results of the load forecast for all villages in Kampong Cham province will now be presented. Figure 21 below shows the yearly consumption of each village for the first year of the planning period (the size of the dot representing villages is proportional to their consumption) while Figure 22 shows results at the district level.

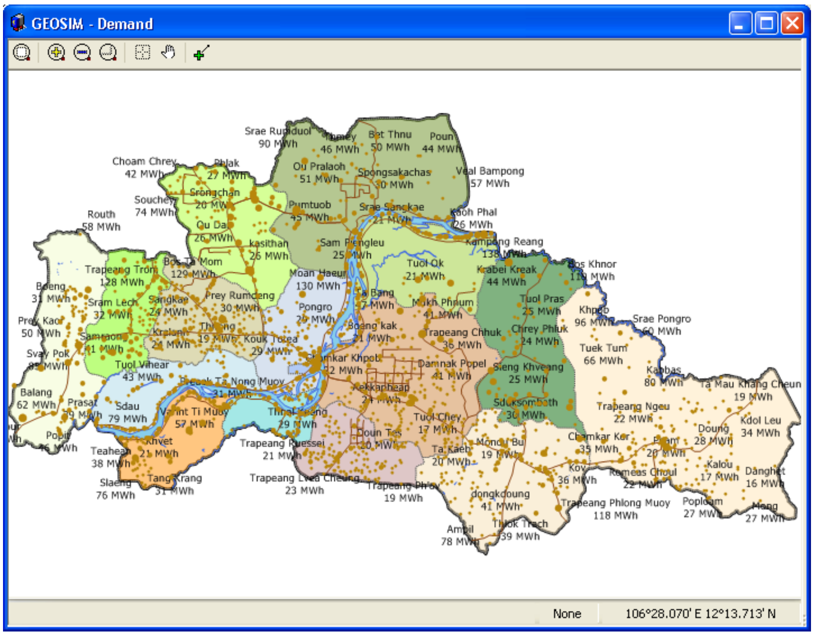


Figure 21 Results per village

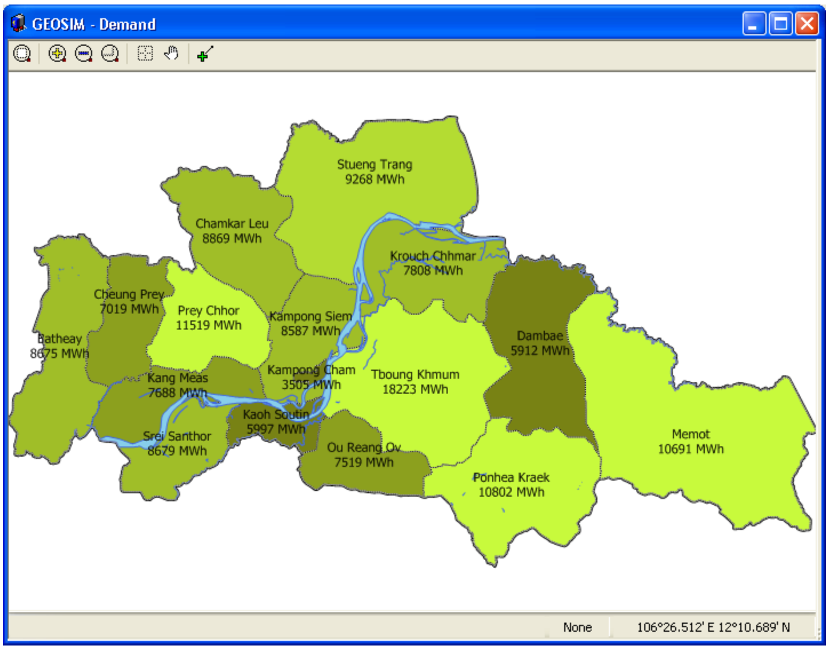


Figure 22 Results per district

The average yearly consumption per capita is around 80kWh for 2008. This figure is consistent with the figure of 55kWh per capita in 2001 **Error! Reference source not found.**, which would be around 94kWh in 2008 assuming an overall consumption growth rate of 8% (taken from **Error! Reference source not found.**).

However, according todata collected from EAC, consumption per capita ranges from 31kWh in Srei Santhor district to 5918 kWh in Ponhea Kraek district, probably due to very large local demands. These discrepancies have not been taken into account in our model. For example in Figure 22, forecasted demand seems lower in Kampong Cham district. This is because we did not treat this district seperatly from the others, i.e. the same parameters have been applied to all districts. Since these parameters are mostly valid for isolated rural areas, the forecasted demand of more urbanized districts is biased. Besides, not all specific demands (large industries) have been included in the forecast yet.

District	Population	Consumption year 1 (MWh)	Consumption year 10 (MWh)	Consumption year 20 (MWh)
Batheay	104 858	8 675	21 424	33 098
Chamkar Leu	114 783	8 869	21 670	33 332
Cheung Prey	88 131	7 019	17 088	26 361
Dambae	72 668	5 912	14 375	22 178
Kampong Cham	44 088	3 505	8 607	13 232
Kampong Siem	106 908	8 587	20 786	32 404
Kang Meas	103 217	7 688	18 863	29 456
Kaoh Soutin	73 156	5 997	14 591	22 854
Krouch Chhmar	105 362	7 808	19 264	29 594
Memot	131 001	10 691	25 690	39 900
Ou Reang Ov	89 738	7 519	17 899	27 625
Ponhea Kraek	132 369	10 802	26 239	40 821
Prey Chhor	140 254	11 519	27 756	43 184
Srei Santhor	108 156	8 679	21 264	32 845
Stueng Trang	114 786	9 268	22 741	35 090
Tboung Khmum	219 465	18 223	44 181	68 599
Total	1 748 940	140 761	342 438	530 573

Figure 23 Consolidated results per district

The list of results for all villages is available in **Error! Reference source not found.**. Yearly consumption, peak demand and domestic share are given for the first year, the 10th and the 20th year.

3.5.2.1.4 Sensitivity analysis

For the purpose of the sensitivity analysis, a high demand scenario has been discussed with stakeholders at the national meeting in Phnom Penh **Error! Reference source not found.**. The main hypothesis is a decrease in the tariff of electricity. We assume that the elasticity of consumption for different classes of households is not the same: poor households will consume more if tariff is higher, while the consumption of rich households will almost remain the same regardless of tariff. Therefore, consumption of different households classes have been multiplied by the following factors:

- 1.3 for the poor class
- 1.2 for the medium class
- 1.1 for the riche class

Schools have been judged suitable for electrification in this scenario, with a consumption of 50kWh per month, a peak demand of 150W and the following average number of schools per village:

Population range[27]	Number of schools
0-700	0.3
700-1400	0.6
1400-2100	0.8
>2100	1.1

Table 17 Number of schools

Finally the annual consumption growth rate of both domestic and non domestic clients is taken equal to 7%, instead of 5%.

The results of the high scenario for the whole province will be studied in the final rural electrification plan of KampongCham province. However, they won't be presented in full detail in this report. We will only show the results for a typical 500 inhabitants village, to allow comparison between the base scenario and the high scenario.

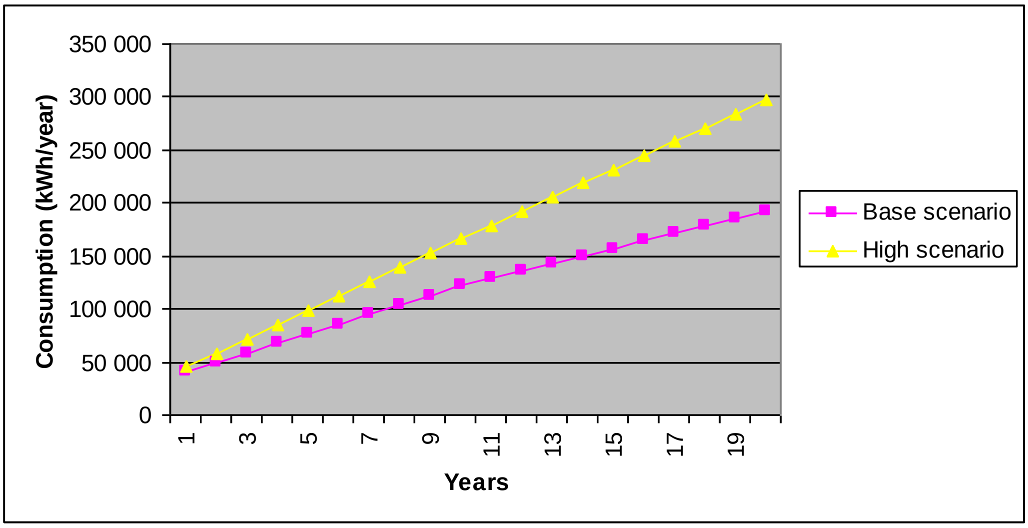


Figure 24 Comparison of consumption between high and base scenarios for a 500 inhabitants village

[27] Population thresholds have been defined according to the ones chosen to calculate IPD (cf. spatial analysis report), i.e. a similar number of villages fall in each population range.

Not surprisingly, the difference between the two scenarios is rather significant at the end of the planning period. In the first year, the consumption in high scenario is 12% above the base scenario, while in the last year the difference reaches 55%. Likewise the difference for peak demand starts at 18% in the first year, and reaches 49% at the end.

3.5.2.2 Khammuon

3.5.2.2.1 Available data

Load forecast parameters have been designed with the help of previous studies, a field socio-economic survey and the GIS multisectoral database created by the CAP REDEO project.

3.5.2.2.1.1 Previous studies

The main sources of data from previous studies are the following:

- "Evaluation of Rural Electrification, Socio-Economic Survey, Establishment of Database for Rural Electrification Planning in Lao PDR", International Development Association. 2004 **Error! Reference source not found.**
- "The study on rural electrification project by renewable energy in the Lao PDR", JICA. 2001 **Error! Reference source not found.**
- "Power Development Plan", Electricité du Laos. 2004 **Error! Reference source not found.**
- "EDL Tariff study", Electrowatt-Ekono Ltd. & Fichtner. 2004 **Error! Reference source not found.**

The first two studies are based on the bottom-up approach. The first one uses a method very similar to the one used by the GEOSIM model: detailed results from socio-economic surveys are collected to evaluate the demand for electricity of different household classes. However, households classes are determined only by income in this report, not willingness to pay and expected level of service. The area covered by this study is broader than Khammuon province, but the focus remains on southern provinces (areas targeted by the SPRE 2 project). Therefore it is assumed that data in this report iq still relevant for our study in Khammuon.

The JICA study is a bit less precise in the sense that input data doesn't come from field surveys but from broad assumptions on a typical 100 inhabitant village.

The last two reports feature aggregated (top-down) figures of electricity consumption for villages connected to EDL grid in Khammuon.

While the first two reports seem more adequate to find missing input data for the GEOSIM model, the top-down results are also of interest, since they give an order of magnitude for the demand of villages connected to the grid. Therefore, they can roughly validate or not the results of our forecast.

3.5.2.2.1.2 Socio-economic survey

In addition to the data from previous studies mentioned above, we conducted a field survey in a few villages of Khammuon province. In total 6 villages have been visited:

- Nonghoy in Hinboun district (electrified)
- Nanhi in Hinboun district
- Namdon in Hinboun district (electrified)
- Phonady in Mahaxai district
- Phonmouang in Mahaxai district
- Huayhoua in Hinboun district

A mix of electrified and not electrified villages have been surveyed, to allow comparison of results. The village selection has been suggested by local authorities of the province (head of PDEM). The first two villages have only been surveyed to test the questionnaires. After a few tests, questionnaires have been changed and used in the other villages.

In each village, the village representative has been interviewed to provide a broad picture of the village.

Then around 3 different businesses or social services have been interviewed in each village to estimate their demand for electricity. In total 13 businesses and services have been interviewed.

Between 15 and 20 households have also been interviewed in each village to better understand their need for electricity and other forms of energy. In total 68 households have been interviewed.

Finally, 3 sites with significant potential for biomass production (1 saw mill and 2 rice mills) have been interviewed. The results will not be used directly by the load forecast model but will allow us to estimate the potential of similar activities for biomass residue production and thus electricity generation, in the next phases on planning

3.5.2.2.2 Load forecast parameters

In this chapter, main assumptions relating to the load forecast will be listed along with their references, so that relevant stakeholders can validate them or make suggestions of improvements.

3.5.2.2.2.1 Technical losses

Technical losses[28] are set equal to 15%, as discussed during the national stakeholder meeting in Vientiane **Error! Reference source not found.**.

3.5.2.2.2.2 Socio-economic data

- Villages are considered not scattered (the coefficient of not scattered households is equal to 100%), i.e. all households of a village are eligible for connection if the village is electrified.
- The population growth rate is 2.2% per year **Error! Reference source not found.**
- On average there are 6 people per household **Error! Reference source not found.**

3.5.2.2.2.3 Market segmentation (household classes)

Relative weights of household classes have been taken from **Error! Reference source not found.** although these classes are defined by income.

	Class 1	Class 2	Class 3
Income boundaries ('000 Kips/month)	< 3053	3053-8107	> 8107

Table 18 Income boundaries

	Class 1	Class 2	Class 3
Year 1	32%	51%	17%
Year 20	33%	49%	17%

Figure 25 Relative weight of classes

3.5.2.2.2.4 Domestic demand

Ownership of appliances (% of households owning at least one appliance of a particular type) has been taken from **Error! Reference source not found.**, and average number of appliance of each type (how many appliances a household owns on average) has been taken from the survey **Error! Reference source not found.**. The following table combines both results:

Appliance	Class 1	Class 2	Class 3
Lighting	2.74	3.77	5.33

[28] Taking into account transmission and distribution losses.

TV & Video-recorder	1.23	1.90	1.77
Radio-cassette	0.11	0.16	0.22
Rice cooker	0.15	0.29	0.40
Iron	0.07	0.19	0.36
Fan	0.70	0.69	1.14
Refrigerator	0.33	0.61	0.81

Table 19 Average number of appliances per households

Consumption load curves of appliances have been designed from survey **Error! Reference source not found.** and calibrated to match the figures of average consumption per household taken from **Error! Reference source not found.** (figures entered in the model are slightly higher to take into account the fact that data from **Error! Reference source not found.** is outdated). Nominal power ratings[29] are indicated below:

Appliance	Power rating (W)
Lighting	40[30]
TV & Video-recorder	100
Radio-cassette	20
Rice cooker	300
Iron	800
Fan	100
Refrigerator	150

Table 20 Nominal power ratings

Resulting demand of each household class for the 24h supply scenario is presented in the following table:

	Class 1	Class 2	Class 3
Consumption (kWh/month)	43	79	117
Peak demand (W)	207	425	525

Table 21 Specific demand of one household for each class, not including distribution losses

3.5.2.2.2.5 Willingness to pay of households

Survey data wasn't consistent nor complete enough to provide an accurate estimate of willingness to pay and level of service expected. Nonetheless, as a rough estimate, when asked directly how much they would be willing to pay for electricity, households answered 26 170 Kips/month (2.9 $) on average, 22 240 Kips/month for the lower class and 30 000 Kips/month for the higher. According to **Error! Reference source not found.**, willingness to pay for the monthly bill is usually not an issue, connection costs being a more serious hindrance.

3.5.2.2.2.6 Public services

- Types of public services and their load curves have been estimated from survey **Error! Reference source not found.** and **Error! Reference source not found.**.
- Number of schools and health centres have been defined the GIS multisector database **Error! Reference source not found.**.

[29] Please note that load curves of a given appliance do not necessarily reach the nominal power rating since these curves show the average power demand of an appliance and it often happens that the appliance is used only in a fraction of households at a given time of the day.
[30] This is the average power rating in the survey **Error! Reference source not found.**. Of course, higher efficiency bulbs would significantly reduce the residential demand for lighting.

- Number of clients for water pumping, public lighting and meeting halls has been taken equal to 1 for all villages. However, their specific consumption is proportional to the population of the village.

Population range[31]	Schools	Health centres & health posts	Water pumping	Public lighting	Meeting hall/Pagoda
0-200	0.5	0.0	1.0	1.0	1.0
200-350	0.7	0.1	1.0	1.0	1.0
350-600	0.8	0.5	1.0	1.0	1.0
>600	1.1	0.8	1.0	1.0	1.0

Table 22 Average number of connections for public services for different population ranges

	Schools	Health centres & health posts	Water pumping	Public lighting	Meeting hall/Pagoda
Monthly consumption	50 kWh/connection	72 kWh/connection	1200 kWh/1000p	1080 kWh/1000p	288 kWh/1000p
Peak demand	150 W/connection	150 W/connection	4000 W/1000p	4000 W/1000p	1600 W/1000p

Table 23 Specific demand of public services, not including distribution losses

3.5.2.2.2.7 Productive uses and small businesses

- Number of connections for different population ranges have been defined from survey **Error! Reference source not found.** (shops & restaurants) and the GIS multisector database **Error! Reference source not found.** for small industries.
- Consumption load curves of have been designed from survey **Error! Reference source not found.** and **Error! Reference source not found.** (for estimates of peak power).

Population range	Small industry (small mills, carpentry, metal works)	Misc. shops and tourism activities (hotels, restaurants)
0-200	0.8	1.2
200-350	2.0	3.4
350-600	2.8	5.8
>600	5.9	12.2

Table 24 Average number of connections for productive uses for different population ranges

	Small industry (small mills, carpentry, metal works)	Misc. shops and tourism activities (hotels, restaurants)
Consumption (kWh/month)	540	83
Peak demand (W)	2 000	150

Table 25 Specific demand of productive uses, not including distribution losses

3.5.2.2.2.8 Growth hypotheses

Main assumptions for connection rates and consumption growth rate have been discussed during the stakeholder meeting in Vientiane. Please bear in mind that connection rate hypotheses are rather optimistic since connection costs are usually too high to achieve such high connection rates, unless generous subsidies are given. Connection rate for households is currently around 60%[32] according to the GIS database (EDL data) **Error! Reference source not found.**.

[31] Population thresholds have been defined according to the ones chosen to calculate IPD (cf. spatial analysis report), i.e. a similar number of villages fall in each population range.

[32] EDL reports mention a total connection rate for households, including households living in not electrified villages. Our load forecast model uses a slightly different figure: it is the average percentage of electrified households in electrified villages.

Growth hypotheses are summarized in the following table:

Years	1	1-5	5	5-20	20
Connection rates					
Households	60%		90%		90%
Infrastructures and services	80%		100%		100%
Consumption growth rates					
Households		4.00%		1.00%	
Infrastructures and services		4.00%		1.00%	

Table 26 Growth hypotheses

3.5.2.2.3 Load forecast results

3.5.2.2.3.1 Example for a particular village

The results of the load forecast for a typical 500 inhabitants village are presented in detail below. Only results of the 24h supply scenario are shown.

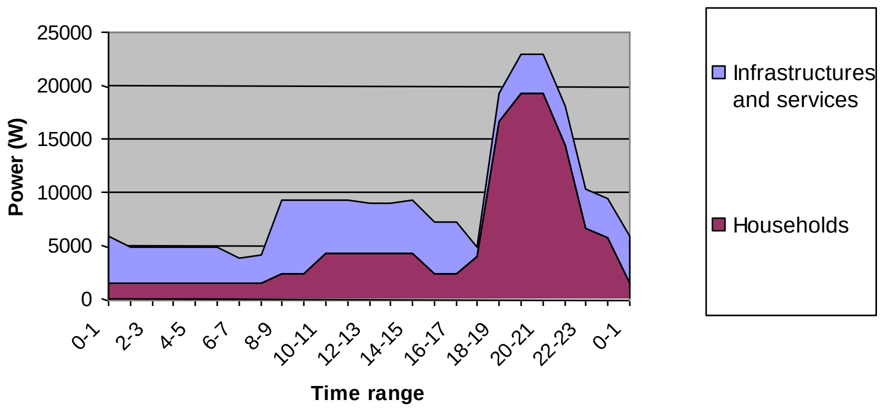


Figure 26 Average daily load curve in W for the first year (without technical losses)

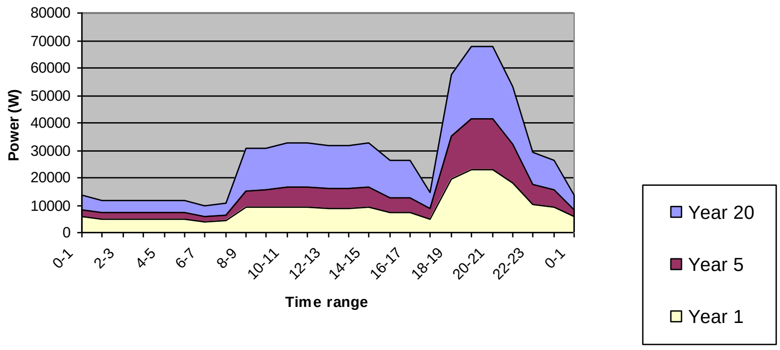


Figure 27 Average daily load curves for the first, 10th and 20th year (without technical losses)

In accordance with **Error! Reference source not found.**, peak demand occurs roughly between 6pm and 8pm. It is mainly a consequence of household demand, while daytime demand is mostly non residential demand.

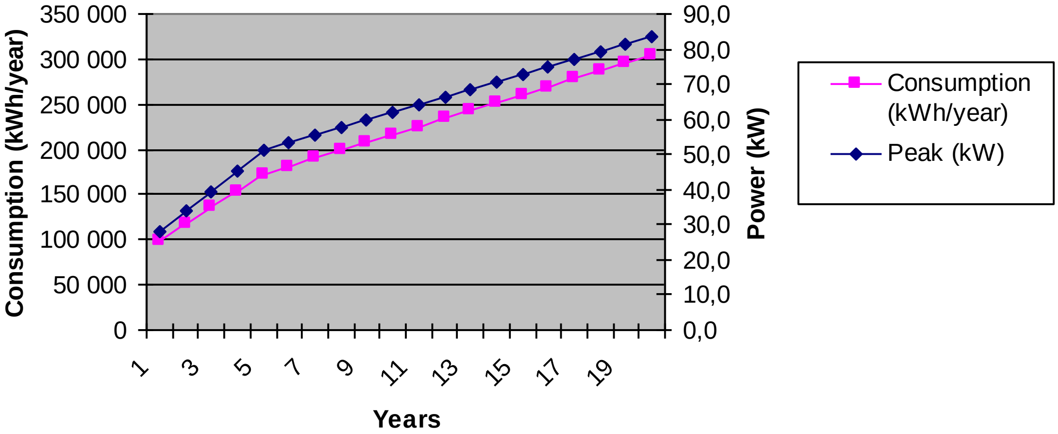


Figure 28 Evolution of yearly consumption and peak demand over the planning period (inc. Tech. losses)

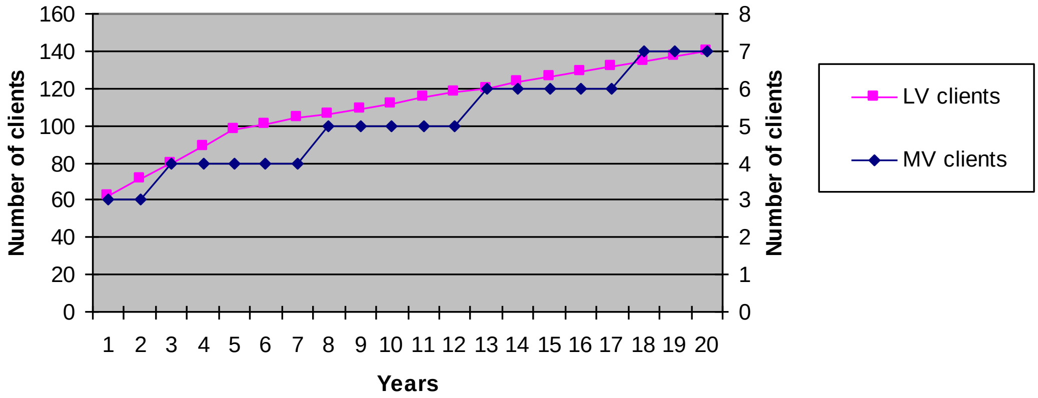


Figure 29 Evolution of LV and MV clients over the planning period (inc. technical losses)

Year	LV clients	MV clients	Yearly consumption (kWh)	Peak demand (kW)
1	62	3	99 347	28.0
2	71	3	117 560	33.8
3	80	4	135 773	39.6
4	89	4	153 986	45.4
5	98	4	172 199	51.1
6	101	4	181 006	53.3
7	104	4	189 813	55.5
8	106	5	198 621	57.7
9	109	5	207 428	59.8
10	112	5	216 235	62.0
11	115	5	225 042	64.2
12	118	5	233 849	66.3
13	120	6	242 656	68.5
14	123	6	251 464	70.7
15	126	6	260 271	72.9
16	129	6	269 078	75.0
17	132	6	277 885	77.2
18	134	7	286 692	79.4
19	137	7	295 499	81.6
20	140	7	304 307	83.7

Table 27 Summary of results (inc. technical losses)

3.5.2.2.3.2 GEOSIM results

The results of the load forecast for all villages in Khammuon province will now be presented. Figure 30 below shows the yearly consumption of each village for the first year of the planning period (the size of the dot representing villages is proportional to their consumption) while Figure 31 shows results at the district level.

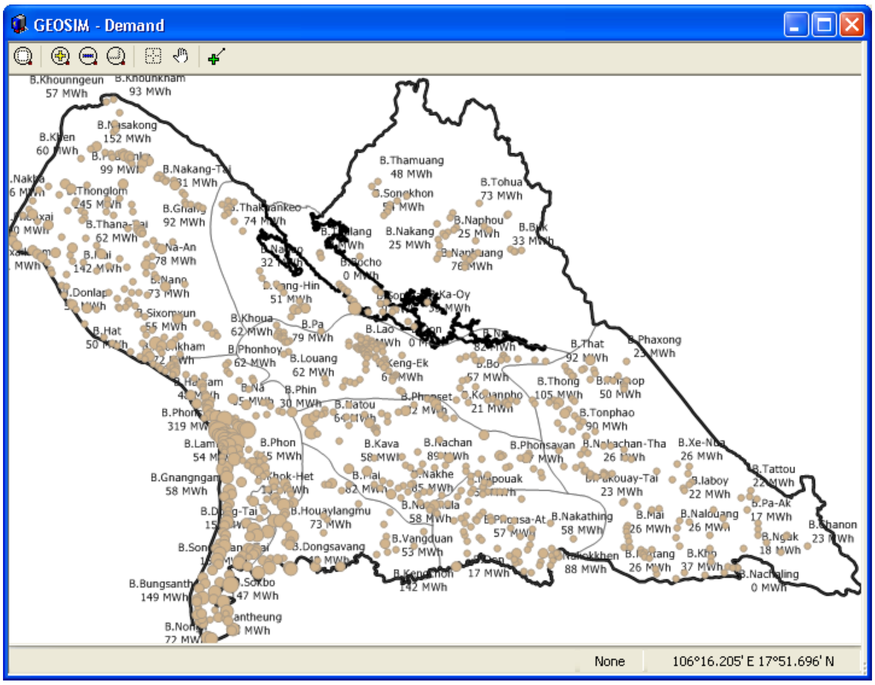


Figure 30 Results per village

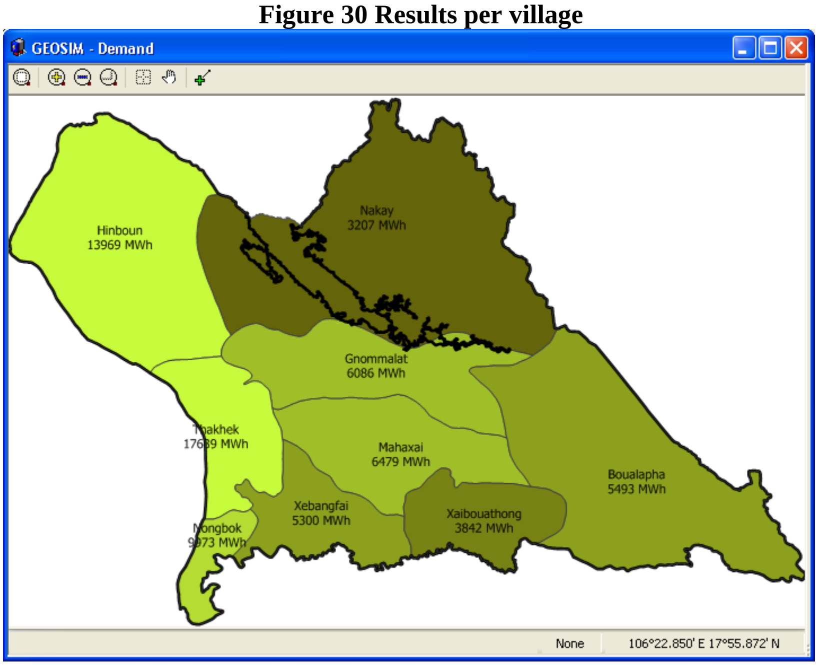


Figure 31 Results per district

District	Population	Consumption year 1 (MWh)	Consumption year 10 (MWh)	Consumption year 20 (MWh)
Boualapha	25 058	5 493	15 436	30 166
Gnommalat	28 063	6 086	17 618	34 942
Hinboun	65 888	13 969	40 819	77 174
Mahaxai	29 976	6 479	18 059	34 630

District	Population	Consumption year 1 (MWh)	Consumption year 10 (MWh)	Consumption year 20 (MWh)
Nakay	20 956	3 207	9 089	17 578
Nongbok	49 161	9 973	28 935	51 662
Thakhek	89 329	17 639	52 107	95 628
Xaibouathong	17 715	3 842	10 811	21 147
Xebangfai	25 856	5 300	15 398	28 162
Total	**352 002**	**71 988**	**208 273**	**391 088**

Figure 32 Consolidated results per district

Demand is naturally higher in populated areas along the Mekong river (Hinboun, Thakhek and Nongbok districts), while remote areas like Nakay and Boulapha districts have a much lower demand.

The power development plan of EDL **Error! Reference source not found.** measured an average yearly consumption of 187kWh per capita in 2002 for Khammuon province. This figure is similar to our result of 202kWh in 2008. However, the forecast of EDL for 2008 was much higher (511 kWh). This can be explained by the fact that the data we used was relevant only for remote rural areas, and not urban centres like Thakhek and areas connected to the grid in general. Besides, specific demands (large industries) haven't been included in the forecast yet.

The list of results for all villages is available in **Error! Reference source not found.**. Yearly consumption, peak demand and domestic share are given for the first year, the 10^{th} and the 20^{th} year.

3.5.2.2.4 Sensitivity analysis

For the purpose of the sensitivity analysis, a high demand scenario has been discussed with stakeholders at the national meeting in Vientiane **Error! Reference source not found.**. The main hypothesis is a decrease in the tariff of electricity. We assume that the elasticity of consumption for different classes of households is not the same: poor households will consume more if tariff is higher, while the consumption of rich households will almost remain the same regardless of tariff. Therefore, consumption of different households classes have been multiplied by the following factors:

- 1.3 for the poor class
- 1.2 for the medium class
- 1.1 for the riche class

Then the annual consumption growth rate of both domestic and non domestic clients is taken equal to 7%, instead of 5%. After the fifth year of the planning period, the growth rate is 2% instead of 1%.

The results of the high scenario for the whole province will be studied in the final rural electrification plan of Khammuon province. However, they won't be presented in full detail in this report. Only the results for a typical 500 inhabitants village in Boulapha district are shown below, to allow comparison between the base scenario and the high scenario.

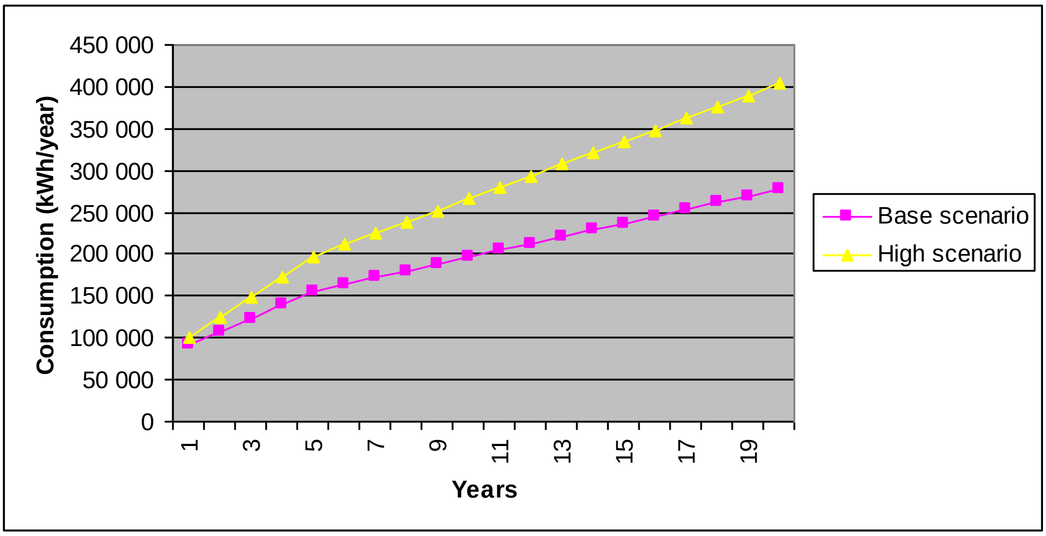


Figure 33 Comparison of consumption between high and base scenarios for a 500 inhabitants village in Boualapha district

Not surprisingly, the difference between the two scenarios is rather significant at the end of the planning period. In the first year, the consumption in the high scenario is 12% above the base scenario, while in the last year the difference reaches 45%. Likewise, the difference for peak demand is 18% in the first year and reaches 54% at the end.

3.5.3 Network Options

3.5.3.1 Electrification status

3.5.3.1.1 Kampong Cham province

3.5.3.1.1.1 General overview

Kampong Cham province is poorly covered by electricity network. No HV transmission line is reaching or crossing the Province and only few districts - Kampong Cham, Ponhea Kraek, Memot, Kampong Siem and Kang Meas - currently benefit from some EDC MV lines. Additional 22kV MV lines, managed by REEs, do exist but because of lack of data, they had to be simulated for the purpose of the study. These REEs are mostly located on Memot-Cheung Prey backbone and should be connected to EDC network within the foreseeable future.

Out of the 1758 localities of the province, only 333 are to date electrified, of which 295 served by REEs (89%). The electrified settlements rate[33] is 23%.

Table 1: Kampong Cham province key figures (2008)

Population	1 750 284
Number of settlements	**1 758**
non-electrified	***1425***
electrified	*333*
Electrified settlements rate	**23%**

[33] % of the province population leaving in electrified settlements

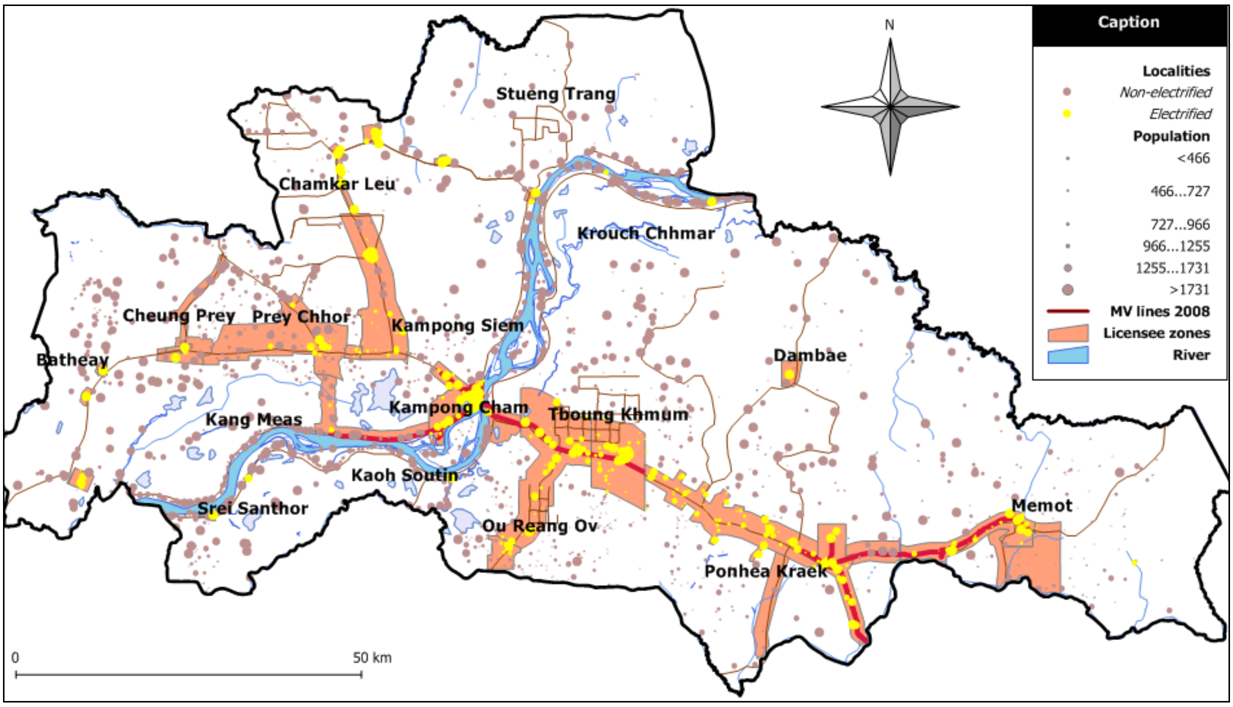


Figure 34: Kampong Cham province electrification status (2008)

3.5.3.1.1.2 Development Poles electrification status

In agreement with MIME, EDC, REF and EAC, 90 Development Poles were identified. At this level, it is important to underscore that the Development Pole notion is only based on socio-economic parameters highlighting the quality of services offered to the population of the Pole itself and to the population located in its hinterland. Poles could be therefore electrified or not.

As we will see in the next chapter, various electrification scenarios were studied. For all those scenarios, it was crucial to take into account the electrification status of the Development Poles, in order to make strategic decision on how they should be considered at planning level.

In 2008, out of the 90 Development Poles identified, 50 are already electrified, which is logical.

3.5.3.1.2 Khammuane province

3.5.3.1.2.1 General overview

The grid network is, so far, well developed within the Khammuane province. Only some remote areas remain out of the scope of the national electrification plan, as illustrated on the map below. Currently, electricity is at a relatively low cost thanks to large Hydro power plants and reasonable grid extension.

Out of the 887 localities of the province, 600 are to date electrified, with an electrified settlements rate[34] of 81%.

Population	371 000
Number of settlements	**887**
non-electrified	***287***
electrified	*600*
Electrified settlements rate	**81%**

[34] % of the province population leaving in electrified settlements

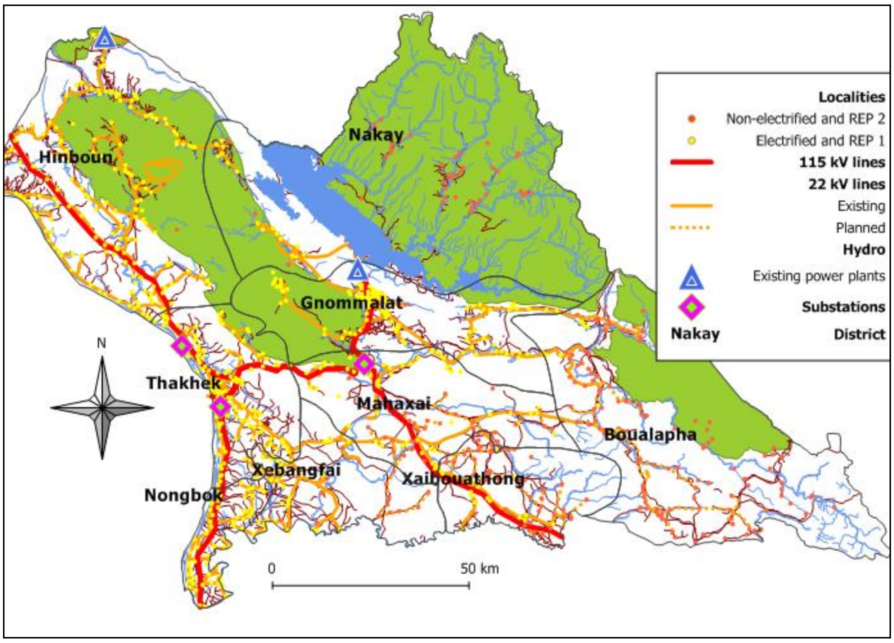


Figure 35: Khammuane province electrification status (2008)

. Two main programs have actually been programmed:

- *Rural Electrification Project (REP 1):* Two components: The first component extends electrification to about 42,000 rural households through connection to EDL grid. The second component provides electrification to about 10,000 households through off-grid technologies; REP 1 is nearly complete.
- REP 2: still subject to resource availability and earliest construction would be mid 2012.

Hence, it was agreed that (i) villages planned for REP 2 and those with no plan for electrification are considered as eligible for off-grid electrification and (ii) no simulation will be carried out then using the GEOSIM© grid extension module, as EDL has already decided on its development plan.

3.5.3.1.2.2 Development Poles electrification status

150 Development Poles have been identified, out of which 132 are or will be soon (through REP1) electrified:

3.5.3.2 Kampong Cham province rural electrification plan(s)

Based on interactive discussions and exchanges with MIME, EDC, REF and EAC, three different scenarios were considered for Kampong Cham province:

- ***Scenario 1*: by 2020, all villages should be grid-connected**

→ Expected outputs: total length of MV lines used, approximate cost for the total investment

- ***Scenario 2:* assessment of the cost for the extension of three additional 22 kV lines which could be undertaken by private operators by 2012, in addition to the lines for which investments have been secured: *Kampong Siem towards Chamkar Leu, Kampong Cham***

***towards Stueng Treng (2 sides of river), from Ponhea Kraek-Skon back-bone towards Dambae*. All villages located less than 5 km from the extended grid should be connected**

➔ Expected outputs: total length of MV lines used, approximate cost for the total investment for the lines considered.

- ***Scenario 3:* by 2012, all villages located within a 5 km buffer around existing and planned 22 kV lines should be grid-connected; remaining villages will benefit from an off-grid option (biomass, hydro, diesel)**

  ➔ Expected outputs: projected grid network likely to exist in 2012 (projected MV lines and electrified settlements) + off-grid projects

All these scenarios were developed and presented using the GEOSIM® software, and presented more in detail in Appendix.

3.5.3.2.1 Scenario 1:100% village electrification by 2020 through grid extension

3.5.3.2.1.1 Working hypothesis

The objective is to assess the required investment to electrify the entire province of Kampong Cham by 2020, considering the MV grid as the only option to supply all the province localities.

<u>Scenario 1 hypothesis:</u>

- 100% village will have been electrified by 2020
- MV grid network to be the unique Network Options
- 98% household will be connected

This simulation was done using the GEOSIM© Grid Extension module, dedicated to assist planners when simulating grid extension.

3.5.3.2.1.2 Simulation phases

Although the objectives at the planning horizon were very ambitious, it is crucial to remain realistic when starting simulating the grid extension, as the current capacity on existing MV lines is quite low. This first scenario was therefore divided in three distinct phases in line with the Cambodian planning process, enabling to take progressively into account new MV lines that would be commissioned during the planning period; each phase was based on specific assumptions.

- ***Phase 2: 2009-2010***

➢ ***Step 1: What is the real electric power landscape in 2008?***

As mentioned above, additional 22kV lines do exist in the vicinity of EDC network, within the REEs zones and, although data on their location were not available, it would have been too approximate to build a grid extension only on the basis of known data. The same observation can be made for Ou Reang and Tbung Khmum districts.

First step therefore consisted in simulating unknown “potential existing MV lines” by connecting all electrified villages located within the licensee zones and close to the existing network. These potential lines are displayed in green on the map below.

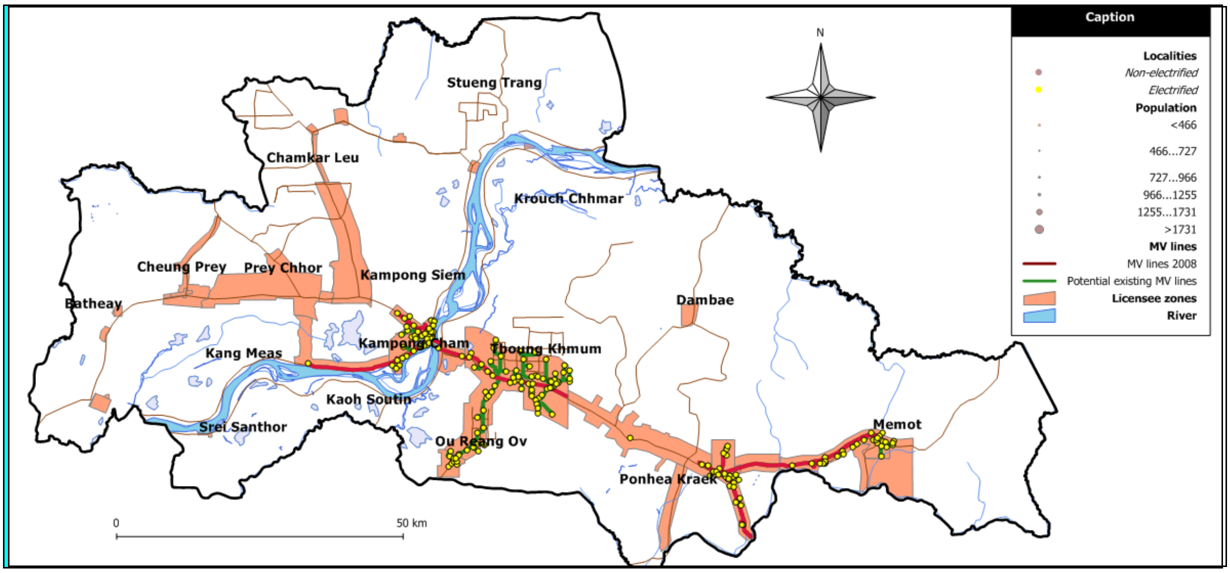


Figure 36: 22 KV lines (2008 + simulation of REEs network)

➢ ***Step 2: 2009-2010 grid extension***

This 1st phase was based on conservative parameters because of low power availability. Taking into account the low penetration of the grid, it was extended to electrify a few villages within reach, at a rate of 15 villages per year, all of them located within a 5 km buffer around the existing network.

2009-2010 extensions are displayed in blue on the map below:

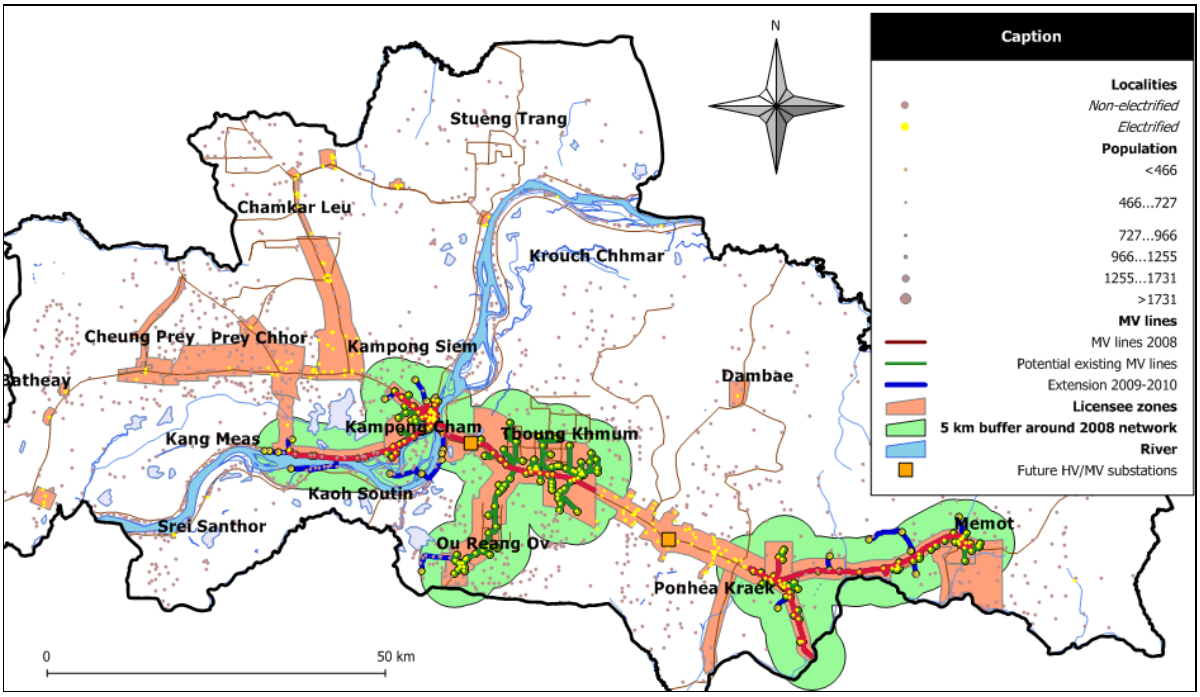


Figure 37: 2009-2010 extension

❑ ***Phase 2: 2011-2015***

According to Cambodian authorities, by 2011 the 22 kV lines between (i) Ponhea Kraek to Skun via Kampong Cham should be commissioned and therefore that villages can be connected up from them. This new line was therefore added to the network obtained after phase 1 extension before launching phase 2 simulation.

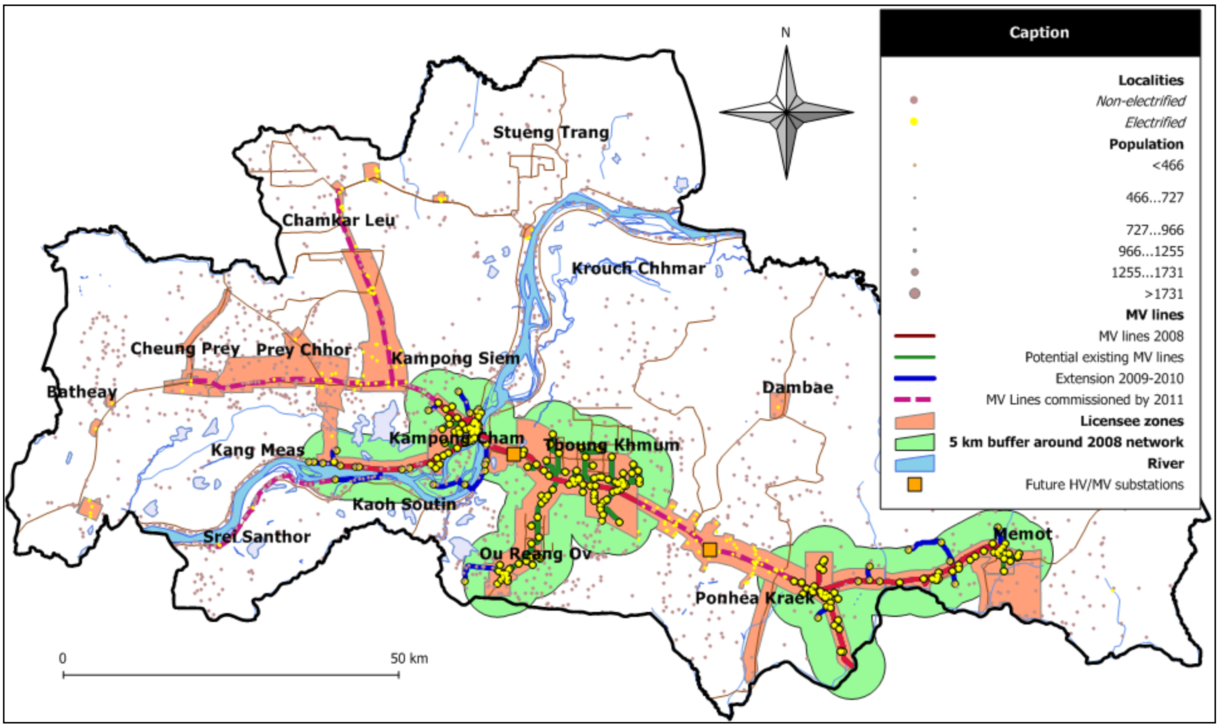


Figure 38: MV lines planned to be commissioned by 2011 (pink lines)

In parallel, the 115 kV line that will be coming from Vietnam will provide increased capacity to the Province and therefore the opportunity (i) to connect localities at a highest rate and (ii) to extend the network more in depth. 154 villages per year were considered for electrification.

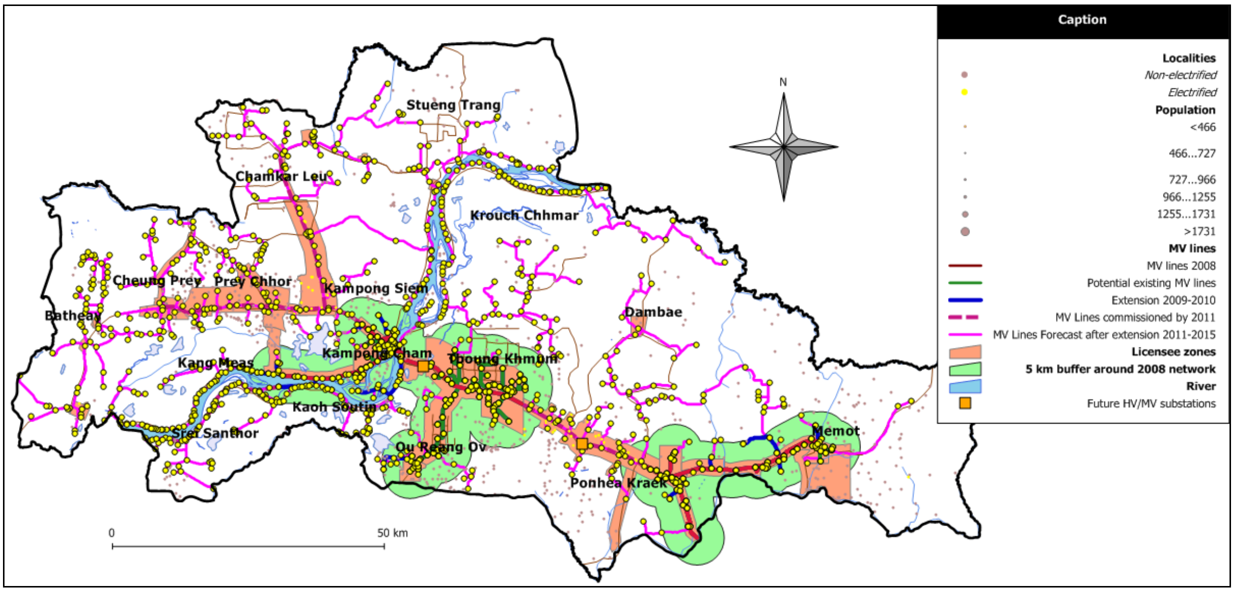


Figure 39: 2013-2016 extension

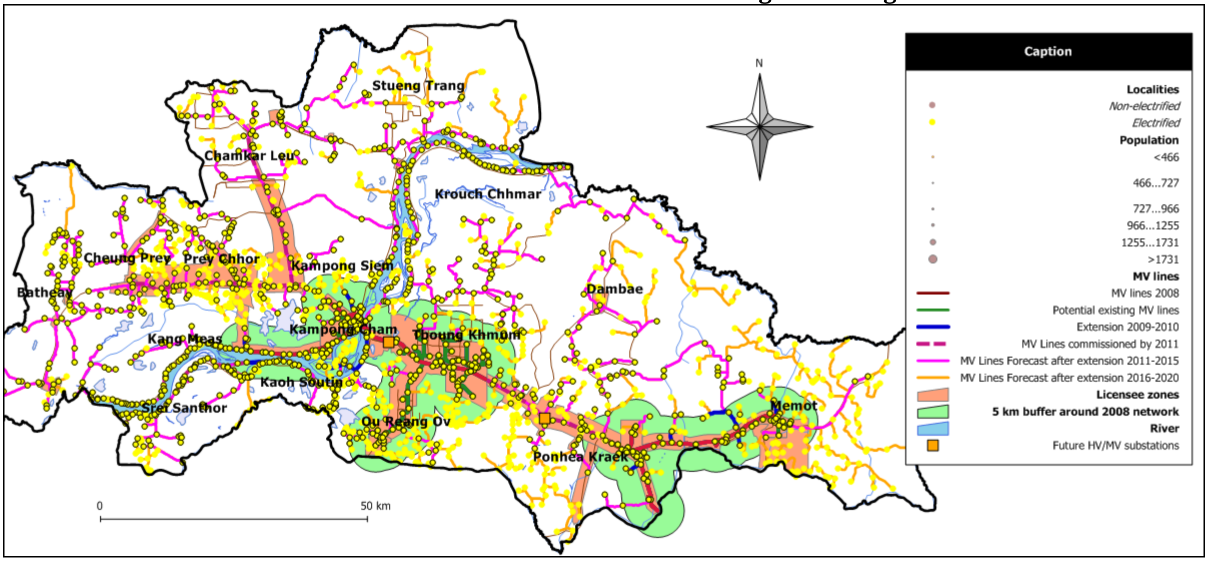
- ***Phase 3: 2016-2020***

Assumption was made that the following MV lines would be commissioned by 2016:

- Skun (Cheung Prey) – Phnom Penh (South West)
- Kampong Cham – Kratie (North East)
- Kampong Cham to the North along the river to Stueng Trang
- Kampong Cham to the South along the river to Srei Santhor

This assumption is fully in line with results got in phase 2 of the extension, as the labove mentioned lines were identified by GEOSIM© as structuring lines for Kampong Cham province. In order to reach 100% village electrified by 2020, a number of 154 villages to be electrified each year was considered.

Figure 40: Figure 13: 2016-2020 extension



3.5.3.2.1.3 Scenario 1 synthesis

If the whole Kampong Cham province was to be electrified considering the grid as the only supply option, around 2 500 km of additional MV lines would be required by 2020, for a total investment of 134 MUS$ (transmission + distribution).

Table 2: Scenario 1 key figures

Phase	Localities connected	Population 2009	Power demand 2009 GWh	Peak MW	kWh /cap	MV line length (km)	km/ village	Cost / village (US$)	Cost per HH[35]
2008*	189	226 488	17,2	4,9	75,8	137	0,7	38 319,1	182
2009-2010	30	57 597	4,4	1,2	76,0	64,5	2,2	123 788,2	368
2011-2015	770	1 113 074	83,1	23,7	74,7	1317	1,7	96 989,6	382
2016-2020	770	448 024	36,0	10,3	80,3	1071	1,4	62 509,5	612
TOTAL	**1 758**	**1 845 183**	**141**	**40**	**76,2**	**2 589**	**1,5**	**76 046,9**	**413**

Table 3: Scenario 1 investments

Phase	Invest. for transmission (MUS$)	Invest. for distribution[36] (MUS$)	Total invest. (MUS$)
2008*	3,3	4,0	**7,2**
2009-2010	1,5	2,2	**3,7**
2011-2015	31,6	43,0	**74,6**
2016-2020	25,7	22,4	**48,1**
TOTAL	**62,1**	**71,5**	**133,7**

[35] Considering 5,7 people per household
[36] Assumption: 150 households per km of LV line

**Densification phase around existing MV lines (including simulated ones)*

Although an equal number of localities was targeted for phases 2 and 3, related total investments are not comparable. Investments for the transmission part are roughly in the same order of magnitude, respectively 31,6 and 25,7 MUS$, which is not the case for the distribution part. Indeed, Phase 2 is 20 MUS$ more costly than Phase 3 due to a targeted population much more higher (1 113 074 and 448 024 in 2009), Phase 3 extensions reaching more isolated areas. But the most relevant indicator when planning investments is the cost per household, which is obviously very high in Phase 3, 60% higher than in phase 2 (382 US$ in phase 2, 612 US$ in Phase 3).

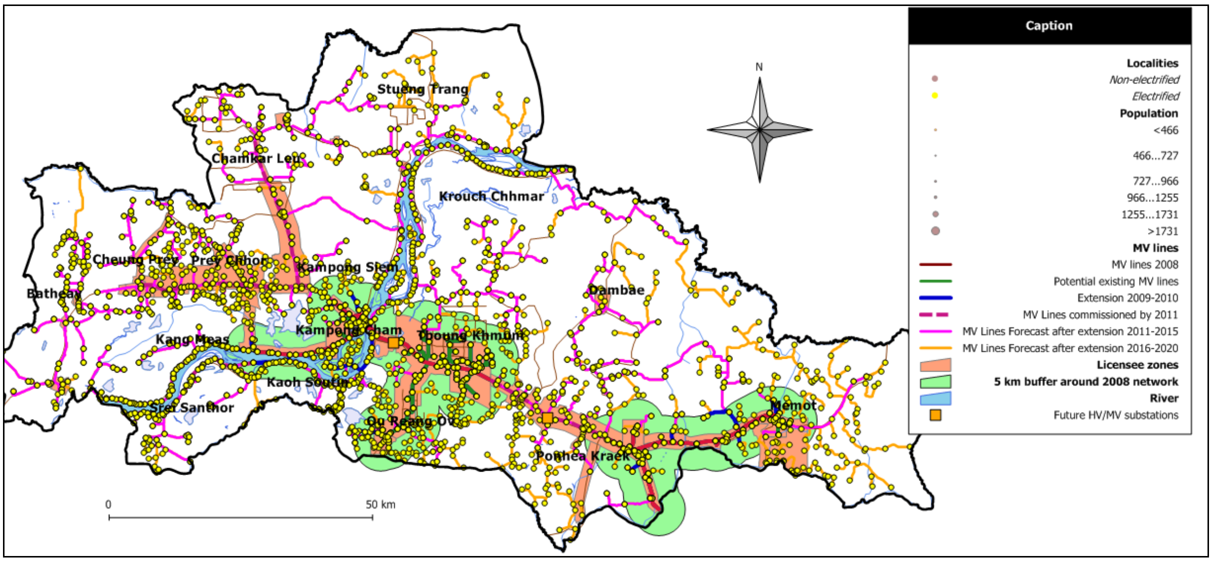


Figure 41: 100% village grid-connexion by 2020 in Kampong Cham province

3.5.3.2.2 Scenario 2: private grid extension projects

3.5.3.2.2.1 Working hypothesis

The 2nd simulation consisted in assessing the cost for the extension of three additional 22 kV lines by 2012, in addition to the lines already planned at this horizon (see Scenario 3 grid extension 3.5.3.2.3.3), and the connexion of all villages located less than 5 km from the extended grid.

The lines targeted were:

- **Kampong Siem towards Chamkar Leu**
- **Kampong Cham towards Stueng Treng (2 sides of river)**
- **From Ponhea Kraek-Skon back-bone towards Dambae**

Three specific buffers were defined to demarcate the areas within which villages should be connected to the grid.

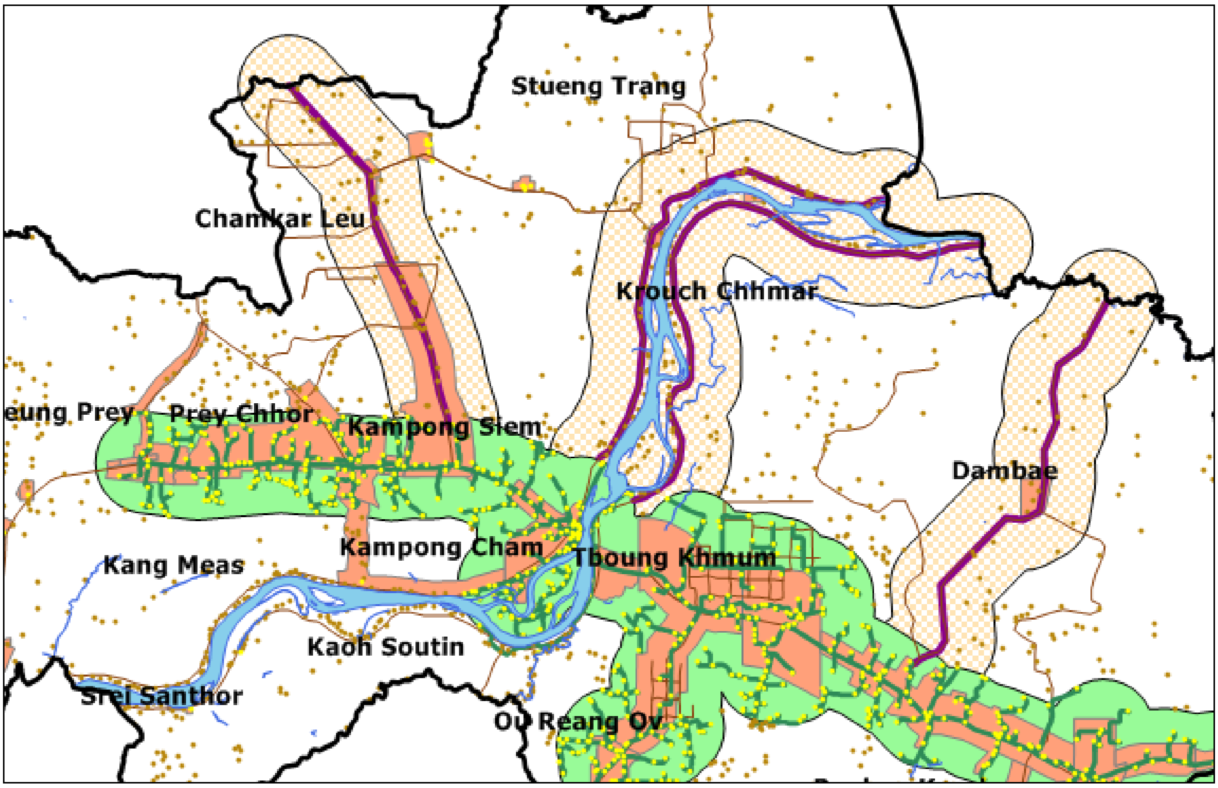


Figure 42: Scenario 2: 5 km buffers around targeted lines

The number of villages to be electrified was then adapted to fulfil the requirements:

	Number of localities targeted
Kampong Siem towards Chamkar Leu	62
Kampong Cham towards Stueng Treng	142
Back-bone towards Dambae	37

Table 4: Scenario 2 planning process

3.5.3.2.2.2 Scenario 2 results

The map below displays grid extensions from the three targeted lines.

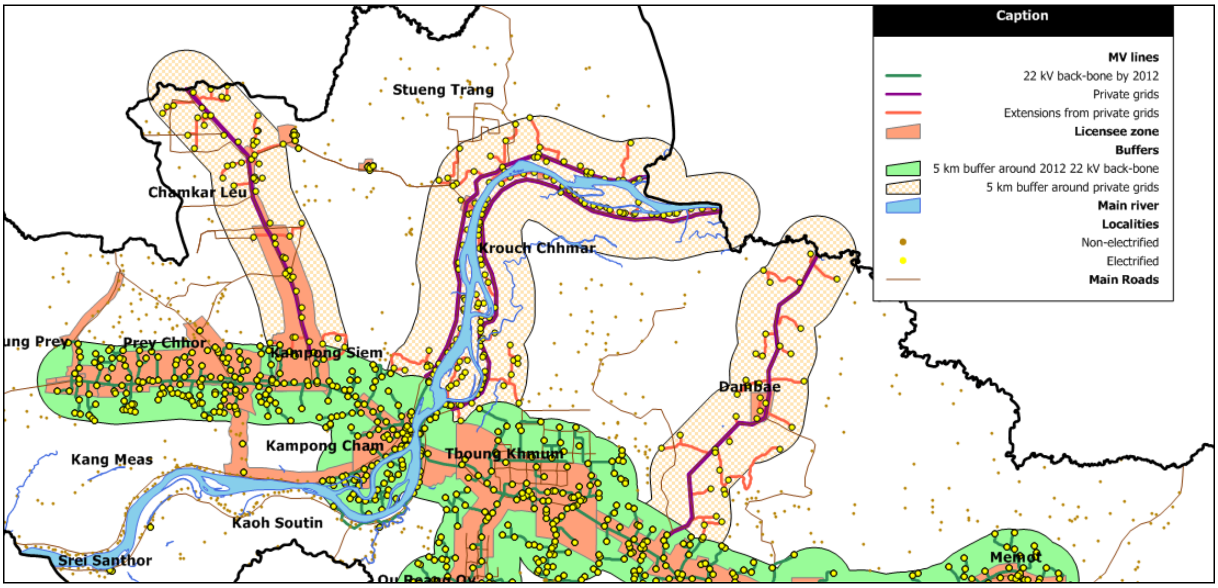


Figure 43: 22 KV lines – private grid extension projects

Key figures and investments

Table 5: Scenario 2 key figures

Grid extension *Towards...*	Localities connected	MV lines length (km)	Population 2009	Power demand 2009 GWh	Km / village	Cost / HH[37]	Cost / MWH
Chamkar Leu	62	84	83 028	6,3	1,3	362,7	845,3
Stueng Trang	142	165	185 335	13,9	1,2	348,9	815,4
Dambae	37	86	38 841	3,0	2,3	541,6	1 238,9
TOTAL	**241**	**335**	**307 204**	**23,1**	**1,4**	**377,0**	**878,0**

Table 6: Scenario 2 investments

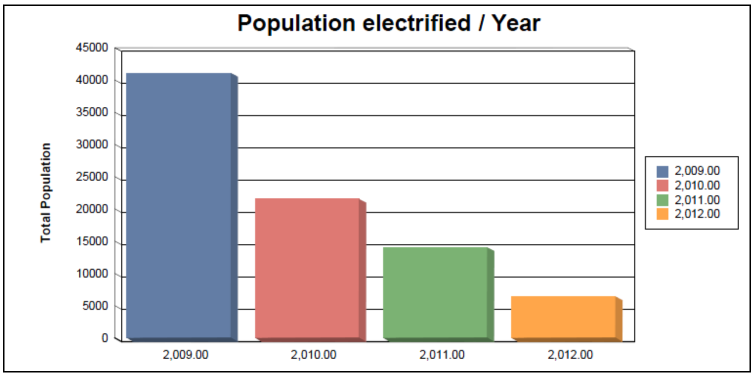
Grid extension *Towards...*	Investment for transmission (MUS$)	Investment for distribution (MUS$)	Total investment (MUS$)
Chamkar Leu	2,0	3,3	**5,3**
Stueng Trang	4,0	7,4	**11,3**
Dambae	2,1	1,6	**3,7**
TOTAL	**8,0**	**12,3**	**20,3**

[37] Considering 5,7 people per household

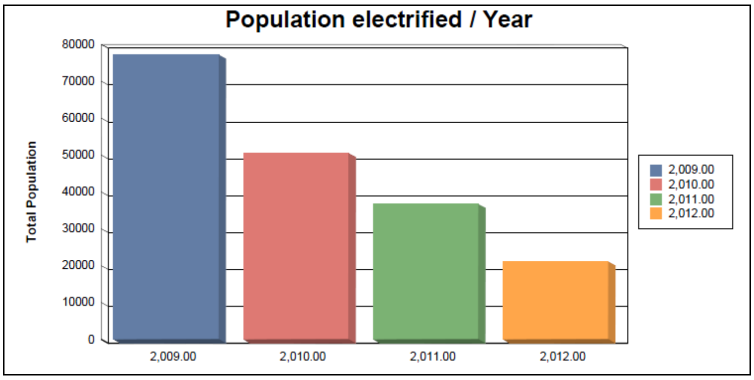
Cost per household is the roughly the same for Chamkar Leu and Stueng Trang extensions, because of very similar ratios (km of transmission MV lines per village, avarage population per village). Regarding Dambae extension, this cost is around 50% higher due to the fact that localities targeted are less populated and more distant from one to another.

The diagrams below give an indication on the population that would be covered each year of the planning period. It clearly highlights the fact that the more the network is extending, the more the population targeted is decreasing. As the grid extension algorithm strives to connect in priority villages with the highest Net Present Value, villages with highest demand, and therefore the most populated ones, will be first connected. Therefore, in 2012, less populated villages will be reached.

Extension towards Chamkar Leu



Extension towards Stueng Trang



Extension towards Dambae

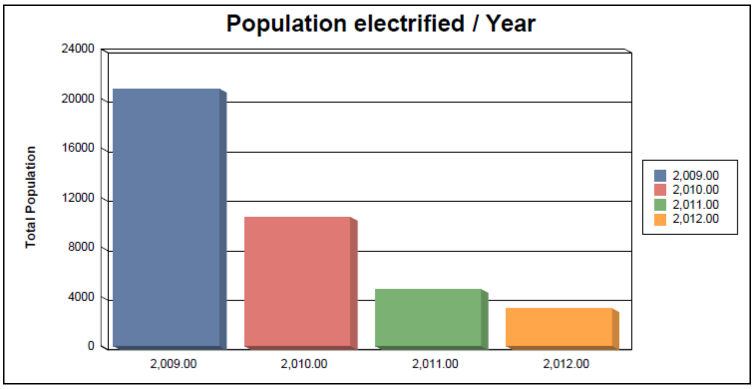


Figure 44: Population covered by 2012

3.5.3.2.2.3 Scenario 2 brief economic analysis

What are the potential financial schemes the scenario 2 could rely on? Different possibilities can be considered:

- If no subsidy could be foreseen ➔ what should be the customer tariff to make the projects viable?
- private investment with a tariff fixed by the regulatory board ➔ what would be the necessary initial subsidy to get an acceptable Internal Rate of Return (IRR)?

❑ ***Project not subsidized***

We make the following assumptions:

REEs purchase price from EDC	**0.15 US$**
Demand increase per year	**6%**
Load factor	**42%**

Table 7: Scenario 2 economic analysis hypothesis

Without any subsidy, and depending on the end-users tariff, we get the following IRR (calculated over the next 11 years, until 2020):

	Customer tariff (US$)		
	0.25	**0.30**	**0.35**
Dambae	1%	9%	15%
Chamkar Leu	8%	17%	25%
Stueng Treng (2 sides of river)	9%	18%	26%

Table 8: IRR without subsidies

For all projects to be viable, considering a discount rate of 10%, customer tariff must be in the range of 0.30-0.35 (IRR will be therefore greater than the discount rate and thus the NPV positive).

At this level it is important to underscore the importance of the demand analysis and therefore of the field surveys. In this kind of exercise, it is crucial to take into account all energy needs of the territory concerned, especially the sites requiring high demand levels that will significantly impact financial figures. If we consider for example in our calculations an additional demand of 1 MW in the vicinity of each line (required for example by a large industry), the respective IRR would evolve as follows:

Additional demand: 1MW	**Customer tariff (US$)**		
	0.25	**0.30**	**0.35**
Dambae	20%	33%	44%
Chamkar Leu	21%	33%	44%
Stueng Treng (2 sides of river)	15%	26%	36%

Table 9: IRR without subsidies - with additional specific demand 1 MW

Considering this additional specific demand, a 0.25$ tariff would make all the three projects viable, while proposing an affordable tariff to customers (and therefore increasing the number of candidates for connexion).

In the perspective to make a relevant economic analysis, demand analysis must therefore not be underestimated. Consumption sites like rubber plantations are for example industries that should be considered. Their required capacity is generally about few MW, with very high consumptions, and their consideration could significantly modify both (i) supply options identification and (ii) economic analysis results. This appear to be even more relevant for Kampong Cham province, where most of Cambodia rubber plantations are located.

- ***End-users fixed tariff***

As explained above, and if we do not take into account any specific demand, an end-user tariff of 0.25US$ would not make the projects viable, IRR being in the three cases lower than the discount rate. What would be therefore the needed subsidy to make them attractive?

	Subsidy (% of the initial investment)			
	0%	**10%**	**20%**	**40%**
Dambae	1%	3%	5%	11%
Chamkar Leu	8%	10%	13%	20%
Stueng Treng (2 sides of river)	9%	11%	14%	21%

Table 10: IRR with subsidies

As we could expect, Dambae project (involving less populated and distant localities) would require a high level of investment to make it viable (40% of the initial investment). For Chamkar Leu and Stueng Trang, an investment of around 10% of the initial investment would be enough.

3.5.3.2.3 Scenario 3: Grid extensions and off-grid options

3.5.3.2.3.1 Working hypothesis

The objective was to make an electrification plan within which all villages located within a 5 km buffer around existing and planned 22 kV lines should be grid-connected by 2012. Beyond grid extension, special attention was therefore given to the grid densification, to exclude situations where a locality would be located close to an MV line without being connected. Still with the ambition to optimise socio-economic development of the Province, an off-grid option (biomass, hydro, diesel) was to be identified for all the Development Poles that would not be located within the buffer and therefore not connected to the grid by 2012.

Scenario 3 hypothesis:

- Grid area: 5km buffer around existing and planned 22 kV lines
- All villages of the buffer connected by 2012
- All remaining Development Poles will benefit from an off-grid option

3.5.3.2.3.2 Scenario 3 approach

The approach adopted for scenario 3 addresses the energy access issue under the development angle, with the objective to optimise the socio-economic impact of rural electrification. This was done by carrying out a spatial analysis (through GEOSIM© Spatial Analyst module), to identify localities that should benefit first from a rural electrification programme in order that the maximum number of people could benefit from it.

Complementarily and prior to classical rural electrification planning approaches, this first step aims to optimise the mandatory public subsidy by giving higher priority to projects which will benefit to the largest number of people (inside and outside electrified settlements) and with the best social and economic impact, characterised by the (ii) the improvement of access to social services (health, education, drinking water, etc.) benefiting from electrification and (ii) the creation of local economic opportunities (business, employment, etc.).

The definition of an off-grid area within which decentralized supply options should be identified requires from the planner to be aware of existing and planned lines by a given horizon. Two questions therefore underlie this scenario and were successively addressed:

➔ Which villages (including Development Poles) are likely to be connected to the grid planned by 2012?

➔ What are therefore the off-grid area and the villages that will be concerned by an off-grid option?

The scenario 2 approach is based on the following observations:

- All Development Poles (not connected to the grid) are candidate for an off-grid supply option
- Priority is given to biomass (from rice husks and off-cuts residues) and hydro technologies over diesel option
- Possible diesel back up for renewable energy based options
- For all options, optimisation of the kWh levelized cost by continuing connecting settlements till this cost increases.

3.5.3.2.3.3 Grid extension

- **Lines commissioned by 2012**

This 3rd simulation appears to be more realistic as only grid extensions for which investments have been secured by 2012 were taken into account in addition to the existing network, constituting a 22 kV grid backbone going from Vietnam (Tan Bien) to Kampong Cham and ending in Kampong Siem.

In other words, localities that would benefit of a grid connexion from those additional lines will not be considered when addressing the off-grid supply options identification. 2012 is therefore a threshold date, beyond which any Development Pole that would not have been connected to the grid would be candidate for an off-grid option.

These additional lines are:

- Viet-Nam – Ponhea Kraek – Memot
- Ponhea Kraek - Kampong Cham
- Kampong Cham – Kampong Siem
- Towards Sieng Seng (Chamkar Leu)
- 22 kV in Tboung Khum region*
- 22 kV in Ou rang Ov region*

** Densification around existing lines carried out in Scenario 1 was retained to connect already electrified localities located in the vicinity of these lines.*

The map below displays the MV network as foreseen in 2012.

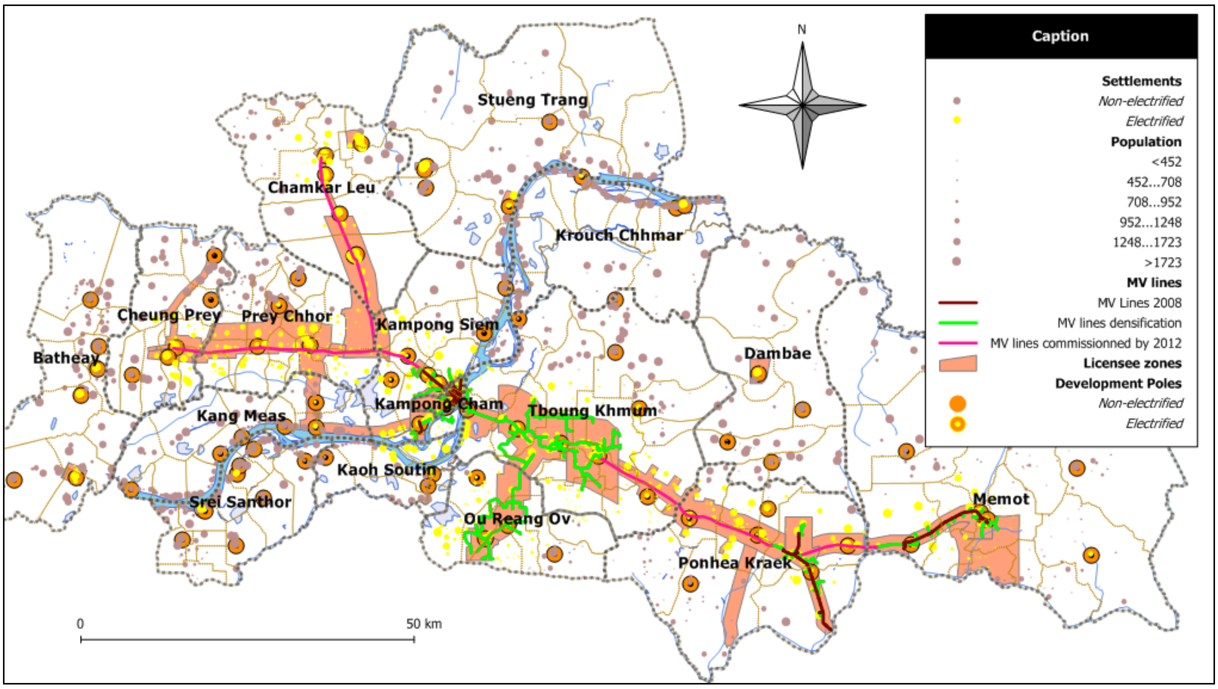


Figure 45: Lines commissioned by 2012

➢ Grid-area specification

A 5 km-buffer was created around the above mentioned backbone, covering roughly most of REE licensee zones which are supposed to be inter-connected with 22 kV lines within the next few years.

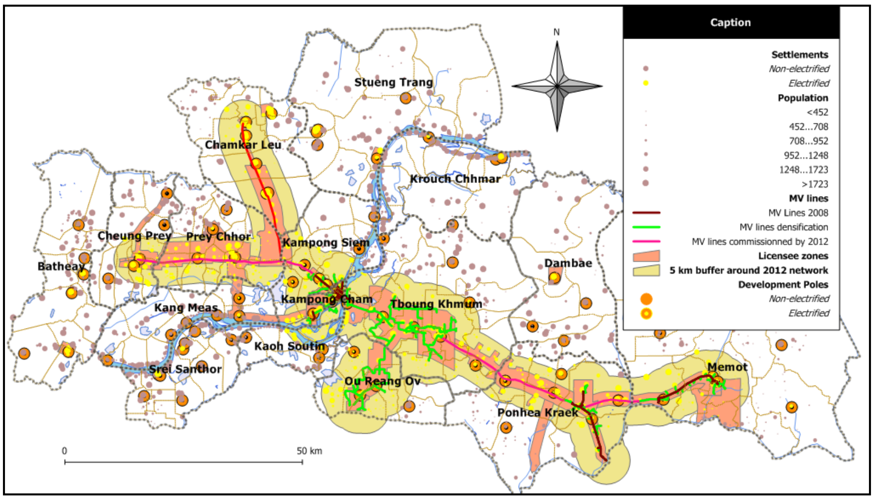


Figure 46: 5km buffer around MV lines

➢ Grid extension

708 localities are located within the buffer, out of which 520 are not electrified to date; an equal number of 130 villages to be connected each year from 2009 to 2012[38] was therefore considered. List of connected localities is provided in Appendix.

[38] 2012 included

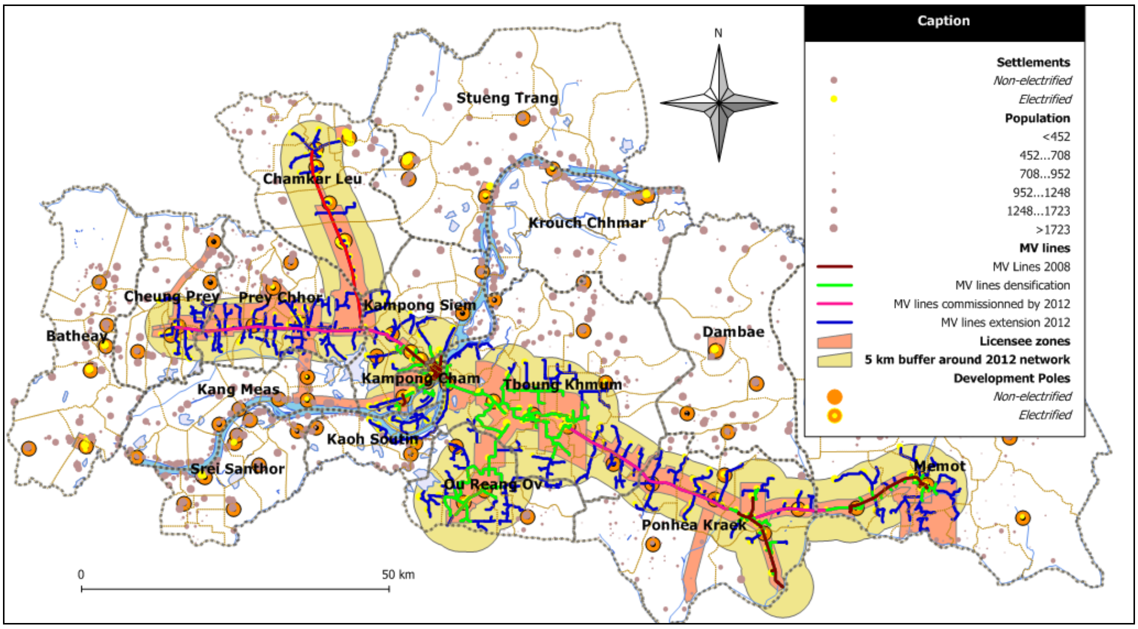


Figure 47: Grid extension by 2012

Over the four-year period, around 670 km of MV lines (displayed in blue on the previous map) would be needed to connect all the buffer villages, for a total investment of 36,7 MUS$.

Table 11: Scenario 3_2012 grid extension key figures

2009 population	MV line length (km)	Investment for transmission (MUS$)	Investment for distribution (MUS$)	Total investment (MUS$)
465 885	668	15,9	20,8	36,7

It is important to keep in mind that, at this level, as in any grid-extension simulation carried out for the purpose of the project, the Development Pole notion does not appear yet and will be considered only in the off-grid approach. This highlights the innovative aspect of the methodology used as, depending on the planning process step, two different approaches were adopted:

- an "economic approach" when simulating grid extension, in line with utilities approach;
- a "development oriented approach" when identifying off-grid options, in order to boost socio-economic development of Poles.

3.5.3.2.3.4 Off-grid supply options

Off-grid area has now been specified; all development poles that were not concerned by grid extension, therefore located outside the 5 km buffer, were candidates for a decentralized supply option.

1/ Renewable energy potentials

In Kampong Cham province, renewable technologies that were considered were small hydro and biomass, both of them being given priority over diesel option. The two tables below provides detailed information on selected sites[39].

➢ Biomass potentials

[39] Cf. CAP REDEO Hydro & Biomass report

For these projects, there is no identification and actual feasibility studies available, so some potentials were derived from available information on rice production.

Significant potential have been identified from rice husks and off-cuts in Kampong Cham province, as shown on map below.

Residue collection points were positioned within a 15 km radius from residue production sites.

Purchase price of residue was taken equal to 7$/tonne (according to the survey conducted in rice mills and saw mills, this is the threshold price under which the sell of residues would not profitable compare to other uses). A sensitivity analysis was nevertheless done with 10$.

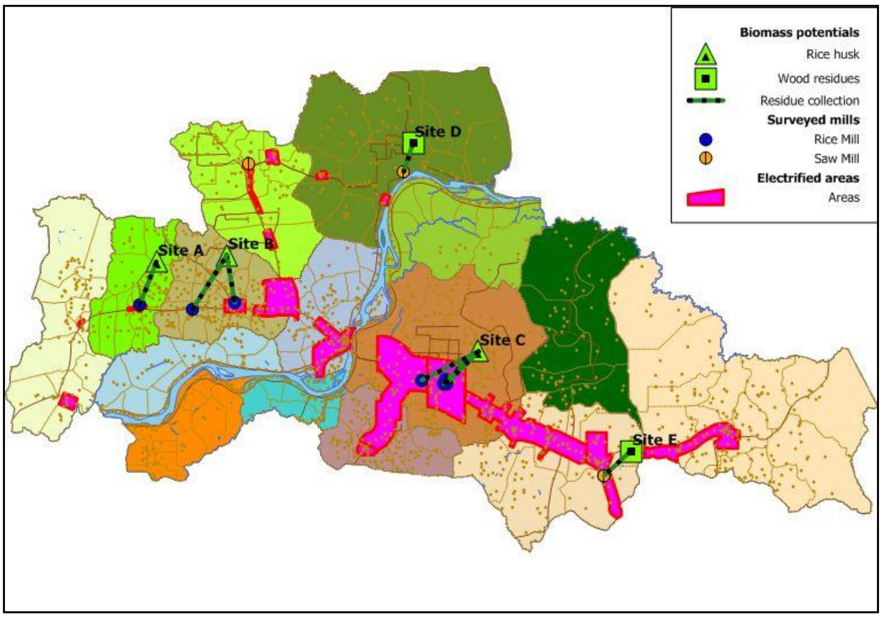


Figure 48: Biomass potentials

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 / year)	1000	650	550	80	420
Total energy output (MWh per year)	**1400**	**950**	**850**	**120**	**630**
Power (kW)	**330**	**220**	**194**	**27**	**144**

Table 12: Selected biomass potentials in Kampong Cham province

- Hydro potentials

On the basis of site visits and map study, two potential hydro sites, located in Stueng Trang and Dambae districts, have been investigated.

Kampong Cham province stretches on a flat territory. Although low estimated capacities (4 kW and 20 kW), the objective was to assess the possibility for some neighbour localities to benefit from potential power plant.

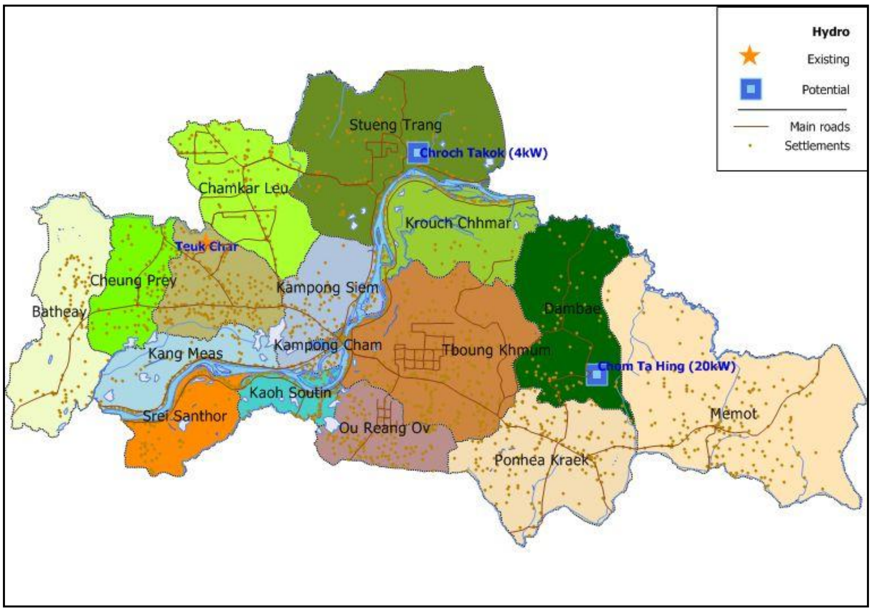


Figure 49: Hydro potentials

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

Table 13: Selected hydro potentials in Kampong Cham province

2/ Projects identification

To identify projects (1 locality or groups of localities) that could benefit from hydro and biomass potentials, the model looks for the closest Development Pole within a defined radius, specified by the planner. If no Development Pole is located within this radius, then the closest settlement is taken.

Diesel gensets will be the default option for all the Development Poles that will not have been allocated any option so far (grid or renewable energy based).

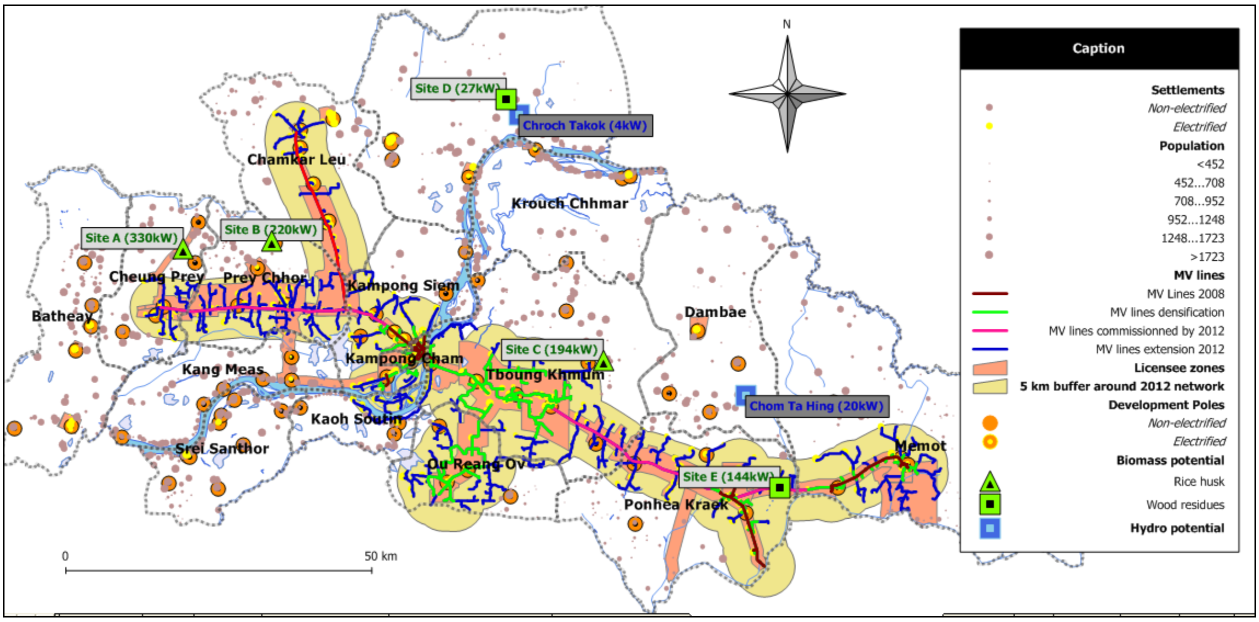


Figure 50: Development Poles & renewable energy sites location

3/ Main working hypothesis

- Running hours: 24 h (for both hydro and biomass options)
- Equipments investment cost: Biomass: 1 350 $/KW Hydro: 3 000 $/KW
- Distance limit between potential biomass site and cluster: 10 km (4 km for site D because of low capacity)
- Distance limit between potential hydro site and cluster: 2 km for 4kW site, 4 km for 20 kW site
- Possibility for diesel back-up
- To take into account seasonality factors, capacity of biomass units is at twice the average load, to take into account seasonality effect: there are only one or two crops a year; as a first approach as well, 1/3 of back up fuel is assumed.

3.5.3.2.3.5 Biomass projects

a) Isolated mode

Table 14: Biomass projects in isolated mode with possible diesel back-up

Site	A	B	C	D	E
District	Cheung Prey	Prey Chhor	Tboung Khmum	Stueng Trang	Stueng Trang
Type of residue	Rice husks	Rice husks	Rice husks	Offcuts	Offcuts
Installed capacity at the site	330 kW	220 kW	194 kW	27 kW	144 kW
Cluster settlements number	6	4	4	1	1
2009 Population covered	7 131	4 443	3 543	2 667	2 827
Energy from biomass (average on planning period)	59%	61%	63%	15%	61%
Total invest. (Years 1 & 2)	1 260 268	776 188	625 980	384 788	558 712

Total investment[40] over the planning period[41] US$ (excluding maintenance)	2 237 057	1 408 785	1 173 117	766 550	1 012 497
Fuel (dual fuel + back-up) cost over the planning period US$	2 135 974	1 238 237	932 395	1 754 442	771 652
% of total investment	***95%***	***88%***	***79%***	***229%***	***76%***
Levelized cost (US$/kWh) (residue cost: 7$/T)	0,35	0,34	0,34	0,44	0,37
Levelized cost (US$/kWh) (residue cost: 10$/T)	*0,35*	*0,35*	*0,35*	*0,44*	*0,37*

Investments for fuel (dual fuel + back-up) appear to be very high but if the sites were to be run without back-up, the demand of the connected localities would not be satisfied any more from year 4 in the best case.

b) Grid integrated mode

Another option would be to consider the connexion of these sites to the grid for net-metering, enabling both (i) to purchase missing energy from the grid or (ii) to inject excess energy produced by the biomass power plants into the grid. Substituting diesel back-up and eventually part of the dual fuel with the grid would be a relevant option to benefit from a more reliable and possibly cheapest energy in case of shortage.
Moreover, this approach would enable to exploit the local renewable energy potentials while offering possibility for the operator to get extra income if an attractive Power Purchase Agreement could be agreed by both parties.

Three scenarios have been considered, depending on the power purchase price from utility - 0,15 US$/kWh, 0,25 US$/kWh and 0,35 US$/kWh - summarized in the table next page.

Considering a residue cost of 7$/T, main conclusions are:

➔ In grid integrated mode, levelized costs are significantly more attractive than the ones got in isolated mode (except for site D, located too far from the grid, with a power purchase price of 0,35 US$/kWh); this is because all the energy produced is placed (excess from the villages' needs is placed on the grid)

➔ With a power purchase price from utility at 0,15 US$/kWh or 0,25 US$/kWh, purchasing part of the needed power from the grid appears to be more interesting than producing it from dual fuel. For all sites, more than 68% of the energy would be drawn from the grid;

➔ With a power purchase price from utility at 0,35 US, levelized costs are still more attractive than in isolated mode (investments and demand remain the same), but the quantity of energy drawn from the grid would be very low, only when the peak load of the clusters will be higher than the plant capacity; at this level, the cost of dual fuel is more attractive. Moreover, in this configuration, operation and maintenance costs would be multiplied by 4 or 5 compare to isolated mode, reaching over the planning period between 3,8 and 9 MUS$

➔ Over the planning period, all sites except site D could sell excess power to the grid (ranging from 9,2 to 20 GWh).

[40] Investments include Biomass generator, Back-up genset, MV & LV lines, Power house, Meters, Transformers
[41] Planning-period: 2009-2020

Site	A			B			C			D			E		
Power purchase price from utility (US$/kWh)[42]	**0,15**	**0,25**	**0,35**	**0,15**	**0,25**	**0,35**	**0,15**	**0,25**	**0,35**	**0,15**	**0,25**	**0,35**		**0,25**	**0,35**
Energy from grid*	70%	70%	8%	69%	69%	7%	68%	68%	5%	83%	83%	51%	69%	69%	6%
Energy from biomass*	30%	30%	30%	31%	31%	31%	32%	32%	32%	17%	17%	17%	31%	31%	31%
Energy from dual fuel*	0%	0%	62%	0%	0%	62%	0%	0%	63%	0%	0%	32%	0%	0%	63%
Injectable energy over the planning period (GWh)	20			13,9			12,5			0			9,2		
Total invest. (Years 1 & 2)	1 326 020			960 788			693 652			1 094 450			568 712		
Total investment over the planning period (US$) (excluding maintenance)	**1 863 834**			**1 310 979**			**1 002 060**			**1 167 785**			**801 756**		
Cost of power purchased from the grid (US$)	421 794	702 990	984 186	232 797	387 995	543 193	154 395	257 325	360 255	409 629	682 714	955 800	141 912	236 520	331 128
% of total investment	*23%*	*38%*	*53%*	*18%*	*30%*	*41%*	*15%*	*26%*	*36%*	*35%*	*58%*	*82%*	*18%*	*30%*	*41%*
Dual Fuel cost US$	0	0	**7 392 227**	0	0	**4 908 599**	0	0	**4 337 955**	0	0	**598 733**	0	0	**3 214 918**
% of total investment	*0%*	*0%*	*397%*	*0%*	*0%*	*374%*	*0%*	*0%*	*433%*	*0%*	*0%*	*51%*	*0%*	*0%*	*401%*
Levelized cost (US$/kWh)	**0,09**	**0,14**	**0,21**	**0,09**	**0,14**	**0,21**	**0,09**	**0,13**	**0,19**	**0,33**	**0,42**	**0,66**	**0,09**	**0,13**	**0,20**

Table 15: Biomass projects in grid-integrated mode

*average on the planning period

[42] Considering a constant price over the planning period

3.5.3.2.3.6 Hydro projects

a) Isolated mode

The table below provides a synthesis of the results obtained in isolated mode with possibility of diesel back-up in case of shortage.

Table 16: Hydro projects in isolated mode with possible diesel back-up

Site	**A**	**B**
Site name	Chroch Takok	Chom Ta Hing
District	Stueng Trang	Dambae
River name	Châmbâk Méas	Stoeng Thom
Power (kW)	4	20
Village(s)	Sre Sankai (1km)	Srâmâr (<1km)
Hydro projects key figures	**A**	**B**
Cluster settlements number	1	1
2009 Population covered	174	1 735
Energy from hydro (average on planning period)	68%	47%
Investment (Years 1 & 2)	111 760	275 698
Total investment[43] over the planning period US$ (excluding maintenance)	**142 561**	**405 765**
Fuel cost over the planning period US$	**54 307**	**681 971**
% of total investment	***38,1%***	***168,1%***
Levelized cost (US$/kWh)	**0,49**	**0,31**

In isolated mode, global investment (including maintenance) for site A would be 211 554 US$. Regarding the targeted population, this investment appear to be extremely high (1 216 US$/capita). This project is not conceivable.

Site B could appear to be a bit more attractive in terms of levelized cost of kWh (0,31 US$/kWh), but only 47% of the total energy consumed would be produced by the hydro power plant. The remaining part would be ensured by the diesel back-up, entailing a fuel cost over the planning period of 0,7 MUS$, meaning 168% of the technical investment. Moreover, given the fluctuant aspect of fuel price, and its incidence on the local environment, this configuration should not be retained.

For both sites, a configuration without back-up is not conceivable, peak demand of connected settlements being much more higher, even in first year of operation, than the rated capacity of the sites.

[43] Investments include SHP generator, Back-up genset, MV & LV lines, Power house, Meters, Transformers

Map displays

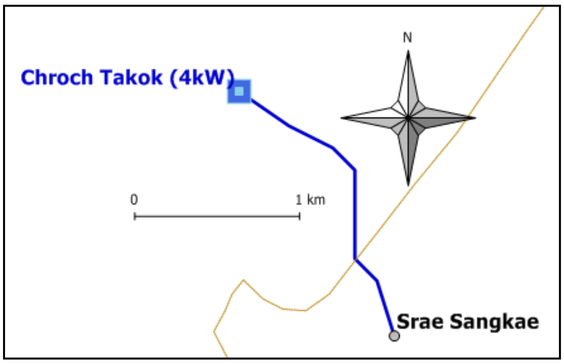


Figure 51: Hydro project from 4 kW site

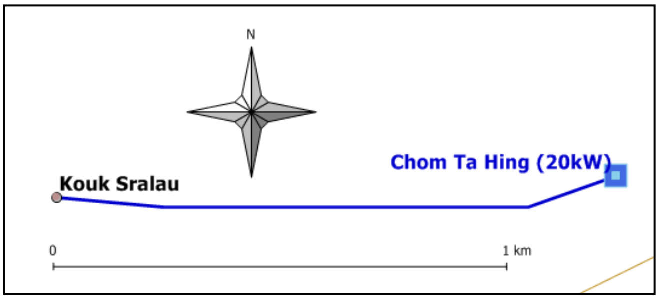


Figure 52: Hydro project from 20 kW site

b) Grid integrated mode

Table 17: Hydro projects in grid-integrated mode

Site	A			B		
Power purchase price from utility (US$/kWh)	**0,15**	**0,25**	**0,35**	**0,15**	**0,25**	**0,35**
Energy from grid	30%	30%	30%	50%	50%	50%
Energy from hydro	70%	70%	70%	50%	50%	50%
Injectable energy over the planning period (GWh)	0			0		
Total invest. (Years 1 & 2)	1 053 414			657 366		
Total investment over the planning period (US$) (excluding maintenance)	**1 055 414**			**677 766**		
Cost of power purchased from the grid (US$)	20 690	34 483	48 276	259 815	433 025	606 235
% of total investment	*2%*	*3%*	*5%*	*38%*	*64%*	*89%*
Levelized cost (US$/kWh)	**2,07**	**2,12**	**2,16**	**0,31**	**0,39**	**0,46**

Site A is located quite far from the grid planned for 2012. A connexion would entail very high investments (1,1 MUS$ over the planning period, out of which 94% would be spent for MV lines only) and a levelized cost of kWh absolutely unbearable by populations (above 2 US$/kWh), whatever would be the power purchase price from Utility. Site A can be definitely ruled out.

Conversely, it could be a relevant option for site B, particularly with a power purchase price at 0,15 US$/kWh. The levelized cost would be then the same than in isolated mode, for a global investment (investment + maintenance) 13% lower. Moreover, in this configuration, 50% of the energy consumed would be issued from hydropower plant, therefore a bit more than in isolated mode (47%).

3.5.3.2.3.7 Diesel projects

Out of the 90 Development Poles initially identified, 30 did not benefit from a grid-connection or a renewable energy based option. Electric clusters were therefore built on these remaining Poles to optimise their supply by diesel gensets.

As for renewable energy based projects, diesel projects built on Development Poles are optimised by connecting other localities to the identified project, until the kWh levelized cost stops decreasing. 29 projects were therefore identified (a project might contain several Poles).
220 additional localities could benefit from identified projects, with a levelized cost ranging from 0,45 to 0,51US$/kWh. Total population impacted would be 314 044 (2009 figure) for a total investment of 26,8 MUS$.

3.5.3.2.3.8 Scenario 2 synthesis

The Table below synthesises the scenario 3 results.

	Targeted villages	2009 Population	Village average size	Investment (MUS$)*
Network	520	465 885	896	36,7
Hydro**	1	1 735	1 735	0,7
Biomass	16	20 611	1 288	3,6
Diesel	250**	314 044	1 256	26,8
Total	**787**	**802 275**	**1 019**	**67,8**

* 2009-2012 investment for network; years 1 & 2 investment for hydro and biomass

** Considering only Site B (grid-connected mode)

***Out of which 30 Development Poles

55% of the currently non-electrified settlements would be targeted (787 out of 1 425), increasing the electrified settlements rate[44] from 23% to 68%.

	Population (2009 figures)	Electrified settlements rate
Total population	1 750 284	
Population covered as 2009	395 703	23%
Population targeted	802 275	46%
Total population covered	**1 197 978**	**68%**

[44] % of the province population leaving in electrified settlements

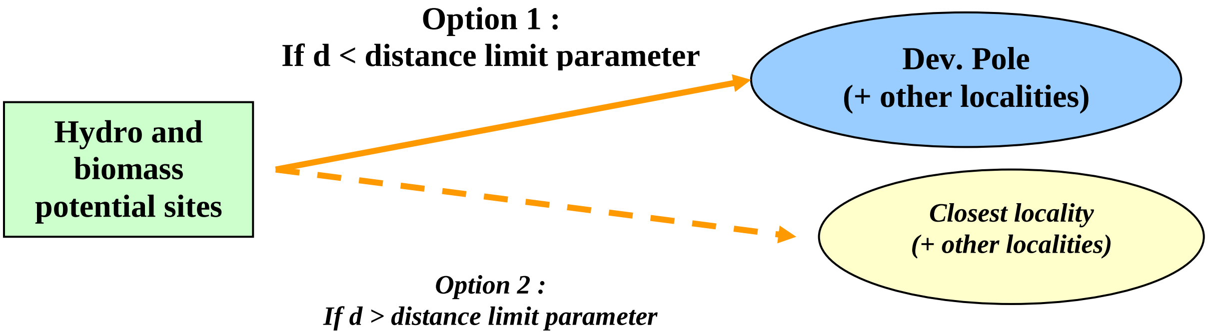
3.5.3.3 Khammuane province rural electrification plan

3.5.3.3.1 Rural electrification strategy

The approach adopted for Khammuane province clearly highlights authorities' willingness to promote renewable energy based options to supply electricity to remote localities or to those not covered by REP1. Emphasis was therefore put on local resources as biomass and hydro, diesel technology being therefore excluded from potential options; a decision consolidated by the constant increase of oil barrel[45].

The methodology presented so far was based on the identification of localities that would be given priority in case rural electrification programs would be conducted in the province. Although the notion of socio-economic impact optimisation still underlies the approach, this latter is slightly different here. Indeed, in Khammuane province case, special focus is made on renewable energy technologies. Therefore, the objective is not any more to specify a supply option for all the Development Poles, as Diesel technology is not considered, but to exploit potential sites that were identified to supply first Development Poles that are located in the vicinity of the sites, and then to optimise the project created by adding other localities. If no Development Pole was to be found close to the sites, the nearest village would be first connected.

Figure 53: Exploitation of hydro and biomass sites



3.5.3.3.2 Biomass and hydro potentials

5 hydro and 4 biomass projects were identified[46]:

Hydro 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"

[45] 136.97 US$/bbl as of 10th July 2008
[46] Cf. CAP REDEO Hydro & Biomass report

Table 18: Selected hydro potentials in Khammuane province

Biomass 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
Capacity(kW)	**99**	**67**	**19**	**32**

Table 19: Selected biomass potentials in Khammuane province

Given seasonality characteristics in the region, the sites have been sized at 1,5 times average capacity, with 75% availability of biomass over the year.

The map below displays identified sites location and their respective assessed capacity:

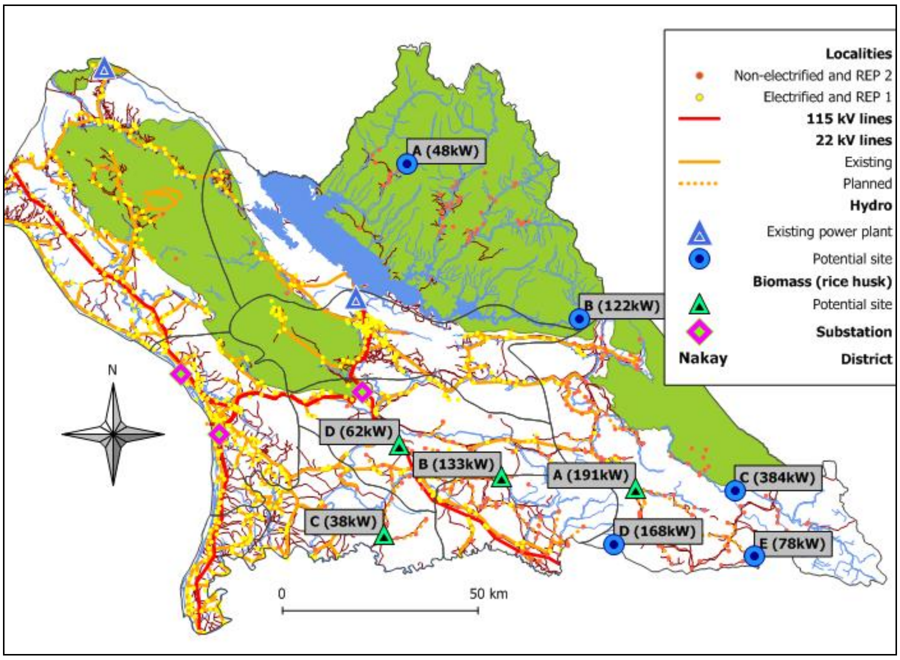


Figure 54: Hydro and Biomass potential sites

3.5.3.3.3 Projects identified

Results are presented in synthetic form. Detailed results are provided in Appendix.

3.5.3.3.3.1 Hydro projects

Site A (48 kW)

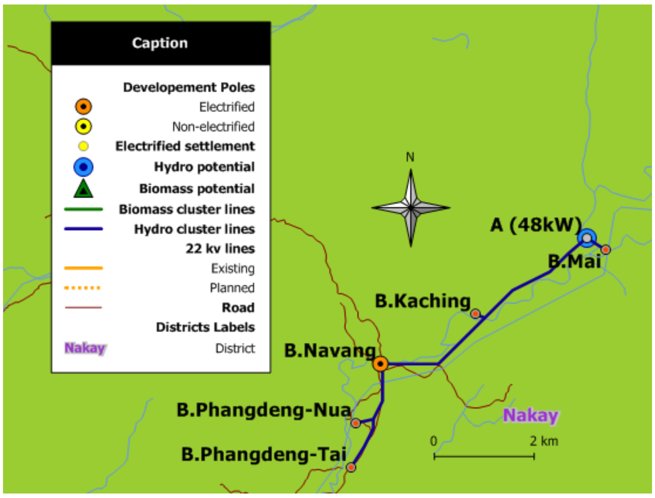


Figure 55: Cluster built from hydro site A

Levelized cost of kWh is almost the same in both isolated and grid-integrated configuration.

But depending on funds availability, connecting the cluster to the grid would enable to satisfy the 18% of the demand that the hydro power plant could not assume over the planning period.

<table>
<tr><td rowspan="5">Site A card
▪ Power: 48 kW
▪ Settlements: 5
▪ Population: 836
▪ Dev. Poles supplied: B.Navang</td><td>Mode</td><td>Isolated</td><td>Grid integrated</td></tr>
<tr><td>kWh levelized cost</td><td>0.26 $/kWh</td><td>0.24 $/kWh</td></tr>
<tr><td>MV lines length</td><td>8.4 km</td><td>36.9 km</td></tr>
<tr><td>Investment (year 1 & 2)</td><td>563 240 $</td><td>1 257 408 $</td></tr>
<tr><td>% of the demand not satisfied over the planning period</td><td>18%</td><td>0%</td></tr>
</table>

Site B (122 kW)

When looking at things on a rural electrification point of view, relevancy of exploiting site B could be discussed as villages that could benefit from it are located close to existing MV lines, and should be therefore connected to the grid in the foreseeable future. However, MV lines are ending in this region (Eastern part of the province), with high voltage losses, and low available capacity. Site B could represent an opportunity to partly offset MV lines voltage losses by injecting power into the grid (net-metering), with a levelized cost of kWh much more attractive (0.10 $/kWh compare to 0.24 $/kWh in isolated mode) .

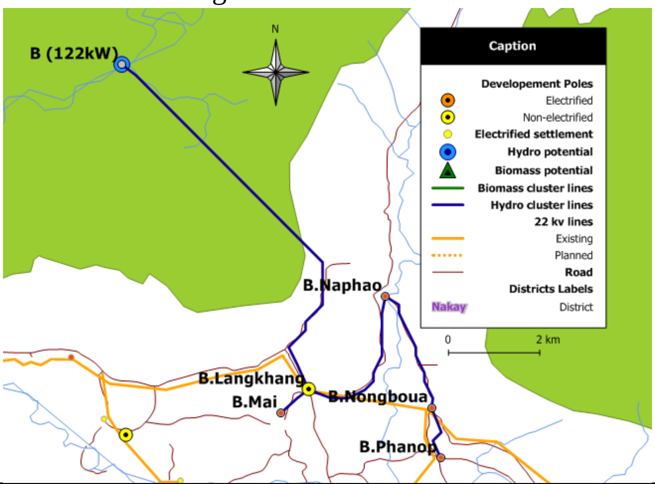


Figure 56: Cluster built from hydro site B

<table>
<tr><td rowspan="3">Site B card
▪ Power: 122 kW
▪ Settlements: 5
▪ Population: 1 774</td><td>Mode</td><td>Isolated</td><td>Grid integrated</td></tr>
<tr><td>kWh levelized cost</td><td>0.24 $/kWh</td><td>0.10 $/kWh</td></tr>
<tr><td>MV lines length</td><td>17.7 km</td><td>17.7 km *</td></tr>
</table>

▪ Dev. Poles supplied: none	Investment (year 1 & 2)	1 187 504 $	2 180 210 $
	% of the demand not satisfied over the planning period	16%	0%

* same value than in isolated mode since the cluster is crossing an existing or planned MV line

Site C (384 kW)

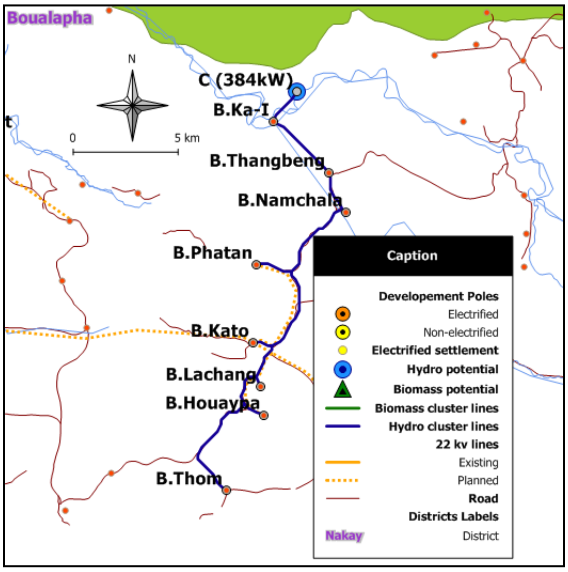


Figure 57: Cluster built from hydro site C

Site C should definitely be considered as an opportunity for net-metering. Required investment for grid-integrated configuration is almost exactly the same than in isolated mode (slightly increased because of the needed connexion protections), as the Cluster crosses a planned MV lines, with a levelized cost of kWh much more attractive. Moreover, the hydro power plant can satisfy the whole demand of targeted villages by the planning horizon, for which peak demand will not reach the estimated capacity by 2020, allowing to continuously inject power into the grid. As Site B, Site C is an opportunity to partly offset MV lines voltage losses in South-East of the province.

Site C card	***Mode***	**Isolated**	**Grid integrated**
▪ Power: 384 kW	kWh levelized cost	0.64 $/kWh	0.04 $/kWh
▪ Settlements: 8	MV lines length	29.5 km	29.5 km*
▪ Population: 1 014	Investment (year 1 & 2)	2 160 210 $	2 170 210 $
▪ Dev. Poles supplied: none	% of the demand not satisfied over the planning period	0%	0%

* same value than in isolated mode since the cluster is crossing an existing or planned MV line

Site E (78 kW)

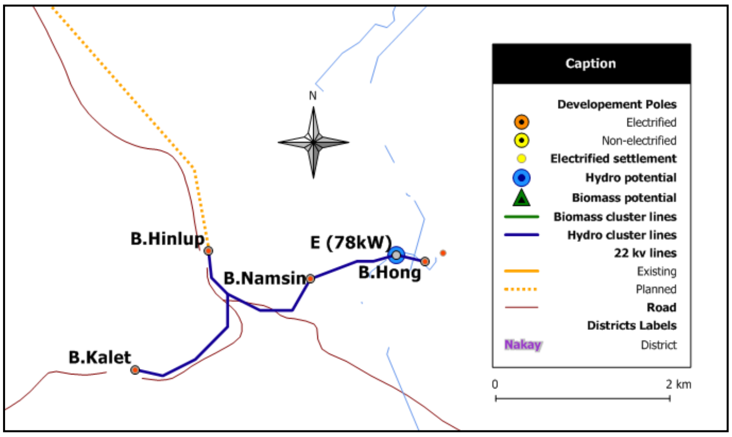


Figure 58: Cluster built from hydro site E

Same observations than for Site C can be made. Cluster built from Site E is in the vicinity of a planned MV lines and grid-integrated configuration should be considered (villages 100% demand would be satisfied by the power plant by 2020, with a capacity still above the peak demand at the end of the planning horizon).

Site E card	*Mode*	Isolated	Grid integrated
Site E card ▪ Power: 78 kW ▪ Settlements: 4 ▪ Population: 526 ▪ Dev. Poles supplied: none	kWh levelized cost	0.31 $/kWh	0.05 $/kWh
	MV lines length	4,8 km	4,9 km
	Investment (year 1 & 2)	494 714 $	506 144 $
	% of the demand not satisfied over the planning period	0%	0%

Site D (168 kW)

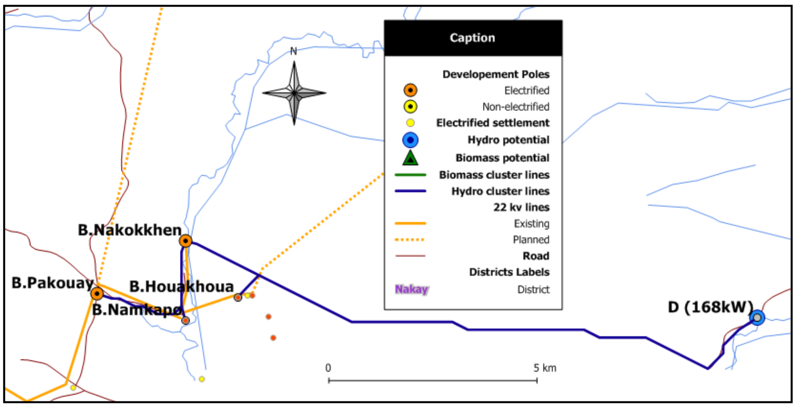


Figure 59: Cluster built from hydro site D

Site D should also be considered in gird-integrated configuration to both satisfy the 8% demand that the hydro power plant could not supply over the planning period and inject excess electricity into the grid when possible.

Site D card	*Mode*	Isolated	Grid integrated
Site D card ▪ Power: 168 kW ▪ Settlements: 4 ▪ Population: 1 864 ▪ Dev. Poles supplied: **B.Nakokkhen + B.Pakouay**	kWh levelized cost	0.25 $/kWh	0.08 $/kWh
	MV lines length	19,8 km	19,8 km*
	Investment (year 1 & 2)	1 384 834 $	1 394 834 $
	% of the demand not satisfied over the planning period	8%	0%

* same value than in isolated mode since the cluster is crossing an existing or planned MV line

3.5.3.3.3.2 Biomass projects

Results are presented in synthetic form. Detailed results are provided in Appendix.

Site A (191 kW)

Site A card	*Mode*	Isolated	Grid integrated
Site A card ▪ Power: 99 kW ▪ Settlements: 2 ▪ Population: 543 ▪ Dev. Poles supplied: none	kWh levelized cost	0,41 $/kWh	0,09 $/kWh
	MV lines length	0,9 km	0,9 km*
	Investment (year 1 & 2)	451 k$	461 k$
	% of the demand not satisfied over the planning period	%	%

Site B (133 kW)

Integrating the site to the grid would imply increasing the investment cost only by 10 000$, as the site is close to the main grid. However, as all energy produced could be placed on the grid, the levelised cost will be reduced to 0,11 $/kW.

Site B card
Isolated mode

- Power:67 kW
- kWh levelized cost: 0.36 $/kWh
- Settlements: 3
- Population: 625
- Investment (year 1 & 2): 459 k$ $
- Dev. Pole supplied: none

Site C (19 kW)

In the case of site C again, grid integration would only cost an additional 10 000$ with the advantage of reducing levelised cost to 23 cents / kWh, for the same reasons as above.

Site C card
Isolated mode

- Power: 19 kW
- kWh levelized cost: 0.32 $/kWh
- Settlements: 1
- Population: 658
- Investment (year 1 & 2): 285k $
- Dev. Pole supplied: 1

Site D (32 kW)

Integrating site D to the grid would increase the investment cost by 10 000$ with the advantage of reducing levelised cost to 23 cents / kWh, for the same reasons.

Site D card

- Power:32 kW
- kWh levelized cost: 0.36 $/kWh
- Settlements: 3
- Population:896
- Investment (year 1 & 2): 498 k $
- Dev. Pole supplied: 1

All the biomass projects identified are located close to planned MV lines. These potential sites could therefore be exploited as rural supply plants for the above listed villages until MV lines are commissioned. As for some hydro projects, net-metering would be then after a crucial issue to address to increase available capacity on the national grid or ensure energy back-up on for the biomass cluster.

3.5.3.3.4 What about remaining villages?

The identified projects would benefit to 48 villages, meaning that still 239 villages of the province remain without any supply solution.

Biomass settlements	**15**
Hydro settlements	**33**
Remote settlements	**239**

Table 20: Targeted and remote villages

PV technology is getting more and more widespread in Lao PDR[47] and could be an option for those

[47] For example, the Village Off-Grid Promotion and Support (VOPS) project has installed 3 750 Solar Home Systems (SHS) since March 2006. 5 750 additional systems are planned.

villages. However, beneficiaries issue must be addressed: should households or community infrastructures be targeted first? Should the available funds not be very high, priority could be given to community infrastructures in the perspective of offering access to modern social services to all the population, without geographic distinction.

3.5.3.4 Conclusion

Results presented in this report highlight a common view of both countries regarding electrification development:

(i) carry out grid extension, depending on available investments

(ii) priority to renewable resources in areas not targeted by the grid

In many cases, integrated mode appears to be the best option to take the most advantage of local resources while offering the possibility to inject excess electricity into the grid. This configuration will obviously require from local authorities to set up power purchase modalities, that should facilitate private operators emergence.

Data bases on which rely the results presented here should be updated regularly, necessitating from technicians trained on GEOSIM© use to launch new simulation to update also planning results. These technicians are now in a position to replicate the approach to other provinces of Cambodia and Lao PDR.

The results provide possible guidelines and tools for policy makers to make their decisions in terms of access to the grid for renewables, purchase tariffs, ...

4 Policy frameworks and recommendations

4.1 Targets and Policy Framework

4.1.1 Targets

The Lao PDR government has fixed a target of 90% households to be electrified by 2020, and 100% village electrification; the situation in 2008 is about 70% villages and about 65% households.

In Cambodia, the target set is for all villages to be connected by 2020 and 70% households by 2030. The situation in 2008 is 27% villages and 20% households.

In order to achieve these targets, sector organisation is being reviewed as well as tariff levels and framework conditions.

4.1.2 Sector organisation

In Laos, the State Utility, EDL had the monopoly for Generation, Transmission and Distribution. Today, there are more than 70 hydropower potential sites in the country,

including investors from France, who has already developed a largest hydropower plant in LAO PDR with a total installed capacity of 1,800 MW.
By 2020, out of total installed capacity of 18,000 MW, Laos will be exporting 7000 MW to Thailand and an additional 3000 MW to Vietnam and Cambodia. Electricity exports are the second revenue earner of the country.

Sector organisation is today undergoing clarifications:

- A new Electricity Construction and Installation Company has been separated from EDL with the same name but has main objective to stand and run the business by their own capacity.
- Regarding transmission system at this moment still in the EDL
- Regarding rural electrification, a Rural Electrification fund managed by MEM secretariat exists and its operating modalities are being clarified
- The modalities under which private sector investments in generation and distribution especially for mini grids for rural electrification and promoting access in remote areas are currently being formulated

In Cambodia, the sector is organised in a utility, EDC, which provides electricity, essentially fuel oil based to the capital city and to Provincial capitals. The transmission network which is currently being constructed will be managed EDC. A regulator, the EAC (Electricity Authority of Cambodia) has been set up which manages the licensing of EDC and some 500 private companies, which have either generation, transmission or distribution licenses, given for 2 to 10 years, depending on the quality of installations and management performance of the Rural Electrification Enterprise. Tariffs are also regulated by the EAC and depend on the costs of the REEs for generating electricity.
Further, an independent Rural Electrification Fund (REF) has been set up to provide financial support to the REEs. The objectives of REF for the initial years of operation are to:

1- provide grant to Rural electricity enterprises (REEs) for 50,000 new connections;
2- provide grant to firms for supplying 12,000 Solar Home Systems (SHS) for households in rural areas;
3- provide grant for development of 850kW of micro hydro; and
4- provide grant for development of 6 MW of mini hydro.

During the year 2007 and first half of 2008, good progress has been done for objective 1 stated above, whereas the progress for the other three objectives is not encouraging. Consequent to mid-term review by World Bank team during May 2008, there are proposals to revise the scope of the two objectives as follows:

1- Instead of providing grant assistance for SHS, REF will bulk purchase the SHS, and directly sell on credit to the rural household with the payback period of five year terms. The project will be managed and implemented through consultants/firms/REEs for related services;

Instead of providing grant assistance for development of generation project; (i) the REF may engage consultant to only do the feasibility study, which will facilitate the development of the project in the future or (ii) construct mini/micro hydro projects and lease out to a REE for operation with payback in installments.

4.1.3 Tariffs

In Lao PDR, there is still a single tariff system throughout the country, which is very much justified for the interconnected grid and given the low cost of large hydro power. Average tariff for domestic consumers in the lowest tranche (under 15kWh /month) works out to 2 cents / kWh.However, connection costs remain high: 80 to 100$ per households, which is a hindrance to achieving high connection rates.
Regarding village level systems (under 20kW) the tariff can be negotiated with local villagers. PPA levels practiced to date, essentially for hydro power, are 10 to 15 cents / kWh.

In Cambodia, there are cross subsidies only in Phnom Penh, where the domestic tariff is in the range of 15 cents / kWh. Outside Phnom Penh, as there is no cross subsidy and no other form of government investment support, tariffs have to reflect costs and are hence in the range of 1800 and up to 3800 Riels: 40 cents to close to a dollar, with generation being diesel / fuel oil or in some marginal cases, gas based.

4.2 Planning, framework measures and incentives

4.2.1 Planning

In both countries, planning of the backbone electrification of the country – high voltage transmission lines and large scale generation has been studied and a number of projects decided with funding under mobilisation and construction on going. Laos has secured funding for Northern and Southern Laos and by 2015 a North – South interconnected grid will exist. At the macro level, demand supply gap is widening due to growing demand in particular from the mining sector – bauxite and aluminium production. With the commissioning of Nam Theun 2 and Nam Nguen, the gap is expected to be bridged by 2012. Regarding Cambodia, the much awaited connections to Viet Nam are under construction which are a necessity to supply the backbone transmission line which will be the beginning of network expansion.

However, regarding access, i.e. achieving the goals described above, planning is still in the making and using a tool such as GEOSIM will be very useful:

- To assess the cost of achieving the global objectives set;
- To detail these objectives and costs on a provincial basis;
- To compare the supply options, and time frames under various scenarios;
- To take decisions as to which investments to prioritise and what kind of framework / support measures would be needed in order to possibly encourage private investments
-

4.2.2 Framework measures and incentives

- **Investment** support to private investors is currently not implemented in Lao PDR for rural electrification size investments – eg up to 20 MW. However, a different scheme for remote rural areas is currently being successfully implemented, which consists in undertaking the bulk purchase of thousands of SHS (15 000 will be achieved by end 2009) which are then “leased” to end users under a higher purchase scheme for 10 years; private operators are contracted to ensure maintenance and operation.
  In Cambodia, the REF had envisaged output based investment subsidies (45$ per new household connection, 100$ per SHS and % of hydro / biomass investment) but the output base (subsidy disbursed only upon commissioning) proved to be a barrier and REEs were not capable to produce business plans acceptable to REF, also mobilising bank financing. Hence, the REF is now considering to implement the bulk purchase

scheme as in Laos and to fund micro and mini power plants to be leased out to private operators. Detailed financing modalities remain to be worked out, in particular with the idea that leasing contracts should be terminated within 5 years and achieve reasonable levels of investment payback.

- **Fiscal** support measures need to be very actively considered, as experience worldwide – eg in India and in Europe, show that they have a very important leverage and high immediate impact on mobilising private investments – in particular for renewable energy investments which have high upfront investment costs. Hence it is recommended to actively look into this tool and in particular regarding renewable energy investments for rural electrification, which are the most sustainable options in the long term:
    - Wave import duties on renewable energy equipment and distribution equipment, which is 30 and 35% in the two countries, which is very high investment premium in the context of capacity to pay of the rural populations of these countries ;
    - VAT exemptions should also be considered ;
    - Tax incentives are currently not being considered : however regulations such as accelerated depreciation, reduced profit tax rates, deduction of a certain proportion of investment from taxes payable have proven to be very high impact measures for the development of renewables, with India for example now being one of the 3 top countries worldwide regarding wind turbine installations – along with Germany and Spain.

- **A stable and transparent framework for grid connection** must be speedily formulated and implemented in order to reassure private investors – be it for renewable energy investment for rural electrification or for rural electrification investments such as bulk purchase from the grid and MV lines + distribution to a cluster of villages. All countries where private – public partnerships have developed and where banks have engaged in such long term investments started with the implementation of such a framework:
    - Off take agreements have to be long term: at least 8 to 10 years, and if possible renewable;
    - Purchase tariffs have to allow for returns to the private investor in line with the risks they are asked to take; either a cost-plus formula, regulating the return investment or a minimum purchase tariff per kWh has to be formulated – the range of 8 to 12 cents for attractive hydro power sites is an international benchmark
    - Take off obligation from the utility for all renewable energy generation under a certain capacity is often very helpful
    - Experience shows that banks will not engage before a few such contracts are signed for Rural Electrification, unless guarantees are provided – the long term PPA and attractive business plan is a requirement, and starting first investments through a dedicated revolving fund can be an interesting option if properly managed.

5 Business opportunities & recommendations

Many surveys were held in Lao PDR and Cambodia to evaluate and identify business opportunities regarding the rural electrification sector. Governmental actors were also surveyed in order to get a full overview of the sector from both sides and understanding bottlenecks and issues to be resolved in order to improve the situation and facilitate private sector actors to make their own business.

5.1 LAO PDR

5.1.1 Perceived problems in implementation of the plans

5.1.1.1 Government

There are several bottlenecks identified in implementing these plans. The first relates to **human resource management issues** within government departments. The high turn-over of government staff often means knowledge or training is lost.

The Head of the Planning Division of EdL, mentioned that **capacity-building** is one issue of concern. For example, there is only one member of staff within each office that was trained by IED on the GIS software program. The four offices who received training were: PDEM, EDL Khammouane, EdL National, and RED. When the trained employee is absent, no one else in the office is able to operate the software.
The Director of the Rural Electrification Division found that **financial resources** are a main constraint for rural electrification development. He is convinced that in order to scale-up the access to rural electrification for the poor it is important to increase funding from international donors to support more projects. Nonetheless, the Director General of the Department of Electricity, Mr. Hatsady Sisoulath, viewed that the lack of information sharing and exchange amongst various actors is a main problem in energy sector.

5.1.1.1.1 Hydropower:

According to PDEM the financial or technical aspects are not really an issue, but the **interest of local investing companies** does constitute a concern. These hydro sites represent long term investments for those companies.
Large private companies will not be interested in this type of projects due to the small size of hydropower capacity and because of the long term return on investment. The PDIC commented that existing private investors that have engaged into the hydro power sector in Khammouane Province still do not see the benefit of this type of long term investment; unlike those involved in timber, hotel and guest house businesses. Furthermore, the sites are very remote and difficult to access, especially in the rainy season. With low incentives but high difficulties and risks in collecting fees from villagers, investors are unlikely to be interested in investment.
PDST thinks that construction of hydro power projects by private investors for selling electricity to villagers is not worth the investment. The reasons put forward for this reside in the difficulty in collecting fees and inaccessible locations as mentioned above. In addition, before any company will invest in these projects, they will have to study and estimate the expected economic benefits for doing so. They require a cost-benefit analysis and a feasibility study to be conducted, both of which are yet to be done. These studies should be

carried out by the project owner, i.e. by the CAP REDEO expert team. The member of PDIP staff interviewed added that the national private companies in Laos do not have financial and technical capacity to conduct such studies, but in general foreign investors do have these capacities. He further asserted that foreign investors are not currently as active due to the global economic crisis.

5.1.1.1.2 Biomass:

All governmental staff consulted did not agree with the idea of developing biomass gasification. They asserted that the main constraints are the **insufficiency of the feedstock and high transportation costs.** They raised the concern of unstable and short (seasonal) supply of the rice husk or saw dust. Rice husk would not only be used to generate electricity but is also used for agricultural and industrial purposes such as production of fertilizers and gypsum board, both of which are in high demand from local farmers and factories. Meanwhile the production of timber has decreased due to lower tree exploitation as a result of stronger legal restrictions on logging. Moreover, PDST reported that there is a Japanese company that invests in the province of Khammouane to process and compact charcoal from saw dust. They explained that the production of this product requires large amounts of saw dust. These additional uses of raw materials induce shortages of such material for the purpose of gasification.

Figure 60: Mr. Singkeo, Head of PST (left)

The distance between the location of the rice mills and the potential biomass plants is another issue. Rice mills are generally small and in scattered locations far away from the non-electrified rural areas. To date, rice mills in these areas are run by diesel generators and are even small, aiming only to serve the people living nearby. As a consequence, small amounts of rice husk are produced there. Rice mills with larger capacities are located in more urbanized areas. Still, these rice mills serve relatively small numbers of customers. In order to supply enough feedstock to the gasifier plant, that would possibly be located in a remote setting, costs of transportation would become a major concern. The small quantities of husk, in scattered locations, make the transportation costs high and impractical. PDEM reported that detailed economic cost analysis and feasibility for such biomass plans do not currently exist. Again, in order to attract investors, detailed feasibility studies would be highly required.

5.1.1.2 Private Companies

The private companies in Khammouane province are likely to encounter several bottlenecks if these plans are to come into practice. The first one relates to **financial capacity**. Most of the companies interviewed described themselves as young and small companies, unable to offer investment.

There are both formal and informal SMEs. One of the interviewed firms named *Khammouane Electronic Company,* which registered a capital investment of 210 million Kip (or

US$24,706), has installed a 0.4 kV line to three villages in two districts, Xaybuathong and Mahaxay.

Another interviewee was a representative agent of the VOPS project. This agent installs solar home systems (SHS) that are provided by VOPS to some villagers in Nakay District. This agent has not yet registered as a licensed company due to financial constraints. However he would like to get the registration license as electrical installation company, which should become possible after the completion of the current assignment for the VOPS project. He also mentioned that he will be able to manage to raise a capital investment registration of 21 million Kip (US$2,471).

Two companies, *Khamphat* and *Khammouane Electronic Company* explained that they do not have the financial capacity to build and supply electrical power to villages. What they can do is to participate in small assignments given by any winning bidders as sub-contractors. Their assignments would include surveys on the distance between houses and power site location as well as hydrologic and demographic surveys of the site, since low investment costs are involved. They have little capital to do so and their access to loans is limited as their assets cannot meet the loan criteria imposed by commercial banks. In this context, the only option for them is to take part in development projects as sub-contractor.

Another interviewed company, *Dongsay Company*, has a capital investment of 2 billion Kip (US$235,294) and provides various services such as construction of irrigation systems and buildings, installation of domestic electrical systems and of irrigation pumps, and a consulting services related to social, economic and environmental issues. Their director raised a similar issue that if they were involved in the implementation of these plans they would require financial support from either government or international private companies in the form of public subsidies and joint venture, respectively.

Besides this concern, another constraint is associated with the **affordability and willingness to pay of the electricity users.** The economic situation of the poor people who would be targeted to receive electricity is very low. Experiences in several parts of the country show that rural villagers would prefer to benefit from free projects and that they do not want to pay for electricity as they are poor, creating difficulties when it comes to collecting monthly fees. It was also commented that a large proportion of households who are connected to the national grid still face difficulties to pay their monthly bills. These off-grid projects might eventually cost more than expected to investors if end-users cannot or refuse to pay.

Mr. Vilath Sihamanivong, President of *Soksay Electrical Co. Ltd*, said that renewable energies offer an ideal method for helping the rural poor gain access to electricity. Although supplying electricity to the poor is a great idea, investing in building small dams and selling power on their own directly to villagers is not that easy because of the difficulties in collecting electricity fees from villagers. Building the dams and selling the power to the villagers through EdL is more viable. Mr. Sum, a Deputy Director of Sengsavang Construction & Electric Installation Co Ltd believes that a small hydropower project is easy to manage. The solar home system however is a small market and more difficult to manage in terms of operation and maintenance. Investors engaged in the rural electrification face high investment risks due to the **absence of specific regulation or legal framework.** The Provincial Council of Commerce recommended creating a Union of local companies in order to be able to compete with international companies. There are about 10 electrical construction and installation companies that joined together to form such a Union. Such Union's were found at both provincial and national levels, however not much cooperation has taken place so far especially at provincial level.

The Director of *Soksay Electrical Installation and Construction Co. Ltd* mentioned that access to financing or a bank loan is major problem when trying to submit bidding document for hydropower dam construction.
When submitting the tender documents, he was required to attach bank warranty to the principal. Previous experience let him down as he tried to gain access to bank loans or loans from Lao Business people in Germany. He complained further that the process of asset inspection and evaluation to be qualified for a loan by a bank was slow. He had to then try to join capital with his friend but there was still insufficient capital to meet the financial criteria set by the principal. He further commented that the policies of the government are good, however sometimes the implementation or the compliance to such policies is different. Things will be improved step by step.
On the contrary, *Sengsavang Construction & Electric Installation Co Ltd* had no difficulty mobilizing funding for their submission of a bidding proposal as they are financially capable to do so. Still, there is implicit concern about the payments made by a government organization, as a previous project on road construction received slow payment. Despite this, the company does not have a problem in financing.
In terms of technical aspects, Sengsavang Construction & Electric Installation Co Ltd is new to the hydropower sector, especially in terms of rural electrification, and has only educational qualification to do so. The interviewee is concerned that without a careful feasibility study there is a risk of water shortage and of his company running into debt. Furthermore, he added that his company does not have the capacity to prepare a Bill of Quantity, since it has never submitted bidding documents for a hydro project before, except for taking over a hydropower project in Xayabouly Province where the former bidding winner abandoned the contract. He is however willing to learn and build the capacity of his company if any NGO can offer support, especially concerning setting up a business model for rural electrification and its operation.

5.1.2 Recommendations to smoothen implementation

5.1.2.1 Government

5.1.2.1.1 Hydro:

In order to smooth the implementation, PDEM suggested inviting **all stakeholders**, including government and private electrical installation and construction companies from Vientiane Capital and Khammouane Province, to participate in a meeting/workshop to be organized by the CAP REDEO project team. This could be the place to continue the discussion on the implementation of the plans: what participants think about them, what information they require and to know if they are interested in these plans. This could be one of the ways to encourage SMEs to participate in the implementation of these plans. Another way could be to disseminate the plans through communication media such as radio messages and newspaper advertisements.
PDPI suggested that there are several ways to support the implementation of these plans. One of them is to **promote local and international partnerships or joint-venture**. This means that the private sector should cooperate with foreign investors to form joint venture companies. These could solve the financial constraints of the local companies and also encourage them to maintain the operations in the long term. Another way suggested could be to develop project proposals (to implement these plans) to be presented for funding to the government or international donor agencies. PDPI suggested that PDEM should then get the responsibility for presenting plans to the Department of Electricity (DoE) within the Ministry of Energy and Mines (MEM). It is actually DoE’s role to **apply for funding from**

international agencies such as the World Bank, the Asian Development Bank, other international donors or foreign countries' governments. The MEM then will have to cooperate with the Ministry of Planning and Investment to seek funds since most of international assistance funds demand going through this Ministry prior to the launching of any cooperation.

PDST highlighted that in order to attract more private investors to get involved in the Lao electricity sector other types of businesses like mining should also be looked at. The mining investment plan in Bualapha district is an ideal example of this, combining both mining investment and the construction of a hydro power dam. This hydro plant does not supply electricity exclusively for the mining but also provides nearby rural villages.

More generally, many departments identified the crucial need for **carrying out comprehensive detailed costs analysis, economic, social, and environmental impact assessment studies**. However, it is not clear who should be in charge of conducting these studies. Some participants suggested that PDEM should take responsibility while some others claim that this lies more with the CAP REDEO project team that initiated these plans. Some recommended that it should be the role of the private implementing companies themselves. Nonetheless, PDIP added that after these feasibility studies are formulated, the results should be presented and clarified to investors.

Meanwhile, PAFO claimed that they can facilitate the studies and construction works by issuing permission letters for the potential contractor and also provide technical staff to accompany the contractor to the site. PDST added that in the case that these plans are found feasible, the role of the government should be to facilitate the resettlement of the affected persons. The role of EDL would be to establish the electricity tariff and amount of subsidies.

5.1.2.1.2 Biomass:

In case the private investor does not have enough human resource capacity or technical knowledge to conduct the study and technical installations, a PDEM representative said that he could invite a local university expert to train them. Besides, PDIC also suggested that PDEM used to play an important role in coordinating the local authorities at provincial, district and village levels as well as with the project owner.

PDIP advised that PDEM should have a key role in providing technical support for both survey studies and construction works, whilst the PAFO could play a facilitation role in providing technical staff to accompany surveyors to the project sites, specifically where electrification projects are located inside the perimeter of a National Biodiversity Conservation Area (NBCA). This proposed role was confirmed by the PAFO representative. In addition, the PDIP identified important roles for PAFO in ascertaining the project locations, where the agricultural raw materials are produced, to supply to the gasifiers. PAFO also reminded the audience that statistical information can be provided to investors or concerned authorities who wish to obtain them.

5.1.2.2 Private Companies

To support implementation, government authorities have an important task in encouraging private companies' involvement in the rural electrification sector. Mr. Khamphanh, from the PSP Company, mentioned that his company will not be able to participate in the CAP REDEO plans, unless the government has a policy asking for decreased interest rates from banks to investors wishing to engage in any rural electrification business.

5.1.3 Requirements needed for successful implementation

Mr. Bounthanong Phonthipasa, Head of VOPS, explained that it is not difficult to find agents in the rural areas to promote and install SHS or pico-turbines. However the procurement process is very slow with lots of procedures, which limits the effectiveness of the project. All equipment needs to be ordered from the Vientiane office, and each time is subject to a request for finance according to WB procedures. Mr. Bounthanong thinks that he could operate more efficiently if he could act as a private actor able to make direct orders for the materials that include transportation (on site delivery) instead of going through all the bureaucratic procedures.
Mr. Hatsady (DoE) mentioned that another option could be for the DoE to take the lead in the second phase of the VOPS - WB REP project. This would notably facilitate the control and monitoring of the financial flows.
Regarding the GEOSIM tool developed by IED, Mr. Boungnong (EdL) argued that more people should be trained in GIS in order to solve the problem of the lack of staff that can operate the software. There should be more than one person at each level and office trained. Mr. Hatsady sees an opportunity to expand the training centre of EdL as a Renewable Energy Technology training centre in the near future.

The following suggestions were made to assure a successful implementation of rural electrification plans:

- Energy demand at the village level should be assessed first and then the local energy plan should be consolidated with the village and the provincial authorities;
- Electricity tariffs practised for off-grid projects should be the same as for the grid (700 kip/kWh). This will principally ease the acceptability of the project by the users and to enrol also the poorest;
- Government to facilitate the private sector in order to allow them to have to faster and better access to bank loans, so that they can develop energy projects on their own or for implementing tenders issued by either government or other international organisations/companies;
- In all cases, subsidies should be provided to support any rural electrification project happening in the Lao PDR;
- The local private companies cannot work independently but need to establish PPPs. The public partner should facilitate the access to financial resources for investment;
- Develop the legal framework in the country to support investment and to facilitate involvement of foreign and domestic private companies in the rural energy sector;
- Further capacity building on rural electrification planning, coordination and implementation by providing more specific and related training courses to more staff of related government departments private companies who need to be upgraded.

Based on the conducted interviews, three main requirements were identified to assure that these plans are implemented successfully, as detailed below.

- **Technical assistance**

The first requirement relates to technical assistance needs. Investors need to have a clear picture of the plans and scenario prior to taking any decision.

To manage this, detailed feasibility studies need to be carried out. These studies should include desk study, environmental and socio-economic baseline studies as well as a socio-economic assessment. These studies can be carried out by consultants hired by a project owner who may be a government or international organisation or private company.

Furthermore, mobilization of villagers is needed to enable them to understand the importance of the off-grid electricity services. Mobilization can be carried out by either government technical staff from PDEM or an experienced short term consultant hired by a project owner or local NGO. This is especially true regarding the biomass gasification projects since this has been a very new technology not yet known by both private entrepreneurs and villagers.

Once all feasibility studies and the mobilization of the villager's are completed the outcomes should be presented and explained to the potential private actors interested in involvement with the projects' implementation. It is suggested that results should include objectives, methodology for implementation, energy production and electricity power sales. Presentation of the results could be launched at a workshop to be held in Vientiane capital and/or Khammouane province.

- **Capacity-building**

The second requirement for the successful implementation of the project plans is to build the capacity of both the government and private companies who are interested in investing in biomass. Biomass technology is not yet well known. It was argued that a project owner, either government, international organisation or private company, should seek a technical expert to provide training to government staff that work in the energy sector and that are involved in supervising energy/electricity projects.

It is also crucial for private company employees to learn about this new technology including the construction, operation and maintenance techniques.

Besides this, the participation of the villagers or a technician, hired by the project owner, is also crucial for the maintenance of the equipment. This would require training on how to supply feedstock to the market and the training of a village technician to repair the gasifier system. A technician in the village or a technician hired by the project owner should be involved in the daily operation and maintenance to assure sustainability.

- **Access to financial resources**

The third factor to be considered is the access to financial resources. Some interviewees mentioned that the government needs to play an essential role as funding provider. When a plan exists to build a hydropower dam, PDEM submits their electricity plan to the national ministry (MEM/DoE) for approval and this ministry usually requests the necessary funds from the Ministry of Finance.

Another way to improve access to financial resources is for the government to present their plans, including detailed feasibility studies, to request a grant or soft loan from international organizations such as WB, ADB, the Japanese International Cooperation Agency (JICA) or other donors. The government could also act as warrantor for the private companies when they wish to apply for local bank loans.

Partial contribution from the government in term of subsidies is another solution. When an investor builds a dam and wants to sell power to villagers with a low tariff, subsidies from the government or international agency are required to allow private firms to gain a profit. ECI Enterprise mentioned that the government can take part in subsidizing half of the price of the electricity produced by private investors.

Private investors argued that to be able to invest government intervention is required to establish special low interest rates for loans dedicated to investments in rural electrification works, allowing more local businesses to participate in the sector.
In the meanwhile, PDEM said it could be a credit warrantor for private companies who wish to invest in this type of business.
However some are of the opinion that in order to enter the market and survive as electricity providers, a local company should seek joint-venture with an international firm that has extensive experience in this kind of business.
Moreover, access to micro finance schemes for the rural people in order to have access to electricity connection can also help to assure the viability of the electrification system.
All of these financial options are possible recommended solutions to increase the access to financial resources. However, the most practical approaches would be a combination of partial government funding, international financial assistance in terms of grant or low long term interest loans that provide financial assistance to the designated government body, like EdL, who would then assist a project owner through the provision of subsidies. The options of lowering interest rates and the provision of micro finance are far more complicated as influencing government financial policies would be a long process. For a joint venture, it is true that it can boost the financial capacity of a local company, but once again a large international company will not be interested in a small potential profit that is generated from a small business.

5.1.4 Overview of follow-up actions

During the provincial and national workshop, participants endorsed the following possible solutions and approaches:

- Conduct **detailed feasibility studies on renewable energy systems** by the project owner in association with consultants or NGOs where necessary:
  - *Objectives:*
    - ✓ Link policy to planning and implementation
    - ✓ Overcome lack of technical capacity for feasibility studies and impact assessments
    - ✓ Informal introduction of standards, and standard operating procedures
  - *Concept:*
    - ✓ A detailed site assessment carried out as on-the-job training for rural energy developers
    - ✓ Provide best practice examples as a template for developers to follow
  - *Dissemination:*
    - ✓ Direct participation of rural energy developers in preparation of feasibility studies
    - ✓ Disseminate the best practice examples, serving as a guide for future studies

- Provide **capacity-building and training** for staff within public and private organisations, on hydropower (pico- and micro) and on biomass gasification technologies, including technology knowledge, sustainable management and implementation schemes:

- *Objectives:*
  - ✓ Support self-sustainable development of RE sector on provincial level
  - ✓ Build technical capacity at the provincial level
  - ✓ Improve efficiency in RE through decentralisation
  - ✓ Raise understanding of RE requirements and opportunities
  - ✓ Improve access to resources, e.g. finance, by developing strong inter-linkages between stakeholders
- *Concept:*
  - ✓ Establish a platform for knowledge exchange at provincial level
  - ✓ Develop appropriate technology tools for RE sector decision makers and developers
- *Dissemination:*
  - ✓ Short class-room training course on technology assessment, operations and management
  - ✓ On-the-job training exercises for site assessment
  - ✓ Training in biomass gasification at existing demonstration facility in Vientiane

➢ In all cases, develop **Informed Choices** manuals on each potential renewable energy technology following an informed choices approach:

- *Objectives:*
  - ✓ Tackle information bottleneck in particular at the local level
  - ✓ Increase rate of access to energy by speeding up assessment and planning stages
  - ✓ Equip communities and small and medium enterprises (SMEs) to review their energy needs and local resources
  - ✓ Enable communities/SMEs to choose appropriate (affordable) energy solutions, and then know whom to contact
  - ✓ Short list of viable potential sites for private investors – saving time and money
- *Concept:*
  - ✓ Information document guiding end-users and stakeholders for decision making
  - ✓ Energy Demand-Based Approach
  - ✓ Consider energy use and not just electricity (e.g. lighting and cooking)
- *Dissemination:*
  - ✓ Extension service approach (like the NICE approach developed by the Lao Extension Agriculture Project - LEAP)

➢ **Provide more training to technicians of District Agriculture and Forestry Offices (DAFO)**

- *Objectives:*
  - ✓ Build capacity to identify sites with potential biomass resources

        - ✓ Raise awareness of improved uses of biomass (e.g. improved cook stoves)
    - *Concept:*
        - ✓ Train DAFO to understand biomass as an energy resource
        - ✓ Train DAFO to assess rural energy demand and available resources at the local level
        - ✓ Enable DAFO to advise villages and project developers on appropriate technologies to improve biomass utilisation
    - *Dissemination:*
        - ✓ Training of trainers approach: DAFO staff will become technical advisors for rural areas
        - ✓ Technical training on biomass energy technologies

- **Study on improving access to credit for the private sector and grants for government authorities**

    - *Objectives:*
        - ✓ Review current financing mechanisms
        - ✓ Formulate recommendations to enable access to credit, either through a new or existing funds
        - ✓ Improve capacity of government staff to raise funding to facilitate access to grants
    - *Concept:*
        - ✓ Study of current loan application process and economic situation
        - ✓ Produce a guide on applying for finance in rural energy
        - ✓ Evaluate the demand to introduce a new credit facility
        - ✓ Training on searching techniques to find grants calls and writing proposals
    - *Dissemination:*
        - ✓ Recommendations to government and sources of funds
        - ✓ Engagement with project developers

- **Develop integral small scale strategy planning research and studies:**

    - *Objectives:*
        - ✓ Improve local capacity to develop complete services packages for decentralised renewable energy (RE) technologies
        - ✓ Achieve greater information sharing through strengthening exchange of knowledge, information and data to better planning rural electrification and RE introduction activities
        - ✓ Raise public awareness of national efforts to increase access to energy for off-grid communities
    - *Concept:*
        - ✓ Develop awareness-raising tools for rural areas like informed choices manuals

- ✓ Detailed review of rural energy supply and demand in a sample area, with support of provincial level actors
- ✓ Develop operational models to implement RE projects at decentralised level, based on pilot sites or demonstration projects that integrate the technical options of the different technologies, natural resources availability within the target area including land use, local socio-economic context, financial conditions, local decision-makers, operators, end-users profiles involving local communities, possible assistance from national authorities

- *Dissemination:*
  - ✓ Targeted training activities
  - ✓ Awareness-raising materials for public distribution

5.2 CAMBODIA

5.2.1 Conclusions

Electrification rates in Cambodia are lagging far behind compared to those in Thailand, Laos and Vietnam and prices of electricity are much higher. Until a few years ago, not much was happening except for rural electrification plans such as the JICA Master Plan. Since the World Bank and ADB started supporting high voltage lines to Phnom Penh from Vietnam and to Siem Reap from Thailand, private investors have constructed high voltage lines connecting Battambang half way to the grid connection with Thailand and many medium voltage lines are constructed. The medium voltage lines are connecting the main district centers areas around Phnom Penh along the main roads and enable the connection of large numbers of households that before either had no electricity or expensive electricity from REEs; in doing so the price drops by half from around $0.70 to around $0.30 per kWh. This makes all kinds of productive uses and household industries more competitive with those in the city who only pay about $0.20 per kWh.
MIME has also developed a master plan for grid electrification and contracts are signed for the most important high voltage lines and large hydro and coal fired plants. EDC has developed a plan to connect 2.5 million households to its grid, including households currently connected by REEs, at an expected cost which seems much lower compared to the cost estimation in the JICA Master Plan.

Within this context the CAP-REDEO electrification planning project was a small contribution to electrification in the country and has resulted among others in capacity building of MIME, EDC and EAC staff. However none of them is planning to use the software tool as it is not their responsibility (MIME is responsible for planning the National Grid and EAC for licensing) and EDC, for whom the planning tool might be most appropriate, is using other GIS software with similar features such as load and investment optimization. EDC suggested that regional EDC offices and REEs would need training and perhaps appropriate software packages to plan grid extension and cost optimization at the local level. GEOSIM could be useful if local prices are used to help REEs select where to develop grid extension. A few single training modules would not be enough to make people use the software: long term commitment for support is needed as most REEs never used a computer. Training needs to optimize the current system are more urgent and could result in direct savings.

REEs and battery charging stations in particular are not yet making a lot of money and have difficulties in finding financial resources for extension and improvement. There is a high pressure now both from EAC and the local population to speed up grid connections, national and international investors are searching for electrification projects and small REEs have to make up their minds to either form larger networks with REEs in neighbouring zones or run the risk to be taken over by larger investors. EDC has not the intention to take over REEs, but EAC is developing stronger policies to create more efficient distribution and scaling-up of networks, demanding REEs to connect also more distant villages. EAC will have an extremely difficult job balancing between hundreds of REEs that need to make a small profit to remain in business and the hundreds of distributors that also demand a return on investment. With the extending grid and more private investors interested in the sector, their role will be more and more challenging and important.
Renewable energy, especially biomass electricity generation from rice husk, might have good prospects in Cambodia as the price of electricity which EDC has to pay to private IPPs and distributors is relatively high and EDC is interested and will develop a feed-in policy. This offers good opportunities for instance for rice mills with biomass gasification systems to run their mills during off-peak hours and provide peak electricity to the grid.
Even if the government target of „70% of all households by 2030" is reached, a few hundred thousand families will not be connected to the grid. For them, better quality battery charging, solar lanterns and solar home systems are probably the best options and systems need to be developed to provide equal investment support. Often millions of dollars are paid for grid extension but only a few millions for off-grid solutions: these should be balanced based on numbers of households. Lately consultants hired by the World Bank presented a Rural Electrification Strategy and Implementation Plan estimating the average grid connection cost over $500 per household. A solar company representative suggested that for that money you could give a solar home system for free and no more cost to pay for years to come". These alternative options should definitely be included in such strategies and implementation plans.

5.2.2 Recommandations

The recommendations are based on issues raised during the workshop and interviews and have been elaborated into suggestions for project activities to support rural electrification:

1. Technical training and investment support for REEs
Present capacities of REEs are still extremely low. The rapid development of the national grid puts a high pressure on REEs to prepare for grid connection. Without a good distribution network up to grid-standards, the REEs will not be able to connect to the National Grid and their license might not be extended. The REEs need to increase the efficiency, management, maintenance, safety, standards. At the same time REEs need to extend the coverage areas and need investment funds with reasonable finance and loan terms.
2. Electricity planning needs
GEOSIM training similar to the one developed for Kampong Cham is not the most optimum support and should be more integrated in existing planning processes and should take into account the level of skills of REEs and local government and utility agencies. EdC recommended that the GEOSIM software tool could be useful for REEs and local EdC offices that will not use the more advanced software of EdC. However such training efforts need long term commitment and follow-up support. Most REEs do not know how to use a computer or have only basic skills, so for most of them an advanced software planning tool is not appropriate.

3. Improve battery charging services
Battery charging stations have been widely neglected by donors and support agencies, despite the fact that they continue to provide electricity to most rural households. Support to battery charging stations to select appropriate generators and energy sources, optimize charging, recycle batteries, and safe treatment of acids could improve the now often precarious charging methods. Coaching and other business development support for these small entrepreneurs could improve their business performance as well as the services to the rural customers.
4. Solar home systems and solar lanterns business development
Several successful solar lantern schemes have been developed in Cambodia, but business development support and appropriate funding are required to launch larger scale production and distribution of the lanterns in Cambodia. In general, a variety of business models adapted to the local institutional context need to be developed to offer a variety of solar products and services in line with the needs of the rural customers.
5. Feasibility study of decentralized renewable energy electricity generation
Implementation of a study to analyze the feasibility of feed-in based on local renewable energy resources and study on the availability and present utilization of biomass resources in the country. The economic benefits of mini-grids using biomass gasification could be increased if connected to the National Grid. The existing decentralized systems are only running for a few hours a day and the actual capacity used is only approximately 10%. The National Grid could also benefit and become more stable by several local feed-in plants. The opportunity in Cambodia is very high as production and transport costs of electricity are already high and subsidies in the form of special feed-in tariffs such as in Thailand are not needed.

6 Conclusion

The new approach of rural electrification developed in this report and implemented through the GEOSIM software was very successful to respond the rural electricity planning issues in Lao PDR and Cambodia. Its full deployment inside national institutions could be very useful for those institutions to start developing a concerted and optimized approach of rural electrification.
The presented results as presented above highly interested planners and decision makers to build a real knowledge in RE planning using an official tool now approved by ACE (ASEAN Centre for Energy) and tested for 2 pilots provinces.
However, it remains some important structural issues to consider for a more sustainable development in the future. Teams turnover and lack of availability are still, too often responsible for a knowledge loss among trained institutions in a long term and this issue can be resolved only by providing additional trainings and regular support while institutions are preparing some RE plans themselves. A stable and trained planning service equipped with GIS capabilities can prove to be more effective.

All deliverables are available on the project website and can be downloaded freely on www.cap-redeo.com

All stakeholders were quite satisfied with the presented results and the whole majority expressed the will to extend the experience to the whole country for others provinces.
A project may even start in February 2010 in Cambodia supported by French Ministry of Economy, Industry and Labour (DGTPE) to extend Rural Electrification planning to the whole country (a.k.a. SREP project - www.srep-cambodia.org).