REDEO
RURAL ELECTRIFICATION
DECENTRALIZED ENERGY OPTIONS

EC-ASEAN Energy Facility
Project Number 24

# REPORT FOR ACTIVITY 4

# APPLICATION OF THE REDEO TOOL TO THE OUDOMXAY PROVINCE IN LAO PDR

JULY 2005

## Disclaimer

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# 1 OBJECTIVES OF THE REDEO TOOL FOR OUDOMXAY PROVINCE

- The objective of this case study is neither to provide a definitive masterplan for rural electrification nor to define projects that should be implemented or cancelled. It is only to gather in a same study indicators on potential projects. The systematic approach of REDEO permit to consider all options: thermal or renewable, centralized or decentralized… But more analysis on more data would be necessary to build a true electrification masterplan.
- According to EdL Power Development Plan (PDP) 2004-13, the objectives for rural electrification in Oudomxay Province are as follows:

| | 2003 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| localities | 687 | 687 | 687 | 687 | 687 |
| ectrified villag | 49 | 53 | 129 | 174 | 249 |
| es electrificati | 7% | 8% | 19% | 25% | 36% |
| HH | 40080 | 43036 | 47982 | 52976 | 57919 |
| electrified HH | 4012 | 5490 | 16013 | 21179 | 32824 |
| electrification | 10% | 13% | 33% | 40% | 57% |

**Table 1: RE objectives for Oudomxay Province**

- The case study focuses on these objectives and gives a project implementation proposition in three phases: 2005-10, 2010-15 and 2015-20. For each phase, the tool gives:
    - The investment cost
    - The life-cycle cost of kWh
    - The number of people supplied
    - Indicators on environment and development
- The second output aims at giving a schedule for this objective. The user can choose one project, REDEO tool gives the corresponding costs and the number of households electrified.

NOTE: Considering the importance of hydropower in Oudomxay Province, seasonality has to be taken into account. For each project with hydro plants, the tool will precise the number of households supplied in wet and dry season.

# 2 CLUSTERING

## 2.1 Objective of the module

The REDEO approach is to contribute to sustainable development by providing electricity in the zones where it is the most needed and the most relevant. Thanks to several indicators such as population, education and health facilities, employment and road access, the tool compute a so-called "Index of Potential for Development" (IPD) for each locality. According to this Potential of Development and to other criteria defined by the user (administrative situation, minimal size of population), the tool defines the Centers with High Potential for Development (CHPD).

All the other localities (OL, meaning "not CHPD") situated in the neighborhood of a CHPD are clustered with it. The notion of "neighborhood" is defined as follows: each OL is clustered with the nearest CHPD, if the distance is inferior to a maximal distance given as input by the user. Then a cluster of villages is considered as a point. The tool works at the cluster scale.

Classic electrification scenarios focus on the most profitable areas or only follow main roads. This way is likely to increase the gap between developed and less developed or remote localities. The definition of CHPDs is a way for the user to define differently the target areas. In the "electrification scenarios" module, this study aims at supplying all the clusters defined by the CHPDs. The selection process of CHPDs is thus a way to reach land use planning objectives.

## 2.2 Definition of CHPDs

The Index for Potential for Development (IPD), is based on the Human Development Index (HDI).

The human Development index is composed by three indicators:

- One health indicator: life expectancy
- One education indicator: composed by literacy rate and rate of children going to school
- One economical indicator: GIP per inhabitant.

For each of these three indicators, a number between 0 and 1 is given, such the repartition of the values taken by each country is correct and occupied the whole interval. For example for the life expectancy a country gets 1 if its life expectancy is 85 years, it gets 0 if it is 25 years. For GIP per inhabitant, it gets 1 if log(GIP/inh)=log(40000) and it gets 0 when log(GIP/inh)=log(100) with a logarithmic scale (in order to have a good repartition).

Then the HDI of a country is the arithmetical average of these three index.

We adapted this indicator to available data for Oudomxay Province. In REDEO tool in general, the user have the possibility to accept predefined criteria for PDI or to define himself an indicator based on available data.

The IPD used for this case study is based on the following data:

| Health infrastructure | index | nb of localities | coeff |
|---|---|---|---|
| Health Center | 1 | 9 | 1 |
| nothing | 0 | 637 | |

| Education infrastrucure | index | nb of localities | coeff |
|---|---|---|---|
| Secondary school | 1 | 15 | 1 |
| Primary school | 0,6 | 360 | |
| nothing | 0 | 271 | |

| Accessibility index | index | nb of localities | coeff |
|---|---|---|---|
| Main Road | 1 | 112 | 0,5 |
| Secondary Road | 0,6 | 106 | |
| Other | 0 | 428 | |

| Economical index | index | nb of localities | coeff |
|---|---|---|---|
| big industry (>100emp) | +0,4 | | 1 |
| medium industry (>10emp) | +0,3 | | |
| small industry (>1emp) | +0,2 | | |
| Other | 0 | | |

| Administrative status | index | nb of localities | coeff |
|---|---|---|---|
| Provincial Office | 1 | 1 | 1 |
| District Office | 0,8 | 6 | |
| Village Office | 0,3 | 484 | |
| Nothing | 0 | 155 | |

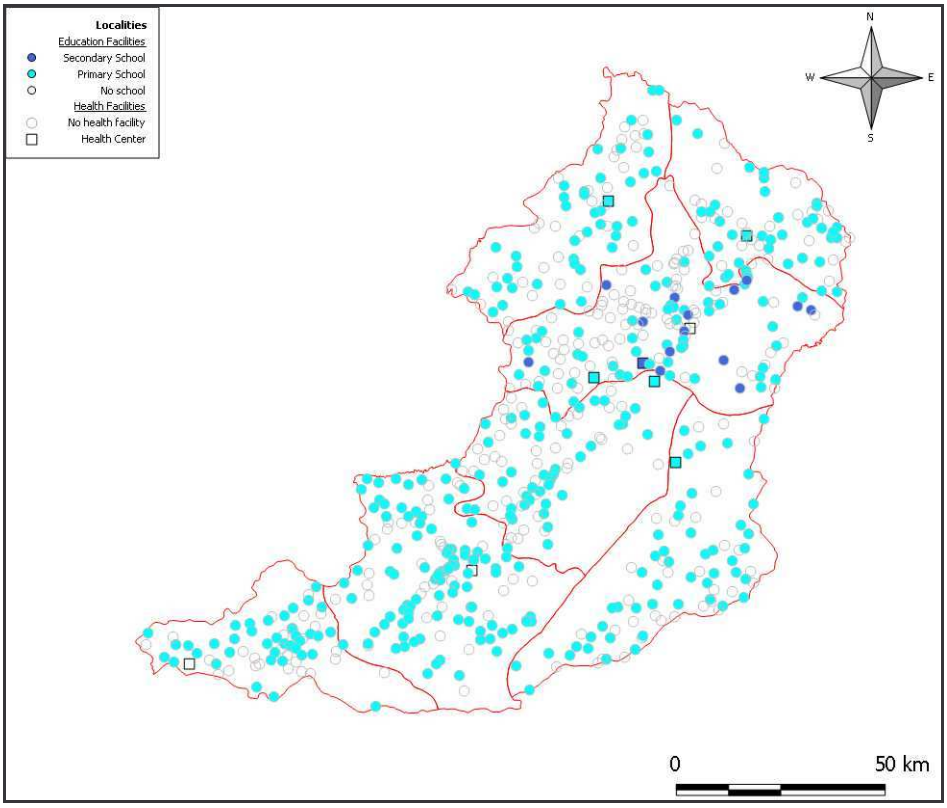
We found important to take the access conditions to the locality into account, as it is an economical factor of development and as electrification and maintenance of a system are easier to do in a reachable locality.

Then the PDI is computed as the arithmetical average of these four indicators. Of course, it is possible for the user to choose other indicators such as:

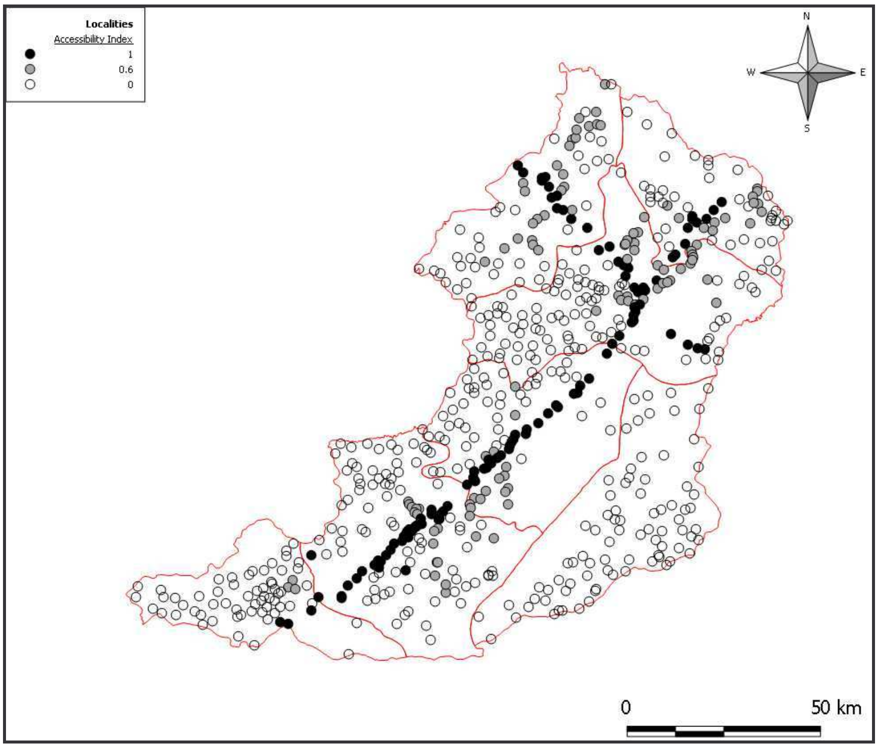
- administrative status
- population
- Presence of an electricity service company…

After having computed PDI, the tool gives to the 132 localities with highest PDI the status of CHPD. 132 is such as 10% of localities are CHPD. Then each other locality (OL) is linked to the nearest CHPD, if it is closer than a cut-off distance : 5 km.

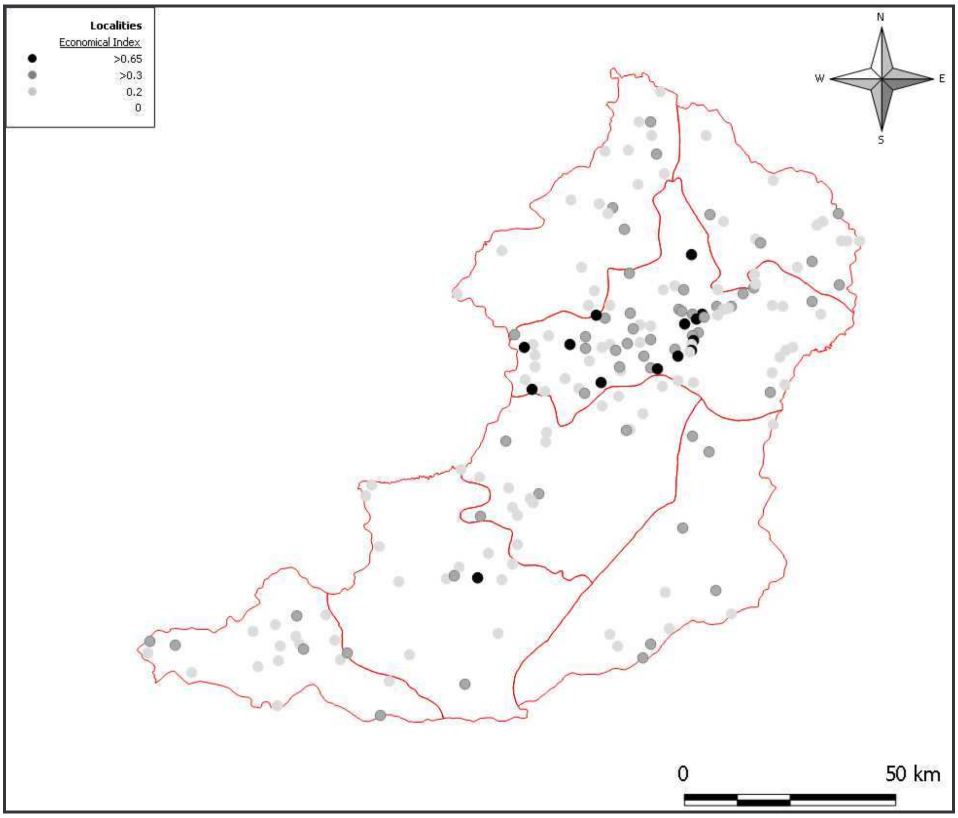
## 2.3 Geographical repartition of IPD's index



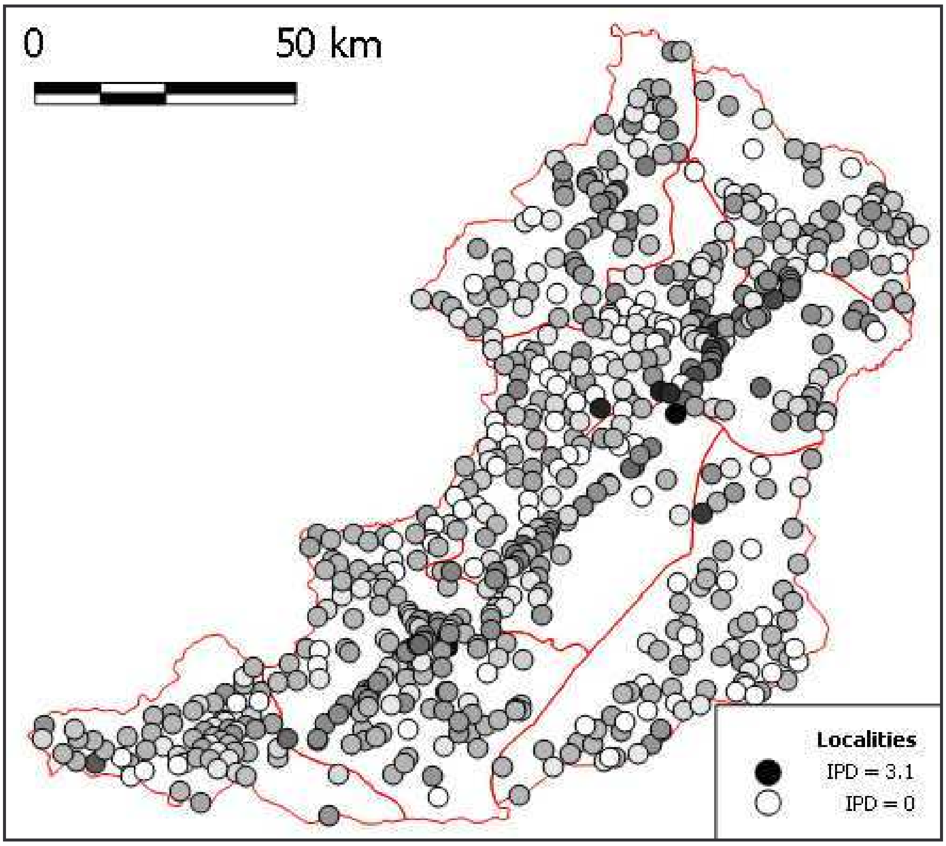

**Map 1: Health and educational infrastructures**




**Map 2: Accessibility index**




**Map 3: Economical index**




**Map 4: Potential for Development Index map**

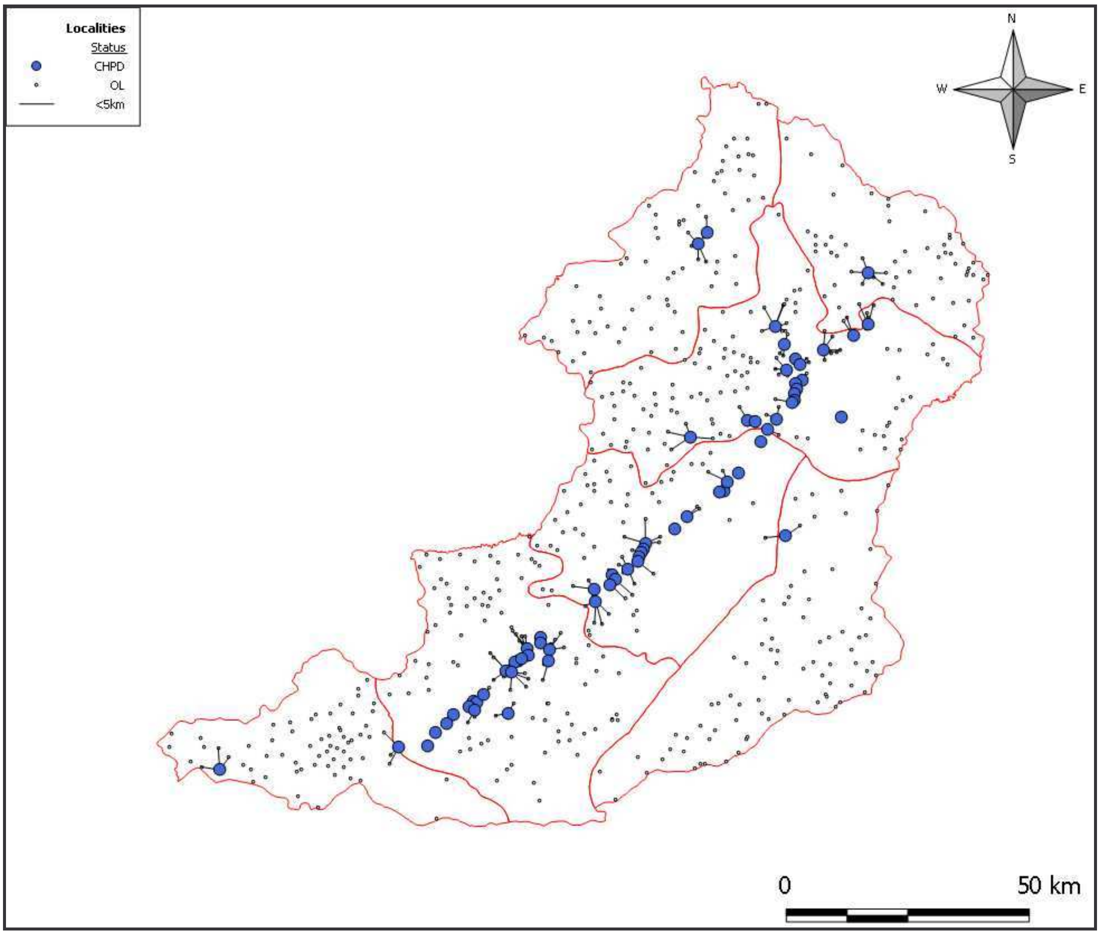
**Repartition of IPD**

A : number of localities with this IPD
B : number of localities with IPD equal or higher
C : corresponding percentage

| IPD | A | B | C |
|---|---|---|---|
| 3,1 | 2 | 2 | 0% |
| 2,9 | 1 | 3 | 0% |
| 2,7 | 2 | 5 | 1% |
| 2,6 | 1 | 6 | 1% |
| 2,5 | 1 | 7 | 1% |
| 2,4 | 1 | 8 | 1% |
| 2,3 | 1 | 9 | 1% |
| 2,2 | 5 | 14 | 2% |
| 2,1 | 0 | 14 | 2% |
| 2 | 1 | 15 | 2% |
| 1,9 | 1 | 16 | 2% |
| 1,8 | 10 | 26 | 4% |
| 1,7 | 1 | 27 | 4% |
| 1,6 | 12 | 39 | 6% |
| 1,5 | 5 | 44 | 7% |
| 1,4 | 64 | 108 | 17% |
| 1,3 | 21 | 129 | 20% |
| 1,2 | 40 | 169 | 26% |
| 1,1 | 52 | 221 | 34% |
| 1 | 7 | 228 | 35% |
| 0,9 | 165 | 393 | 61% |
| 0,8 | 14 | 407 | 63% |
| 0,7 | 7 | 414 | 64% |
| 0,6 | 16 | 430 | 67% |
| 0,5 | 40 | 470 | 73% |
| 0,4 | 8 | 478 | 74% |
| 0,3 | 78 | 556 | 86% |
| 0,2 | 2 | 558 | 86% |
| 0,1 | 0 | 558 | 86% |
| 0 | 88 | 646 | 100% |

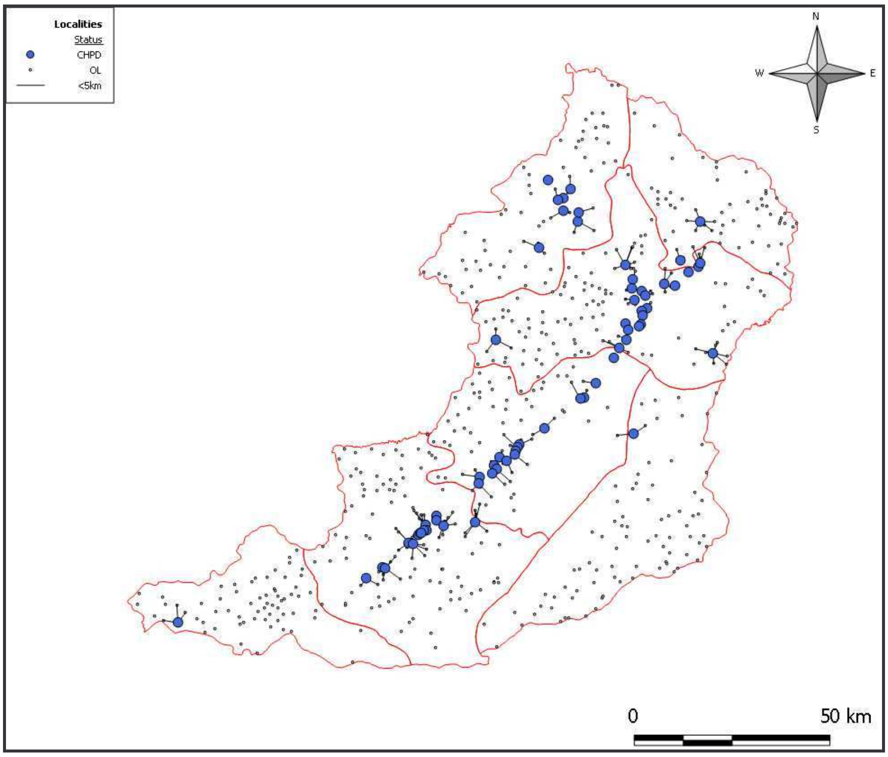
- The last map, showing IPD for each localities, tells that localities with highest IPD are mainly situated on the main road of the province.
- When we look at the table giving IPD for each locality, we remark that IPD don't take continuous values and a lot of localities have the same IPD. For example, localities located on a big road, having a primary school, no health facilities, a village office and no industry are numerous and they all get the same IPD : 1.4.
- If we choose to select 10% of localities as CHPDs, a choice has to be done between all localities with the same IPD.

## 2.4 Results

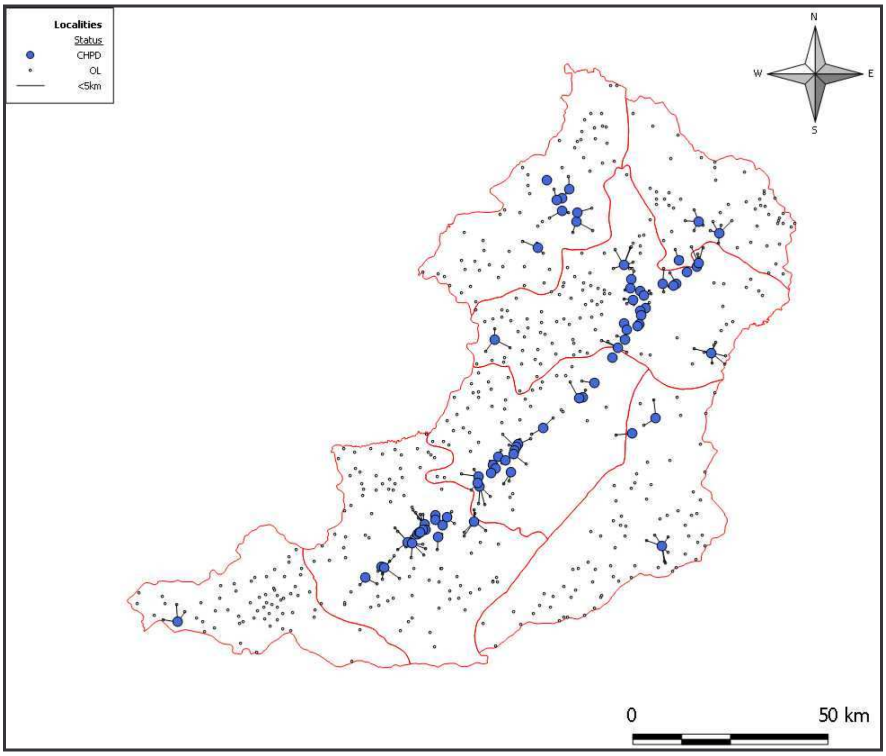



**Map 5: First clustering**

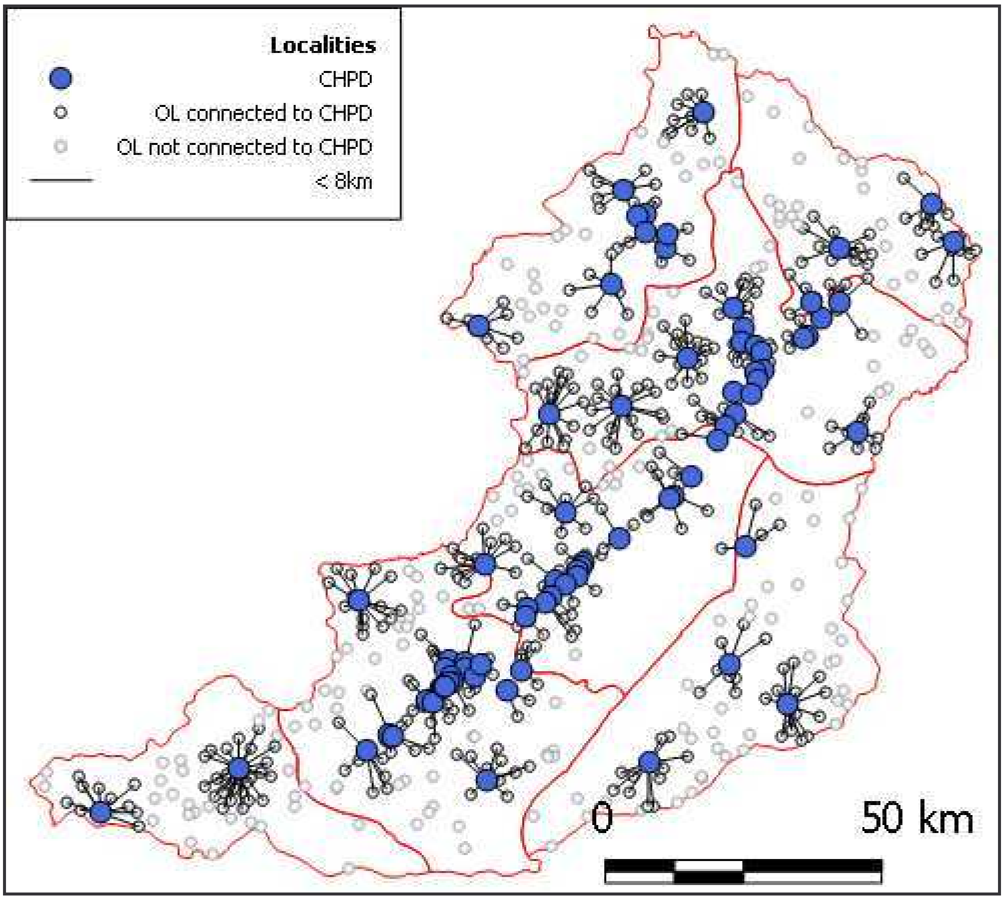
- The upper map shows the result of a “raw” clustering: 10% of localities with highest IPD have been selected as CHPDs. Then all localities situated at atleast 5 km from a CHPD are clustered. Among localities having an IPD of 1.4, at the boundary between CHPDs and other localities, the most populated were selected.
- This clustering is not very satisfying because it covers a small part of the Province and concerns few people.
- To improve this clustering, we determine cut-off such as only localities with at least 200 inhabitants can be CHPDs. The results are as follows:




**Map 6: clustering with cut-off on population : 200 inhabitants**




**Map 7: clustering with cut-off on population : 300 inhabitants**




**Map 8: Final clustering for Oudomxay Province**

- As political objective is to reach an electrification rate of 57% by year 2020, we added localities in isolated areas in our CHPDs set. Furthermore this is better in a land-use planning perspective.
- Some details on the population concerned by this clustering are given in next part.

# 3 LOAD FORECAST

## 3.1 Model and inputs

The model is relatively simple. As said in introduction, the aim of this case study is not to manage a precise analysis of future demand to dimension systems but to obtain figures that corresponds to existing forecasts to make a global analysis.

As no economical analysis is done, we do not focus on tariffs. Our economical indicators are investment costs and life-cycle kWh costs. So only the global values of energy demand are interesting for this study. Consequently, there is no need to build a model based on precise categories of customers.

Furthermore the more a model is complex and supposed to approach reality, the more each parameter has to be carefully studied. We use average values for energy consumption at the locality scale. Thus, as coefficient are rather few, this is easy for the user to adapt them in order to obtain the same results than deeper studies.

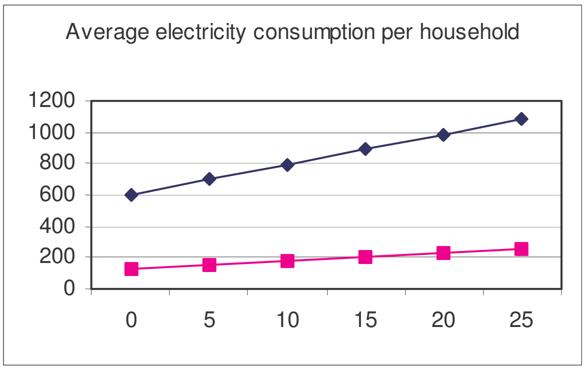
Concerning residential energy consumption, our model is based on average values. Only two categories are considered : people in CHPDs or in OLs. The inputs are presented in next paragraph. Concerning non-residential energy consumption, health and education infrastructures are taken into account. In addition to that, a default value is given for public energy consumption in each locality in function of its status (CHPD/OL).

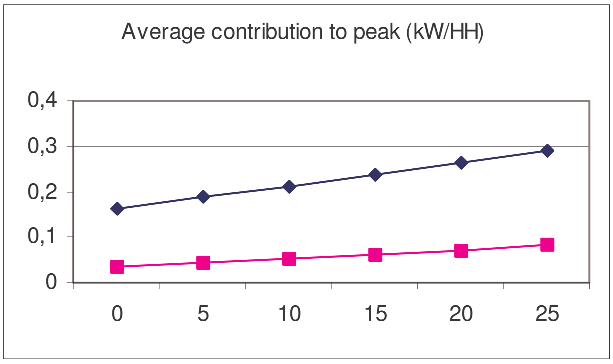
### 3.1.1 Residential and small shops load forecast

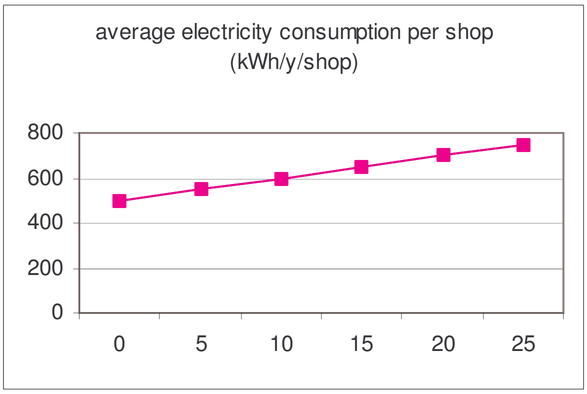
The parameters used for load forecast in Oudomxay Province are as follows:

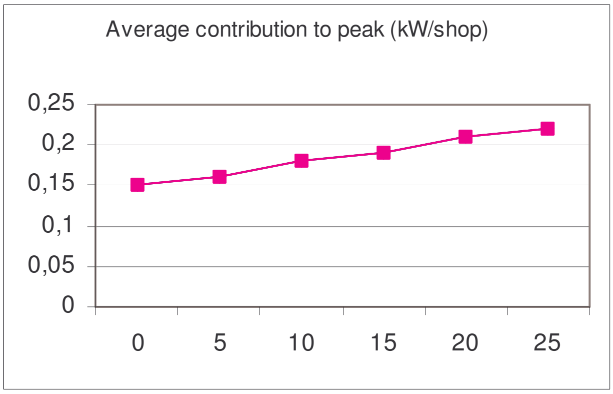
| | Parameter | Unit | CHPD | OL |
|---|---|---|---|---|
| residential | Average electricity consumption by household - year 00 | kWh/year/household | 603 | 130 |
| | Average electricity consumption by household - year 05 | kWh/year/household | 699 | 150 |
| | Average electricity consumption by household - year 10 | kWh/year/household | 795 | 175 |
| | Average electricity consumption by household - year 15 | kWh/year/household | 891 | 200 |
| | Average electricity consumption by household - year 20 | kWh/year/household | 987 | 225 |
| | Average electricity consumption by household - year 25 | kWh/year/household | 1083 | 250 |
| | Average contribution to peak demand - year 00 | kW/household | 0,161 | 0,036 |
| | Average contribution to peak demand - year 05 | kW/household | 0,187 | 0,042 |
| | Average contribution to peak demand - year 10 | kW/household | 0,213 | 0,052 |
| | Average contribution to peak demand - year 15 | kW/household | 0,239 | 0,062 |
| | Average contribution to peak demand - year 20 | kW/household | 0,265 | 0,072 |
| | Average contribution to peak demand - year 25 | kW/household | 0,291 | 0,082 |
| | penetration rate - year 00 | % | 40% | 30% |
| | penetration rate - year 05 | % | 55% | 40% |
| | penetration rate - year 10 | % | 70% | 50% |
| | penetration rate - year 15 | % | 80% | 55% |
| | penetration rate - year 20 | % | 85% | 60% |
| | penetration rate - year 25 | % | 90% | 65% |
| | Population growth rate | % | 3,00% | 2,00% |
| small shops | Average electricity consumption by shop - year 00 | kWh/year/shop | 500 | 500 |
| | Average electricity consumption by shop - year 05 | kWh/year/shop | 550 | 550 |
| | Average electricity consumption by shop - year 10 | kWh/year/shop | 600 | 600 |
| | Average electricity consumption by shop - year 15 | kWh/year/shop | 650 | 650 |
| | Average electricity consumption by shop - year 20 | kWh/year/shop | 700 | 700 |
| | Average electricity consumption by shop - year 25 | kWh/year/shop | 750 | 750 |
| | Average contribution to peak demand - year 00 | kW/shop | 0,15 | 0,15 |
| | Average contribution to peak demand - year 05 | kW/shop | 0,16 | 0,16 |
| | Average contribution to peak demand - year 10 | kW/shop | 0,18 | 0,18 |
| | Average contribution to peak demand - year 15 | kW/shop | 0,19 | 0,19 |
| | Average contribution to peak demand - year 20 | kW/shop | 0,21 | 0,21 |
| | Average contribution to peak demand - year 25 | kW/shop | 0,22 | 0,22 |
| | Average number of small shops by 100 inhabitants | shops/100 inh | 1 | 0,5 |
| | penetration rate for shops | % | 80% | 80% |

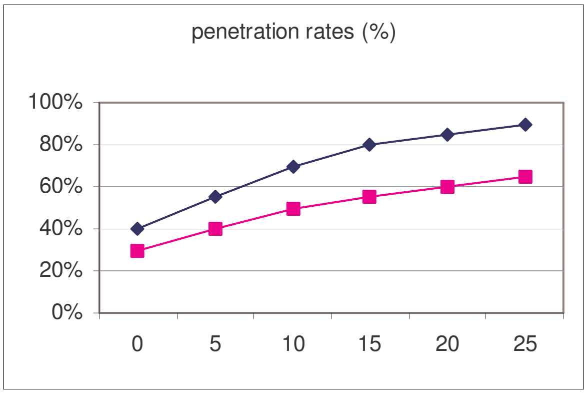
**Table 2: Parameters used for residential load forecast and their values**

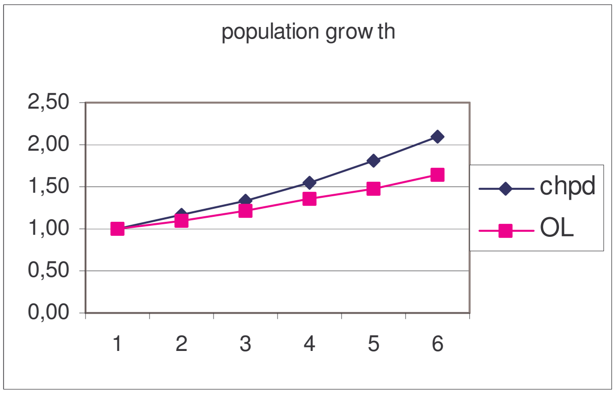



- All these data are estimates that correspond to EdL's situation and hypothesis for forecasting:
  - The growth rates for electricity consumption per household are those expected by EdL.
  - The number and average consumption of shops are only raw estimates.
  - The penetration rates are only expected. As the political objective is to supply 57 % of households in Oudomxay Province by 2020, the expected penetration rates have to be high.
  - The population growth rate is as average population growth rate in Oudomxay Province between 1995 and 2000.
  - The contribution to peak are computed from the annual energy consumptions, with a load factor of 0.4 (current load factor for Oudomxay Province).

### 3.1.2 Non-residential load forecast

### 3.1.3 Infrastructures

As we currently have no specific data on villages, we propose to take the following public consumption for villages. They correspond to EdL average public energy consumptions in Northern Laos. However, the REDEO tool will be able to compute public consumption more precisely by taking into account hospitals, schools, government building or public lighting.

| | | CHPD | OL |
|---|---|---|---|
| Public electricity consumption | kWh/year | 43800 | 20000 |
| District town public electricity consumption | kWh/year | 354000 | - |
| Public contribution to peak | kW | 12,5 | 8 |
| Distric town public contribution to peak | kW | 101 | - |

### 3.1.4 Industrial consumption

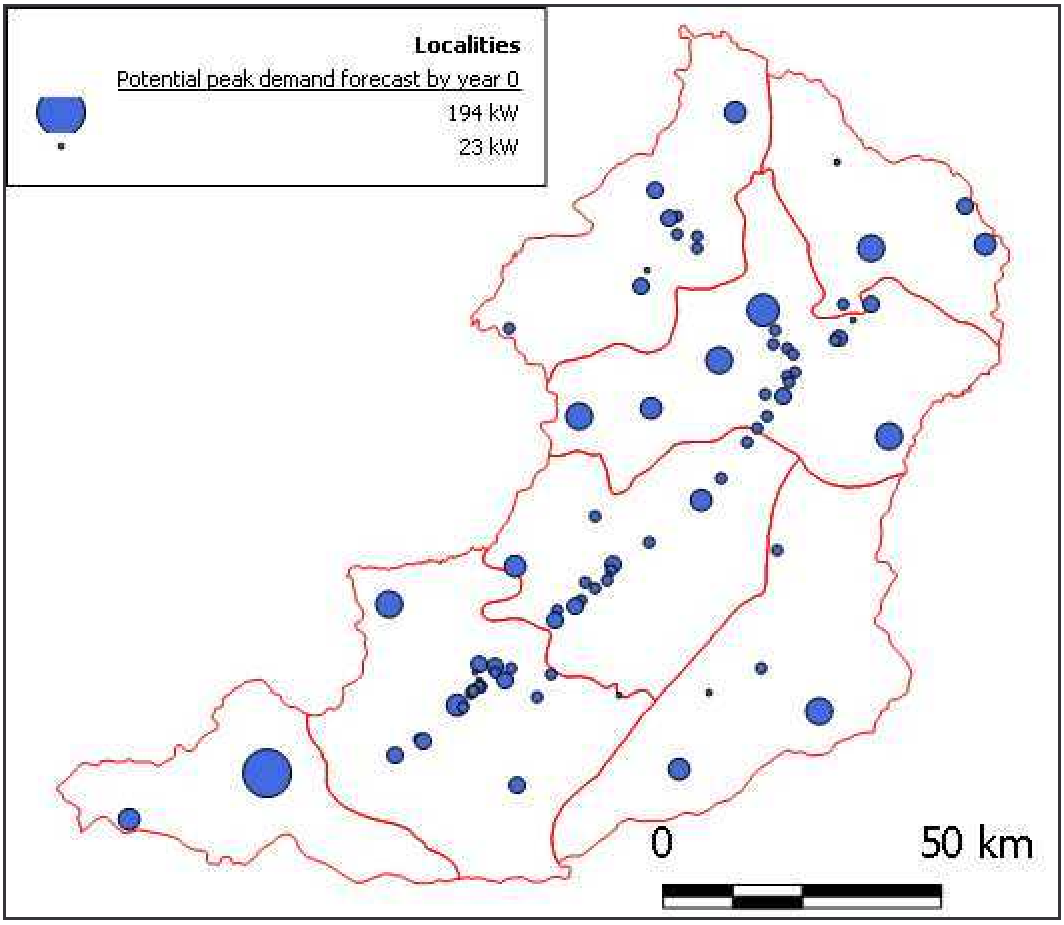
This case study doesn't take industrial energy consumption into account, as no data on specific energy consumption were available.

### 3.2 Results

The obtained figures are not effective values based on electrification scenarios: the peak demand forecast is the **potential peak demand if all the localities of all the clusters are considered**. But they don't consider that all households are supplied because a households penetration rate is used to obtain these figures.

Then the load forecast at the cluster level is computed as the sum of the load forecasts in the corresponding localities.

The following map represents the results of clustering and load forecast:




**Map 9: Peak demand forecast by year 0**

| District | Peak Demand forecast (MW) | | | Energy consumption forecast (GWh/y) | | |
|---|---|---|---|---|---|---|
| | year 0 | year 10 | year 20 | year 0 | year 10 | year 20 |
| Namo | 0,5 | 0,7 | 1 | 2,2 | 2,9 | 4 |
| La | 0,3 | 0,4 | 0,6 | 1,5 | 1,8 | 2,4 |
| Xai | 1,3 | 1,9 | 2,8 | 5,5 | 7,6 | 10,8 |
| Beng | 0,9 | 1,3 | 1,9 | 3,6 | 5 | 7,2 |
| Houn | 1,1 | 1,7 | 2,5 | 4,8 | 6,7 | 9,6 |
| Pakbeng | 0,3 | 0,4 | 0,5 | 1,4 | 1,6 | 2 |
| Nga | 0,3 | 0,4 | 0,6 | 1,5 | 1,8 | 2,3 |
| **TOTAL** | **4,6** | **6,7** | **9,8** | **20,3** | **27,7** | **38,4** |

**Table 3: Potential load forecast for Oudomxay Province**

The increasing of electricity demand can be explained by three main reasons:

- increasing of penetration rate (around 40% by year 0, around 80% by year 20)
- increasing of average individual energy consumption (+5% per year)
- increasing of population (3% per year for CHPDs, 2% for Ols)

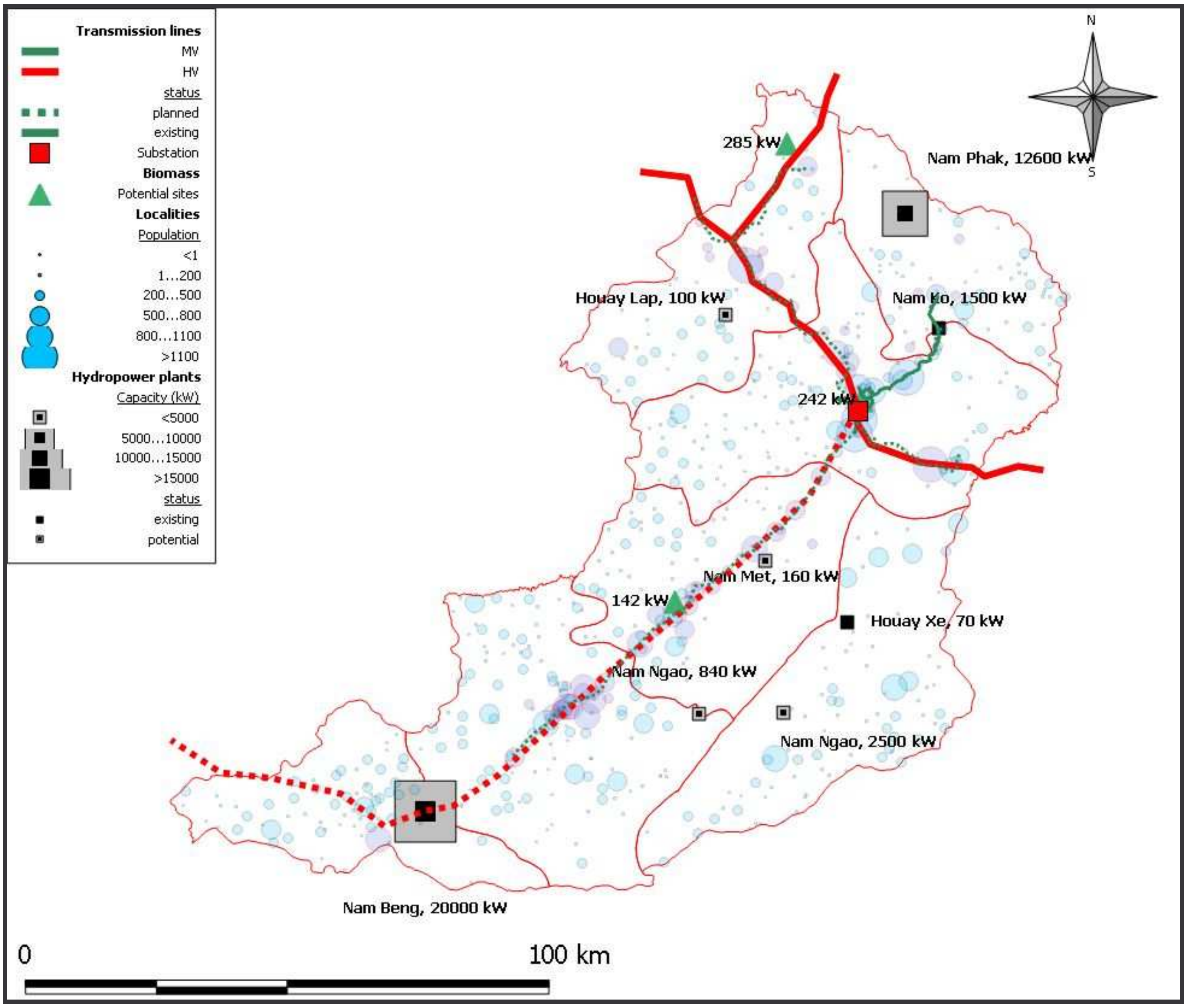
| District | Cluster avg population | population concerned | total population | % of pop concerned* |
|---|---|---|---|---|
| Namo | 1455 | 13093 | 16540 | 79% |
| La | 1944 | 7774 | 10931 | 71% |
| Xai | 1591 | 31824 | 35257 | 90% |
| Beng | 1277 | 21715 | 24217 | 90% |
| Houn | 1313 | 27566 | 32729 | 84% |
| Pakbeng | 4161 | 8322 | 13239 | 63% |
| Nga | 2270 | 9079 | 16252 | 56% |
| **TOTAL** | 1550 | **119373** | **149165** | **80%** |

**Table 4: population concerned by this clustering**

As we considered penetration rates by year 20 of 60% for OLs and of 85% for CHPDs, these forecasts correspond to political objective of 57% of population supplied by year 20 and are significanly higher the these objectives if we consider villages electrification rate, which objective is 36%.

# 4 PRODUCTION OPTIONS

The following map shows our hypothesis for production options in Oudomxay Province, that are going to be presented in this chapter:




## 4.1 Main grid installations

### 4.1.1 Transmission lines

- The 115 kV transmission lines in Oudomxay Province are as follows:

**Figure 1: existing and planned 115 kV transmission lines**

| n° | line | status |
|---|---|---|
| 1 | Luangprabang-Oudomxay | already commissioned |
| 2 | Oudomxay-Namo | already commissioned |
| 3 | Namo-Luangnamtha | already commissioned |
| 4 | Namo-Boun Neua | already commissioned |
| 5 | Oudomxay-Nambeng | planned for 2008 |
| 6 | Nambeng-Houayxay | planned for 2008 |

- The 22 kV transmission lines in Oudomxay Province are as follows:

**Figure 2: existing and planned 22 kV transmission lines**

| n° | line | voltage | status |
|---|---|---|---|
| A | Nam Ko-Oudomxay | 22 kV | already commissioned |
| B | Oudomxay-Phoukham (Houn District) | 22 kV | planned* |
| C | under 115kV lines 1, 2, 3, 4 | 34,5 kV | planned (NARPDP 2006) |

*According to a map given by EdL to IED in Oudomxay in January 2005, line B is planned but we have no indication on the planning. We guess that it will be commissioned by 2008.

### 4.1.2 Substations

- The only 115/22 kV substation in Oudomxay province is in Oudomxay.
- Another one is planned in Nambeng (2008).

### 4.1.3 Power availability

- Today power peak demand in Oudomxay Province is 2 MW. EdL's forecasts for 2020 are 10.4 MW. Consequently we can guess that the main grid will be able to supply **10.4 MW by 2020** and no more. As Nam Beng is supposed to be commissioned by 2008, we consider that this power will be available since 2008.

### 4.1.4 KWh price

- A raw estimate of the kWh cost at Oudomxay substation gives the following results:
  - Cost of production in the hydropower plants of Central 1 region: 1.9 cents/kWh
  - Cost of transport to Oudomxay: 1 cent/kWh
  - Cost of Oudomxay 115/22 kV substation: 0.4 cent/kWh
  - Losses: 30%
  - Total cost of kWh in Oudomxay substation: **4.3 cents/kWh**.

- The NARPDP program take a cost of 5 cents/kWh as hypothesis.

- As this cost is hard to evaluate, a sensibility analysis will be done from these prices.

### 4.1.5 Construction costs for main grid installations

- Standard costs for MV grid are as follows:

| Component | Distribution Tranformer Requirements | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 34,5 kV | | | | 22 kV | | | |
| | 50 kVA | 100 kVA | 160 kVA | 250 kVA | 50 kVA | 100 kVA | 160 kVA | 250 kVA |
| Cost | $ 6 175 | $ 6 901 | $ 7 861 | $ 8 665 | $ 5 728 | $ 6 334 | $ 7 414 | $ 8 338 |

| Component | MV line Requirements | | | | Shunt Capacitors | | 22 kV Transfer switch | Pow Transf. 34,5/22kV 3000kVA |
|---|---|---|---|---|---|---|---|---|
| | 34,5 kV | | 22 kV | | Rating 30% | | | |
| | Main | Branch | Main | Branch | 34,5 kV | 22kV | | |
| Cost | | $ 8 712 | $ 12 804 | $ 9 052 | $ 5 | $ 5 | $ 10 000 | $ 30 000 |

Source : NARPDP main report

**Table 5: Standard prices for MV grid**

- However, the first version of the REDEO tool will have only one cost for transformers: **$ 6,000**.
- 22 kV transmission line life duration: **25 years**.
- Transformer life duration: **25 years**.
- Operation and Maintenance for lines and transformers: **2% of the installation cost per year.**

## 4.2 Diesel plant

- REDEO tool will compute production costs from diesel options thanks to a catalog of costs and technologies given by the user.
- As we don't have such a catalog, the following model has been used for this study:

| | |
|---|---|
| investment cost | 33000 + 630 x installed capacity |
| life duration | 7 years |
| Operation and Maintenance | annually 2% of investment cost |
| fuel cost | $0,1 per kWh |

**Table 6: standard costs used for diesel option**

- The evaluation of diesel plants investments costs is very raw. It has be chosen such as bulk production is cheaper than little production but it doesn't consider a database of technologies or of plant models with precise characteristics. In our model, the investment costs in function of installed capacity are as follows:

| capacity | investment cost | price/kW installed |
|---|---|---|
| 50 kW | 64500 $ | 1290 $/kW |
| 100 kW | 96000 $ | 960 $/kW |
| 200 kW | 159000 $ | 795 $/kW |
| 500 kW | 348000 $ | 696 $/kW |
| 1000 kW | 663000 $ | 663 $/kW |

**Table 7: corresponding investment costs depending on capacity**

## 4.3 Hydro plants

We should keep in mind that results given by the REDEO tool can only be considered as departure points for true feasibility studies. Indeed, the question of hydro plants dimensioning is a very difficult one which is not treated by REDEO. However, the tool gives an idea of the zones that can be mainly supplied by hydro plants energy.

The REDEO approach concerning hydro plants dimensioning is relatively simple: For each potential site, the user has to precise:

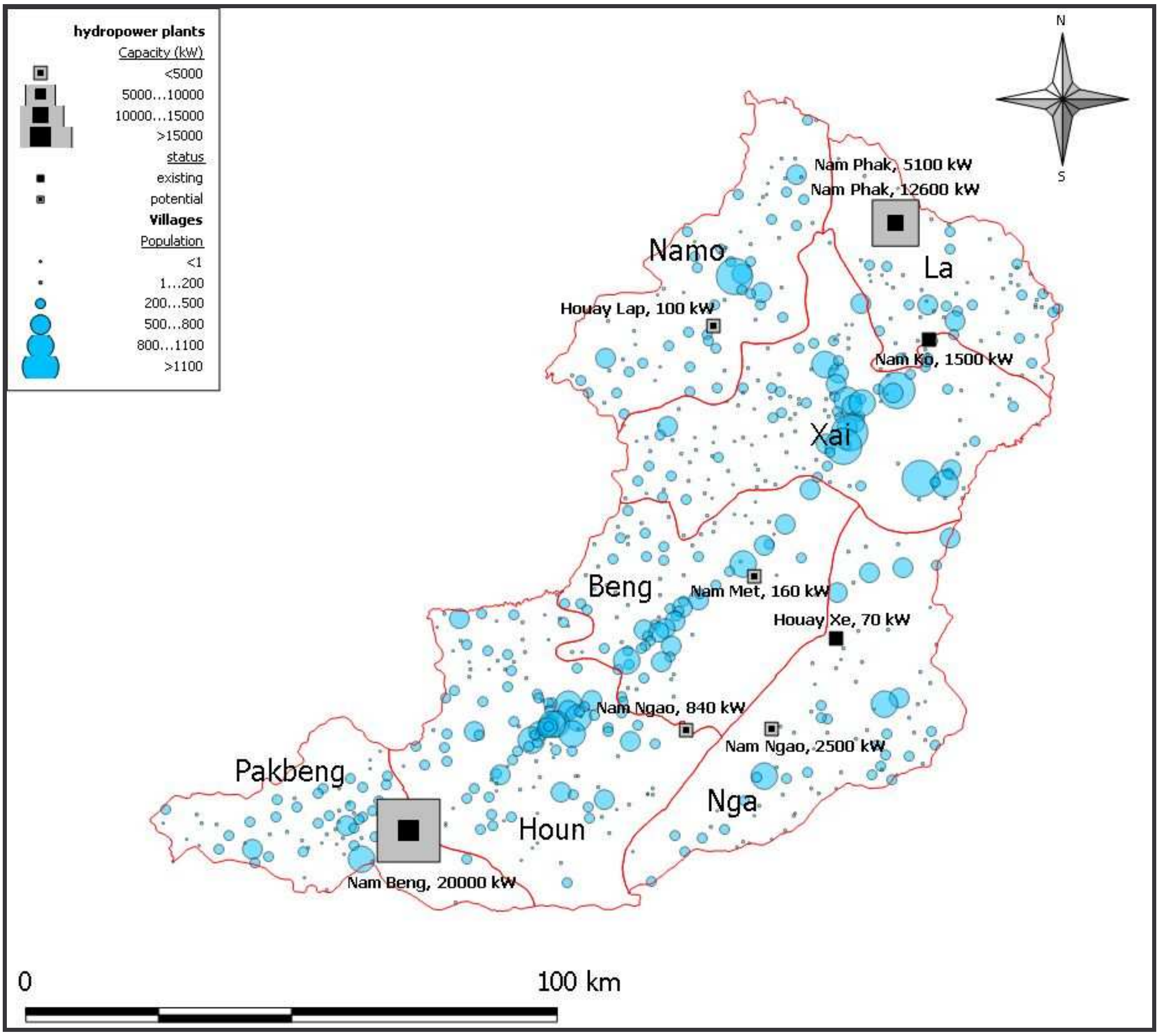
- an estimation of investment cost
- an estimation of potential capacity
- an estimation of annual energy output.

The following table shows actual and potential hydro sites in Oudomxay Province:

| N° | Site name | district | localisation | status | (to be) installed capacity | capacity in dry | Energy output | source | Estimed installation cost | price of the installed kW | evaluation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nam Ko | La | B. Longgna | built | 1,5 MW | 400 kW | 9,2 GWh/y | all | - | - | - |
| 2 | Houay Kasen | Pakbeng | ? | built | 70 kW | 20 kW | 491 MWh/y | Maunsell, JICA | - | - | - |
| 3 | Houay Xe | Nga | ? | built | 70 kW | 20 kW | 490 MWh/y | MIH - RED | - | - | - |
| 4 | Nam Ngao | Beng/Houn | B.Nahom | 2006-10 | 840 kW | 246 kW | 4,9 GWh/y | Maunsell, JICA | 4,4 M$ | 5240 $ | yes |
| 5 | Nam Beng | Pakbeng | ? | 2008 | 20 MW | 7 MW | 67 GWh/y | all | 30 M$ | 1500 $ | no |
| 6 | Nam Met | Beng | B.Namet | 2010-20 | 160 kW | 50 kW | 940 MWh/y | Maunsell | 800 k$ | 3500 $ | no |
| 7 | Houay Lap | Namo | B.Pheng | 2010-20 | 100 kW | 30 kW | 580 MWh/y | Maunsell | 500 k$ | 3500 $ | no |
| 8 | Nam Phak | La | ? | unplanned | 12,6 MW | 4 MW | 72,3 GWh/y | Maunsell | 35 M$ | 2500 $ | no |
| 9 | Nam Phak | La | ? | unplanned | 5,1 MW | 945 kW | 30 GWh/y | JICA | 18,5 M$ | 2800 $ | yes |
| 10 | Nam Tale | Pakbeng | ? | unplanned | 79 kW | 42 kW | 480 MWh/y | JICA | 800 k$ | 10000 $ | yes |
| 11 | Nam Ngao | Nga | ? | 2000-15 | 2,5 MW | 800 kW | 15 GWh/y | NARPDP | 12,5 M$ | 2500 $ | no |
| 12 | Nam Beng | Beng | ? | unplanned | 1,5 MW | 500 kW | 9 GWh/y | NARPDP | 7,5 M$ | 2500 $ | no |

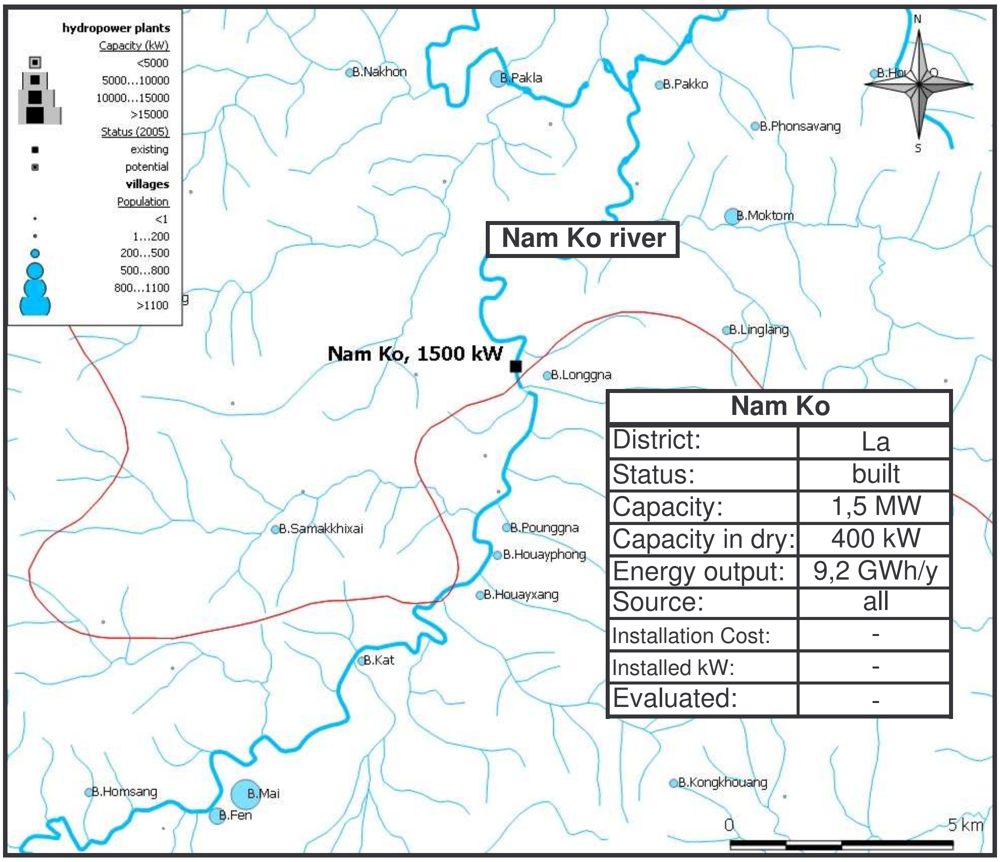
**Table 8: existing and potential hydropower plants in Oudomxay Province**

- Warning: only the **bold figures** were found in the quoted documents. **Other figures are only raw estimates**. Indeed, only the JICA study gives estimations of building costs.
- The column “evaluation” says whether or not we have a cost given by an evaluation study.
- We don’t take into account the dates of commissioning given in the upper table, so that the scenario given by this study is independant from already done choices.
- Sometimes, the name of the closest village is given, or the river was found in our GIS database, but sometimes we are not able to have a precision better than 10km. The following maps show the expected localization for hydro plants:

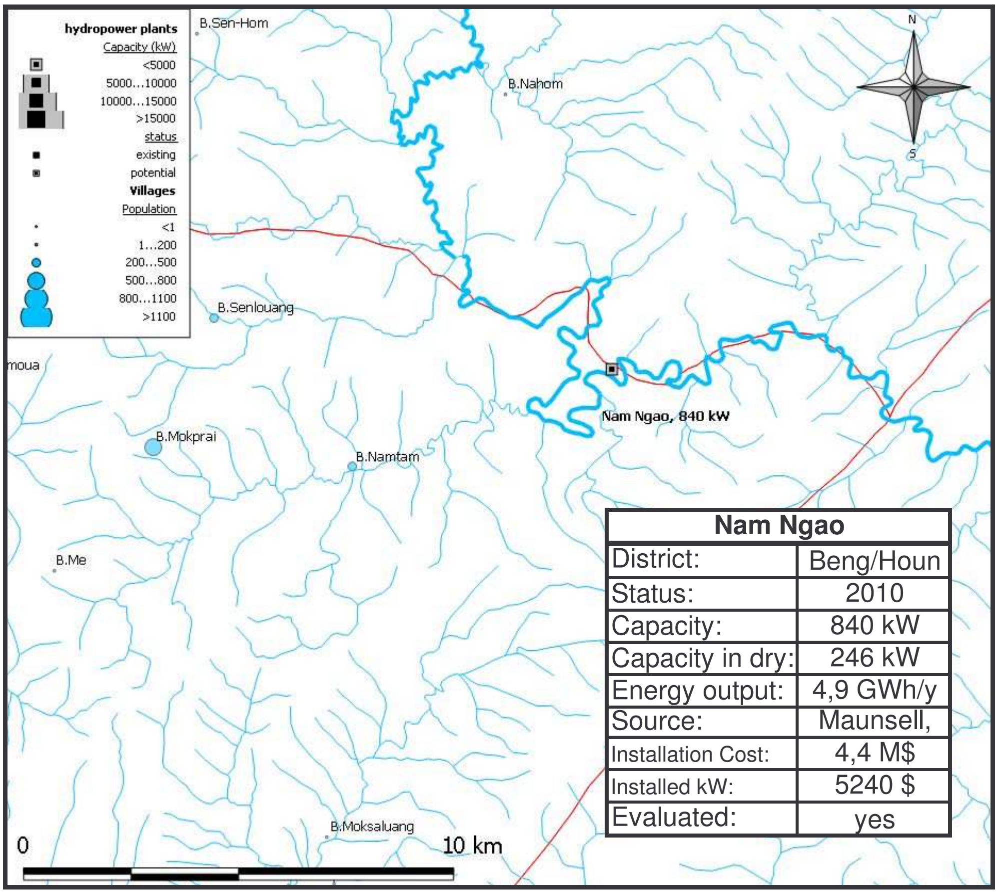



**Map 10: Oudomxay Province potential and existing hydropower plants**

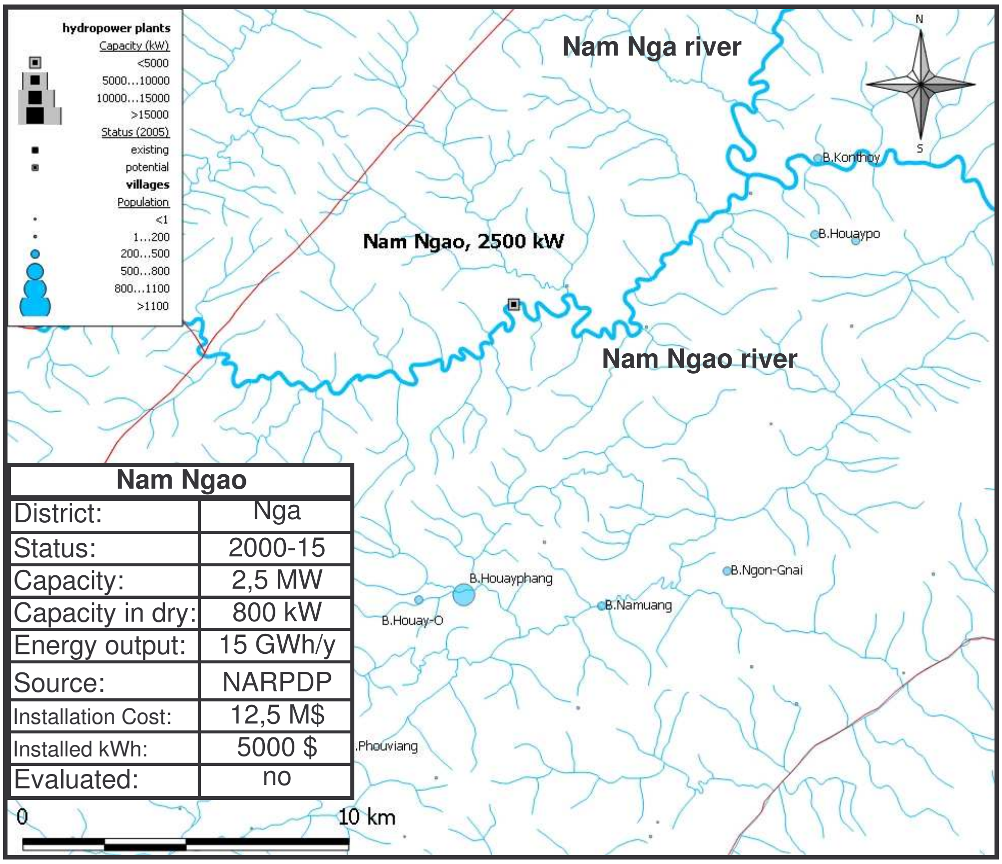
- The localization of the following sites is exact: Nam Ko, Nam Ngao (840 kW) and Nam Phak (5100 kW).
- For Nam Phak (12.6 MW, found in Maunsell study), we guess that it is the same localization than Nam Phak (5.1 MW, found in JICA study).
- For Houay Lap and Nam Met, Maunsell study gives the name of the closest village.
- For Houay Xe and Nam Ngao (2.5 MW), we just roughly estimate their localization.
- The following maps gives more precisely the expected situation of each site:



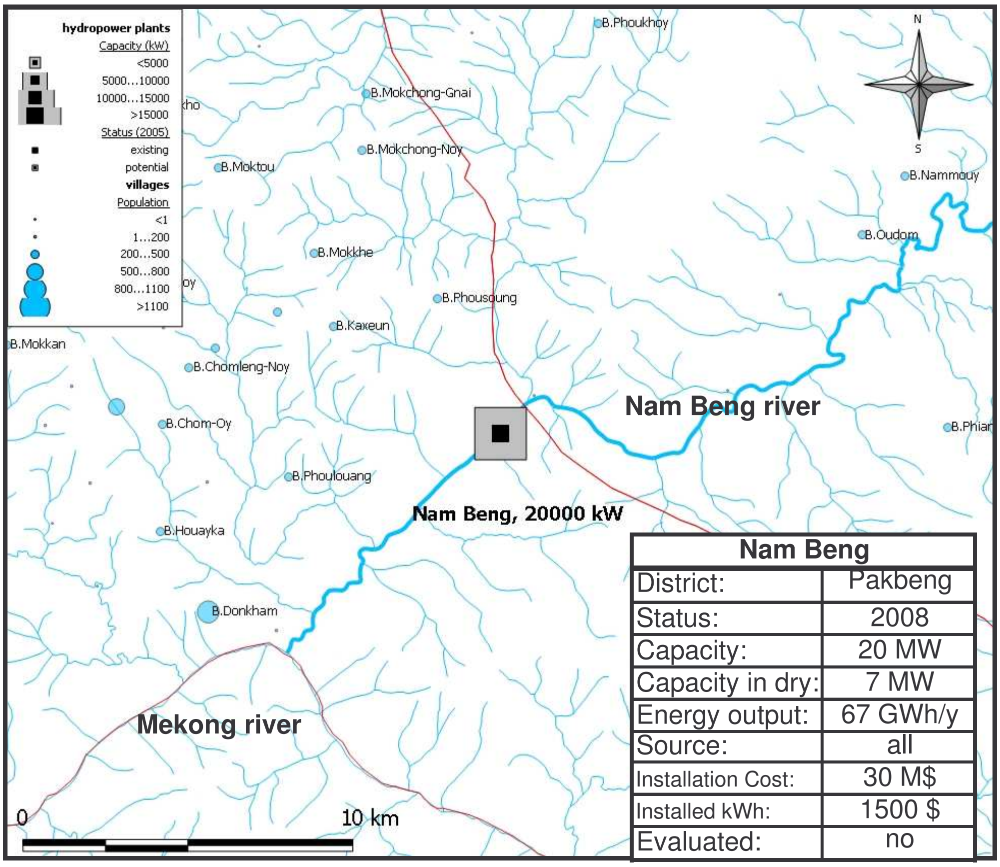

| Nam Ko | |
|---|---|
| District: | La |
| Status: | built |
| Capacity: | 1,5 MW |
| Capacity in dry: | 400 kW |
| Energy output: | 9,2 GWh/y |
| Source: | all |
| Installation Cost: | - |
| Installed kW: | - |
| Evaluated: | - |



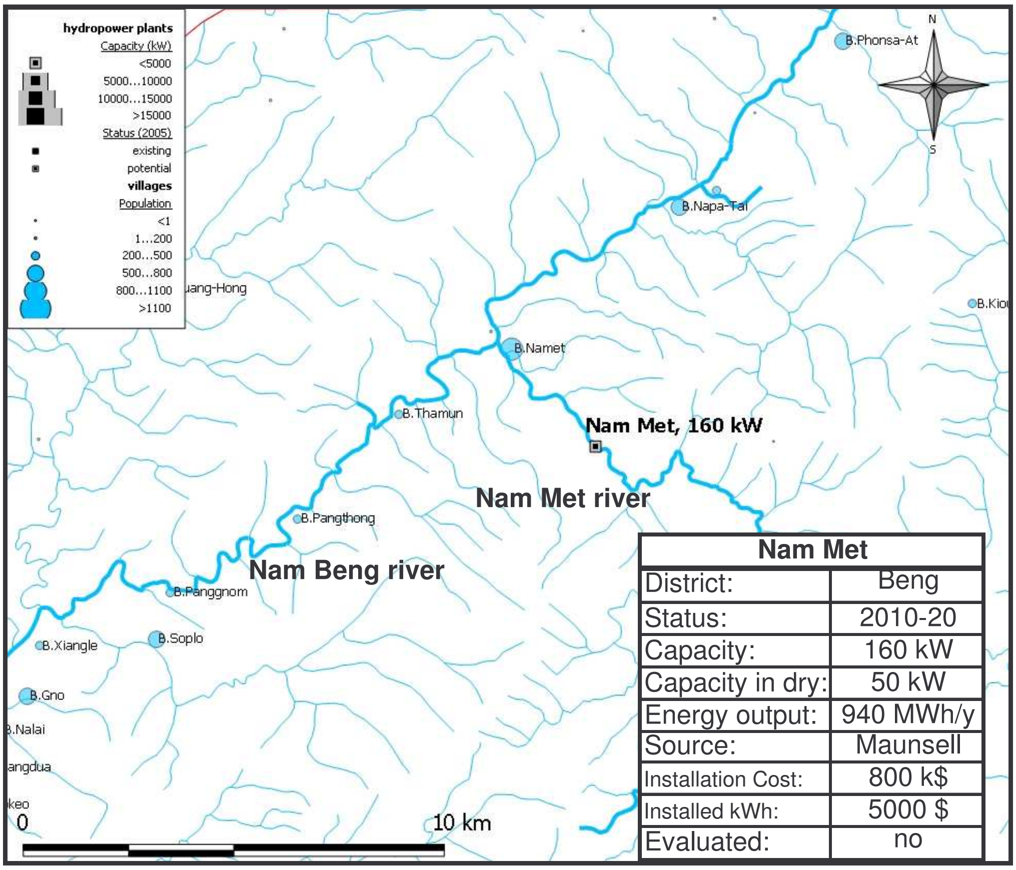

| Nam Ngao | |
|---|---|
| District: | Beng/Houn |
| Status: | 2010 |
| Capacity: | 840 kW |
| Capacity in dry: | 246 kW |
| Energy output: | 4,9 GWh/y |
| Source: | Maunsell, |
| Installation Cost: | 4,4 M$ |
| Installed kW: | 5240 $ |
| Evaluated: | yes |



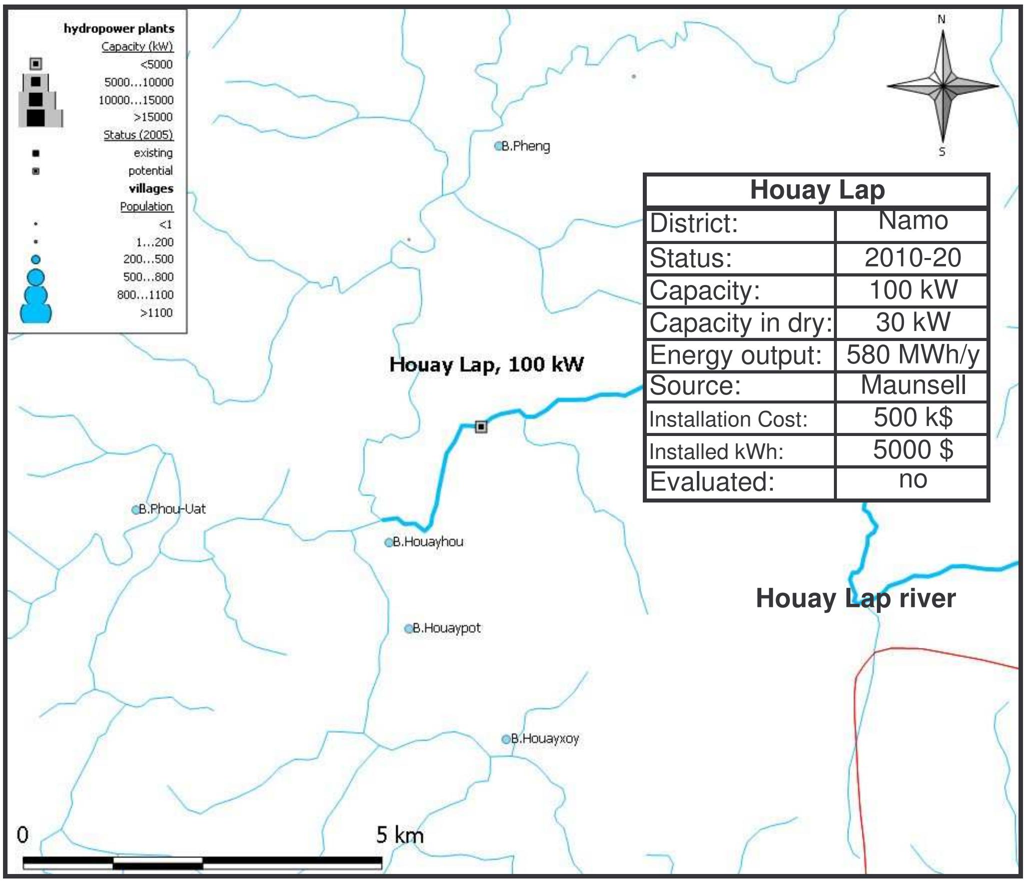

| Nam Ngao | |
|---|---|
| District: | Nga |
| Status: | 2000-15 |
| Capacity: | 2,5 MW |
| Capacity in dry: | 800 kW |
| Energy output: | 15 GWh/y |
| Source: | NARPDP |
| Installation Cost: | 12,5 M$ |
| Installed kWh: | 5000 $ |
| Evaluated: | no |



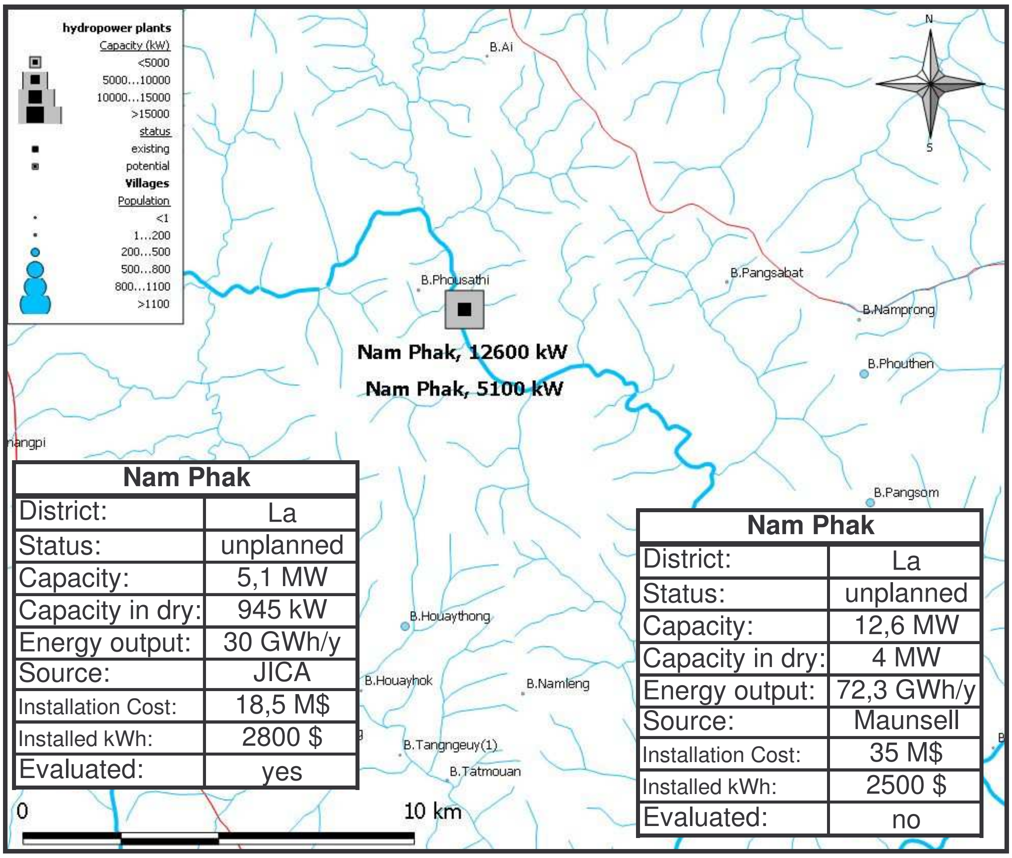

| Nam Beng | |
|---|---|
| District: | Pakbeng |
| Status: | 2008 |
| Capacity: | 20 MW |
| Capacity in dry: | 7 MW |
| Energy output: | 67 GWh/y |
| Source: | all |
| Installation Cost: | 30 M$ |
| Installed kWh: | 1500 $ |
| Evaluated: | no |




| Nam Met | |
|---|---|
| District: | Beng |
| Status: | 2010-20 |
| Capacity: | 160 kW |
| Capacity in dry: | 50 kW |
| Energy output: | 940 MWh/y |
| Source: | Maunsell |
| Installation Cost: | 800 k$ |
| Installed kWh: | 5000 $ |
| Evaluated: | no |

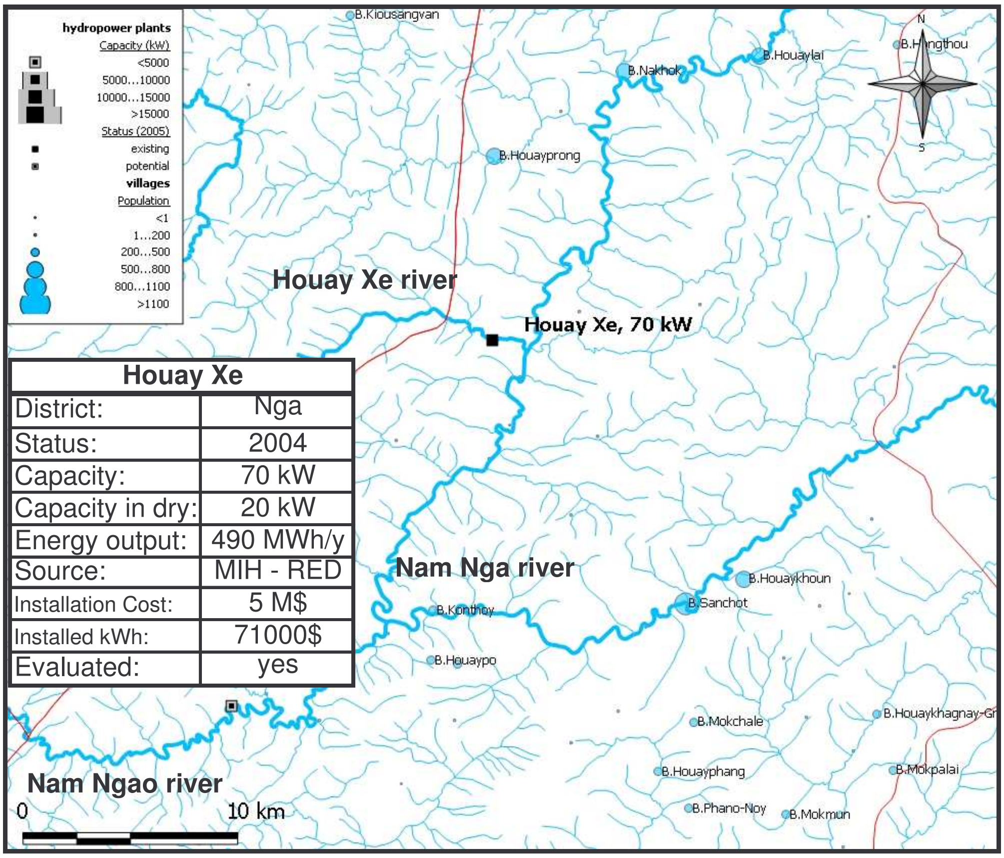



| Houay Lap | |
|---|---|
| District: | Namo |
| Status: | 2010-20 |
| Capacity: | 100 kW |
| Capacity in dry: | 30 kW |
| Energy output: | 580 MWh/y |
| Source: | Maunsell |
| Installation Cost: | 500 k$ |
| Installed kWh: | 5000 $ |
| Evaluated: | no |




| Nam Phak | |
|---|---|
| District: | La |
| Status: | unplanned |
| Capacity: | 5,1 MW |
| Capacity in dry: | 945 kW |
| Energy output: | 30 GWh/y |
| Source: | JICA |
| Installation Cost: | 18,5 M$ |
| Installed kWh: | 2800 $ |
| Evaluated: | yes |

| Nam Phak | |
|---|---|
| District: | La |
| Status: | unplanned |
| Capacity: | 12,6 MW |
| Capacity in dry: | 4 MW |
| Energy output: | 72,3 GWh/y |
| Source: | Maunsell |
| Installation Cost: | 35 M$ |
| Installed kWh: | 2500 $ |
| Evaluated: | no |




| Houay Xe | |
|---|---|
| District: | Nga |
| Status: | 2004 |
| Capacity: | 70 kW |
| Capacity in dry: | 20 kW |
| Energy output: | 490 MWh/y |
| Source: | MIH - RED |
| Installation Cost: | 5 M$ |
| Installed kWh: | 71000$ |
| Evaluated: | yes |

## 4.4 Biomass

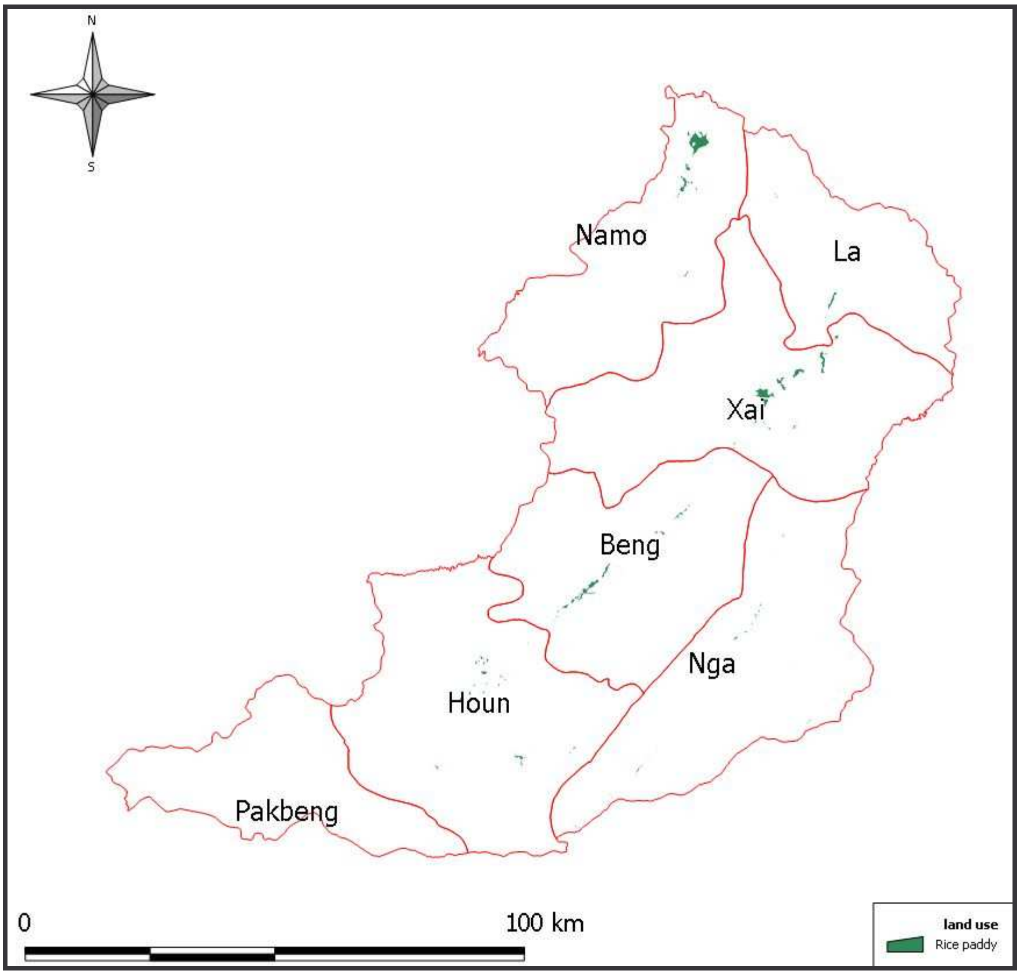
- In South-East Asia, Power can be produced from the following natural components:
    - Rice husk and straw
    - Cane trash and bagasse
    - Palm Oil residues
    - Animal Wastes
    - Urban Municipal Waste
    - Tapioca production
    - Wood processing and plywood industries
    - Energy crops

- In Lao PDR, all these technologies are poorly developed. However, as RE is a long-term issue, we have to consider the areas were biomass plants are likely to be interesting.
- Almost all these technologies, only the rice paddy is **clearly available** in Oudomxay Province. The land-use layer of the GIS map doesn't give any data on other possibilities, but **it doesn't mean that other technologies can not be used**.
- Characteristics of biomass plants based on rice husk are collected in the following catalog corresponding to the "production options" module" output:

| Parameter category | Parameter | Unit | Manifold name | type | | |
|---|---|---|---|---|---|---|
| CROP AND RESIDUE PRODUCTI | Crop residue: production ratio (%) | % | ResProd | Percentage | 22% | 22% |
| | Residue Name | - | ResName | Text | Rice husk | Rice husk |
| | Residue availability (%) | % | ResAva | Percentage | locally dependant | locally dependant |
| | LHV | MJ/kg | LHV | Integer | 13 | 13 |
| | Moisture content | % | Mois | Percentage | 8 | 8 |
| | Residue preconditioning | - | ResPrecond | Text | no treatment | no treatment |
| | Minimum Total Crop Production | Tonne | MinCropProd | Floating Point (single) | 0 | 195000 |
| | Maximum Total Crop Production | Tonne | MaxCropProd | Floating Point (single) | 195000 | - |
| TECHNOLOGY | Conversion process | - | ConvProc | Text | **<2MW** | **>2MW** |
| | Electricity production per tonne of crop | KWh/tonne | ElecProdCrop | Floating point (single) | 100 | 100 |
| | Plant efficiency | % | Efficency | Floating Point (single) | 30% | 30% |
| | % of days operating in a year | % | DaysOper | Percentage | 100% | 100% |
| | Life time | Year | LifeTime | Integer | 20 | 20 |
| | Time to Commissioning | Years | TimeCommiss | Integer (Years) | 3 | 3 |
| COSTS | Investment cost | $/kW | InvestCostkW | Floating Point (single) | 1750 | 1450 |
| | O&M | $/kWh | OMCost | Floating Point (single) | 3,24 | 3,24 |
| | Fuel cost | $/kg | FuelCost | Floating Point (single) | locally dependant | locally dependant |
| OTHERS | Potential employees | - | PotEmp | Integer | 3 | 10 |

**Table 9: Characteristics of biomass systems based on rice residues**

- We have no idea of the rice residue cost in Oudomxay Province. This cost is locally dependant and the actual use of these residues have to be taken into account. However, the price of rice residues after milling process is not high because the use of rice husk for biomass plants avoid using land for rice husk disposal, avoid the risk of wild rice husk burnings.
- If rice husks are burned through efficient suspension boilers, they produce a good quality ash containing a high silica content that can be sold to electronics or steel industries. The price of this ash can be around $200/ton, corresponding to $40/ ton of rice husk or $8 / ton of paddy. But all these figures are only raw estimations that should be adapted to the local context.
- According to the land use layer of the GIS maps of Oudomxay Province, only three sites are likely to be interesting: in Namo district and in Xai district.
-




**Map 11: Important rice paddy areas in Oudomxay Province**

- The zone in Namo district represents around 2000 ha. Around Xai, we have about 1700 ha and 1000 ha in Beng district.
- We consider an average yield of 5 tons per hectare and per year.
- Consequently, as biomass technology is able to produce 100 kWh per ton of paddy, we have the following capacities:
    - Namo: 1000 GWh/year
    - Xai: 850 MWh/year
    - Beng: 500 MWh/year
- If we take a load factor of 0.4 (as in EDL forecasts), it corresponds to:
    - Namo: 285 kW
    - Xai: 242 kW
    - Beng: 142 kW
- Investment Cost: 1700 $/kW (source [6])
- O&M: 3.24 $/MWh (idem)

# 5 ELECTRIFICATION SCENARIOS

## 5.1 General Ideas

The aim of the REDEO tool is to provide to the user good indicators for electrification planning. It is neither to do a complete economical or financial study nor to determine precisely the power flows in a future network. It is to propose a set of projects and their main characteristics:

- life cycle kWh cost
- initial investment
- Annual expenses if any
- Indicators on Environment and Development.

To build this set of projects, REDEO follows two approaches:

- one based on renewable energy options
- one based on national grid extension and diesel plants options

These indicators will permit the user to build a preliminary framework for electrification planning and to determine which projects should be deepened by feasibility studies.

## 5.2 Hydro plants

### 5.2.1 Methodology and inputs

For each potential hydro plant, REDEO determines an area with a potential peak demand forecast by year 10 corresponding to potential installation capacity of the plant.

One consequence of this dimensioning is that other technologies are needed to provide a continuous and good quality service. Indeed, in dry season, the plant cannot supply the same area than in rainy season. Furthermore, the demand is very increasing and the plant can only answer to half of the peak demand by year 20. REDEO tool doesn't give estimation of costs engendered by this additional technology (mainly diesel).

To determine the area supplied by the plant, REDEO tool uses a very simple algorithm: the nearest cluster is connected. While plant capacity is enough, the nearest cluster from the set "plant + already connected clusters" is connected. This way is not the most effective: we can imagine an optimal situation connecting far localities that are very near each others and not connecting some localities closer to the plant but in an other direction. We prefer to keep this solution because it is more satisfying in a land use planning perspective. Anyway the user have the possibility to change manually the selected clusters.

The input used for the computation of costs are as follows:

**Figure 3: General Parameters for hydro plant costs computation**

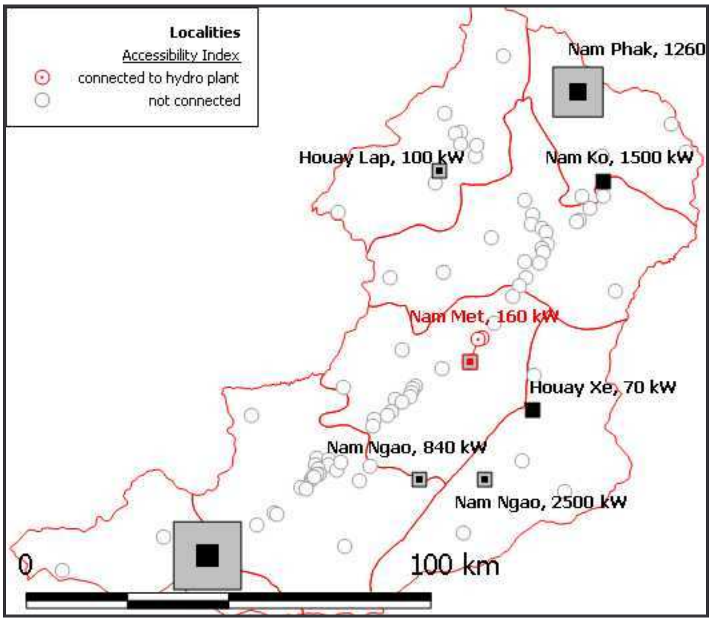
| | | |
|---|---|---|
| tranformer price | 6000 | $ |
| lines km cost | 11000 | $ |
| computation period | 15 | years |
| hydro plant life duration | 25 | years |
| discount rate | 0,08 | |

As plants life duration is higher than computation period, a residual value is given to the plant at the end of the computation period. This residual value is determined with a linear rule: the residual value at year 15 is equal to ten twenty-fifths of the initial value. Discounted residual value is then deduced from investment cost

#### 5.2.2 Results

The following pages give, for each potential site:

- a map representing the plant and clusters so that their potential peak demand by year 10 is equal to plant capacity
- a very brief economical analysis in order to determine life-cycle kWh cost.




# Nam Met

| | | |
|---|---|---|
| kWh sold (years 0 to 14) | 9 603 000 | kWh |
| Investment Cost | 800 000 | $ |
| Residual Value (year 15) | 320 000 | |
| Discounted Res Value | 100 877 | |
| Investment - Disc Res Val | 699 123 | |
| annual O&M Costs | 16 000 | $/y |
| total discounted O&M costs | 137 600 | $ |
| Production expenses | 836 723 | $ |
| **Production Cost** | **8,713** | **USc/kWh** |

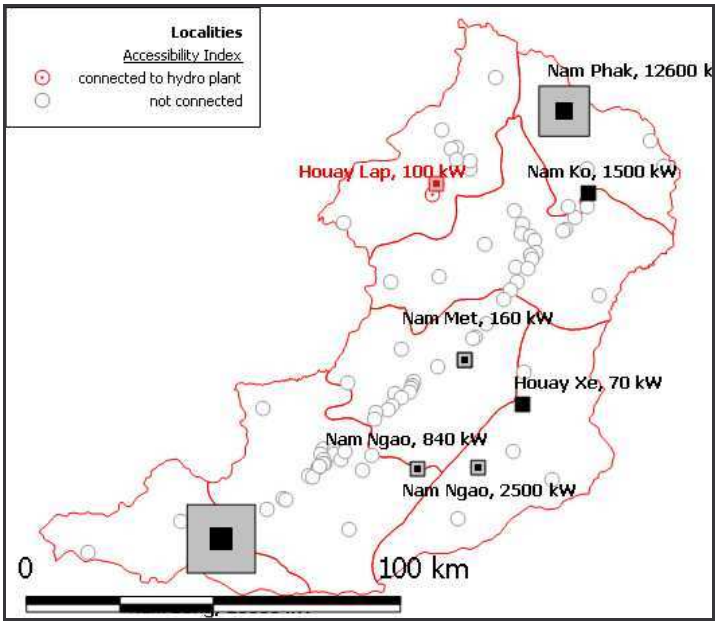
| | | |
|---|---|---|
| distribution lines length | 6,98 | km |
| Investment Cost | 76 780 | $ |
| Transfo investment costs | 12 000 | |
| Residual Value of (10) and (11) | 35 512 | |
| Investment - Disc Res Val | 77 585 | |
| total discounted O&M costs | 14 358 | $ |
| **Distribution & transfo Cost** | **0,957** | **USc/kWh** |

| | | |
|---|---|---|
| **TOTAL AVERAGE kWh COST** | **9,671** | **USc/kWh** |

| | | |
|---|---|---|
| Annual Capacity | 940 000 | kWh |
| Consumption year 0 | 483 000 | 51% |
| Consumption year 5 | 578 000 | 61% |
| Consumption year 10 | 708 000 | 75% |
| Consumption year 15 | 862 000 | 92% |

| | | |
|---|---|---|
| Power capacity | 160 | |
| Peak demand forecast year 0 | 117 | 73% |
| Peak demand forecast year 5 | 142 | 89% |
| Peak demand forecast year 10 | 160 | 100% |
| Peak demand forecast year 15 | 160 | 100% |

| | |
|---|---|
| **Population in clusters** | **2 550** |




# Houay Lap

| | | |
|---|---|---|
| kWh sold (years 0 to 14) | 5 691 000 | kWh |
| Investment Cost | 500 000 | $ |
| Residual Value (year 15) | 200 000 | |
| Discounted Res Value | 63 048 | |
| Investment - Disc Res Val | 436 952 | |
| annual O&M Costs | 10 000 | $/y |
| total discounted O&M costs | 86 000 | $ |
| Production expenses | 522 952 | $ |
| **Production Cost** | **9,189** | **USc/kWh** |

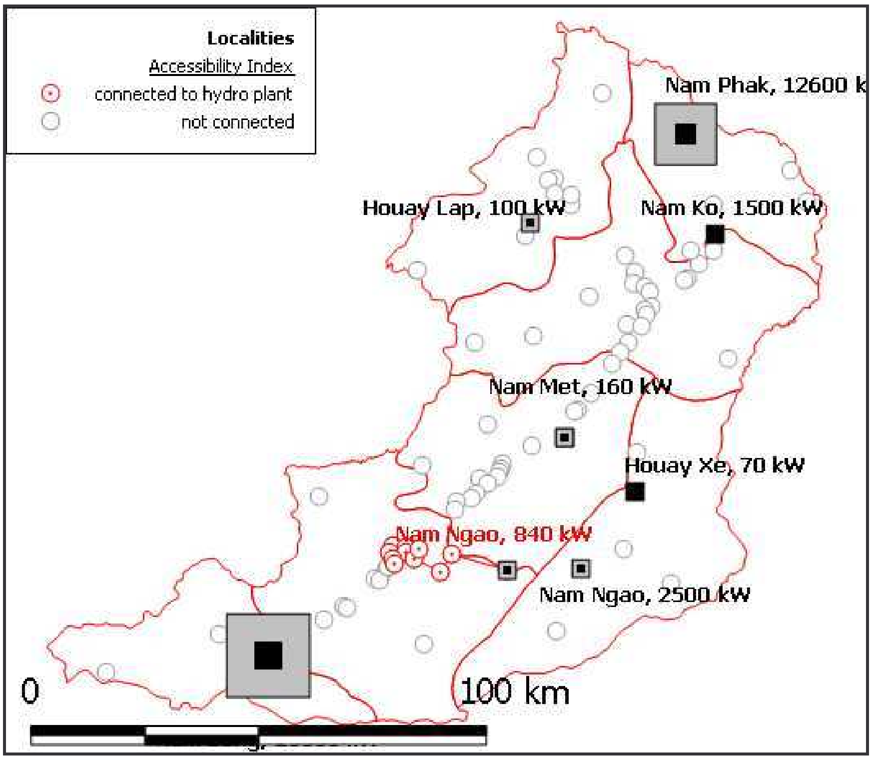
| | | |
|---|---|---|
| distribution lines length | 3 | km |
| Investment Cost | 33 000 | $ |
| Transfo investment costs | 6 000 | |
| Residual Value of (10) and (11) | 15 600 | |
| Investment - Disc Res Val | 34 082 | |
| total discounted O&M costs | 6 171 | $ |
| **Distribution & transfo Cost** | **0,707** | **USc/kWh** |

| | | |
|---|---|---|
| **TOTAL AVERAGE kWh COST** | **9,896** | **USc/kWh** |

| | | |
|---|---|---|
| Annual Capacity | 580 000 kWh | |
| Consumption year 0 | 321 000 | 55% |
| Consumption year 5 | 357 000 | 62% |
| Consumption year 10 | 405 000 | 70% |
| Consumption year 15 | 459 000 | 79% |

| | | |
|---|---|---|
| Power capacity | 100 | |
| Peak demand forecast year 0 | 71 | 71% |
| Peak demand forecast year 5 | 81 | 81% |
| Peak demand forecast year 10 | 94 | 94% |
| Peak demand forecast year 15 | 100 | 100% |

| | |
|---|---|
| **Population in clusters** | **2 142** |




## Nam Ngao (840 kW)

| | | |
|---|---|---|
| kWh sold (years 0 to 14) | 42 106 000 | kWh |
| Investment Cost | 4 400 000 | $ |
| Residual Value (year 15) | 1 760 000 | |
| Discounted Res Value | 554 825 | |
| Investment - Disc Res Val | 3 845 175 | |
| annual O&M Costs | 88 000 | $/y |
| total discounted O&M costs | 756 800 | $ |
| Production expenses | 4 601 975 | $ |
| **Production Cost** | **10,929** | **USc/kWh** |

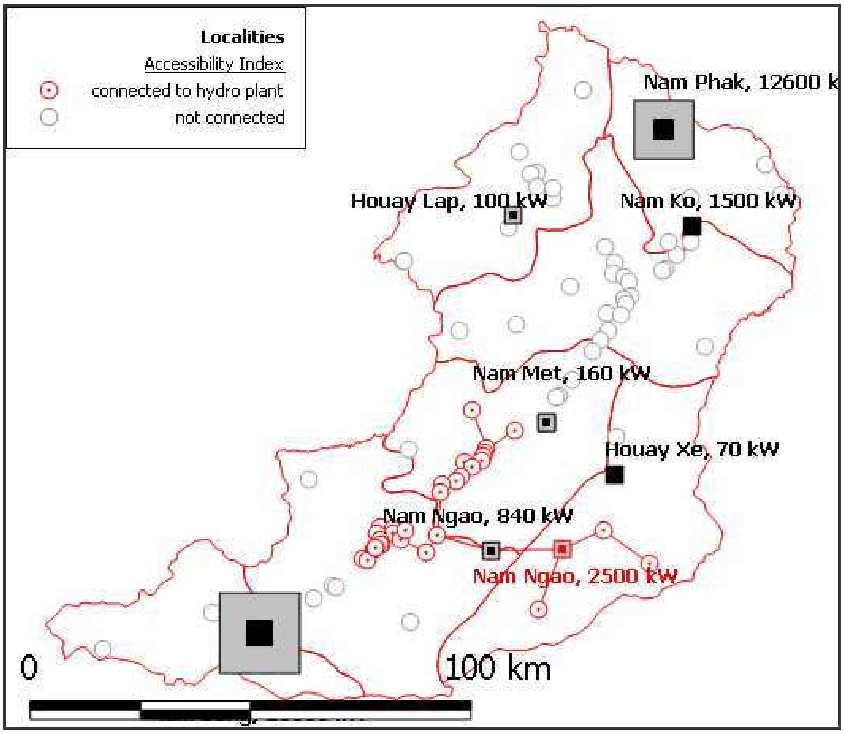
| | | |
|---|---|---|
| distribution lines length | 38 | km |
| Investment Cost | 418 000 | $ |
| Transfo investment costs | 66 000 | |
| Residual Value of (10) and (11) | 193 600 | |
| Investment - Disc Res Val | 422 969 | |
| total discounted O&M costs | 78 166 | $ |
| **Distribution & transfo Cost** | **1,190** | **USc/kWh** |

| | | |
|---|---|---|
| **TOTAL AVERAGE kWh COST** | **12,120** | **USc/kWh** |

| | | |
|---|---|---|
| Annual Capacity | 4 900 000 | kWh |
| Consumption year 0 | 2 051 000 | 42% |
| Consumption year 5 | 2 507 000 | 51% |
| Consumption year 10 | 3 132 000 | 64% |
| Consumption year 15 | 3 879 000 | 79% |

| | | |
|---|---|---|
| Power capacity | 840 | |
| Peak demand forecast year 0 | 518 | 62% |
| Peak demand forecast year 5 | 641 | 76% |
| Peak demand forecast year 10 | 827 | 98% |
| Peak demand forecast year 15 | 840 | 100% |

| | |
|---|---|
| **Population in clusters** | **12 616** |




# Nam Ngao (2,5 MW)

| | | |
|---|---|---|
| kWh sold (years 0 to 14) | 131 930 000 | kWh |
| Investment Cost | 6 000 000 | $ |
| Residual Value (year 15) | 2 400 000 | |
| Discounted Res Value | 756 580 | |
| Investment - Disc Res Val | 5 243 420 | |
| annual O&M Costs | 120 000 | $/y |
| total discounted O&M costs | 1 032 000 | $ |
| Production expenses | 6 275 420 | $ |
| **Production Cost** | **4,757** | **USc/kWh** |

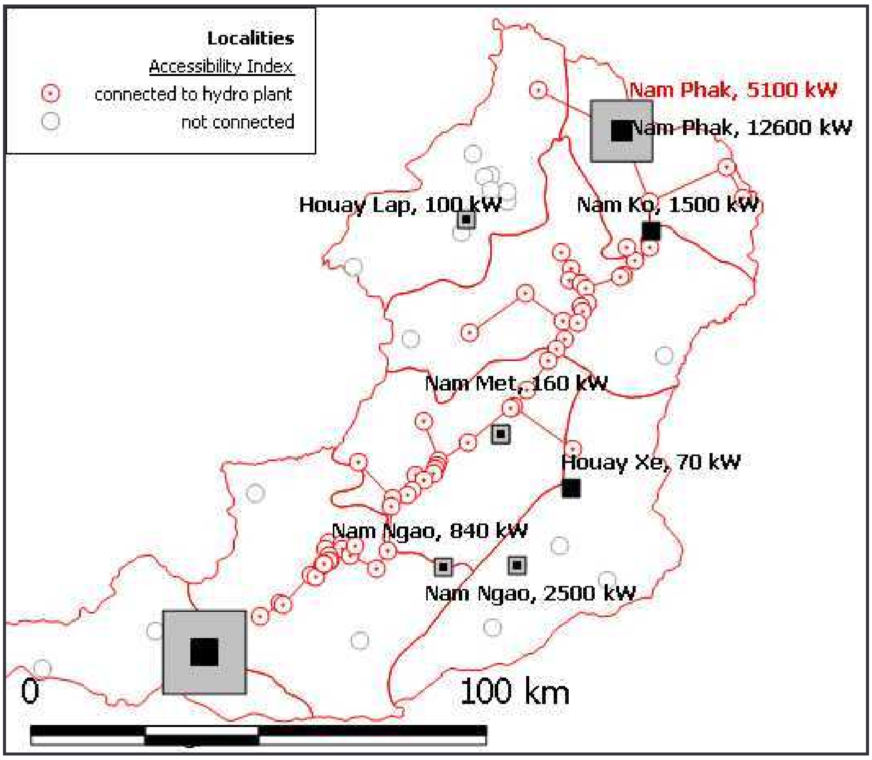
| | | |
|---|---|---|
| distribution lines length | 141 | km |
| Investment Cost | 1 551 000 | $ |
| Transfo investment costs | 186 000 | |
| Residual Value of (10) and (11) | 694 800 | |
| Investment - Disc Res Val | 1 517 970 | |
| total discounted O&M costs | 290 037 | $ |
| **Distribution & transfo Cost** | **1,370** | **USc/kWh** |

| | | |
|---|---|---|
| **TOTAL AVERAGE kWh COST** | **6,127** | **USc/kWh** |

| | | |
|---|---|---|
| Annual Capacity | 15 000 000 | kWh |
| Consumption year 0 | 6 780 000 | 45% |
| Consumption year 5 | 8 001 000 | 53% |
| Consumption year 10 | 9 665 000 | 64% |
| Consumption year 15 | 11 630 000 | 78% |

| | | |
|---|---|---|
| Power capacity | 2500 | |
| Peak demand forecast year 0 | 1622 | 65% |
| Peak demand forecast year 5 | 1942 | 78% |
| Peak demand forecast year 10 | 2451 | 98% |
| Peak demand forecast year 15 | 2500 | 100% |

| | |
|---|---|
| **Population in clusters** | **16 874** |




# Nam Phak (5,1MW)

| | | |
|---|---|---|
| kWh sold (years 0 to 14) | 269 960 000 | kWh |
| Investment Cost | 18 500 000 | $ |
| Residual Value (year 15) | 7 400 000 | |
| Discounted Res Value | 2 332 789 | |
| Investment - Disc Res Val | 16 167 211 | |
| annual O&M Costs | 370 000 | $/y |
| total discounted O&M costs | 3 182 000 | $ |
| Production expenses | 19 349 211 | $ |
| **Production Cost** | **7,167** | **USc/kWh** |

| | | |
|---|---|---|
| distribution lines length | 294 | km |
| Investment Cost | 3 234 000 | $ |
| Transfo investment costs | 360 000 | |
| Residual Value of (10) and (11) | 1 437 600 | |
| Investment - Disc Res Val | 3 140 809 | |
| total discounted O&M costs | 604 758 | $ |
| **Distribution & transfo Cost** | **1,387** | **USc/kWh** |

| | | |
|---|---|---|
| **TOTAL AVERAGE kWh COST** | **8,555** | **USc/kWh** |

| | | |
|---|---|---|
| Annual Capacity | 30 000 000 | kWh |
| Consumption year 0 | 14 020 000 | 47% |
| Consumption year 5 | 16 427 000 | 55% |
| Consumption year 10 | 19 713 000 | 66% |
| Consumption year 15 | 23 600 000 | 79% |

| | | |
|---|---|---|
| Power capacity | 5100 | |
| Peak demand forecast year 0 | 3285 | 64% |
| Peak demand forecast year 5 | 3920 | 77% |
| Peak demand forecast year 10 | 4916 | 96% |
| Peak demand forecast year 15 | 5100 | 100% |

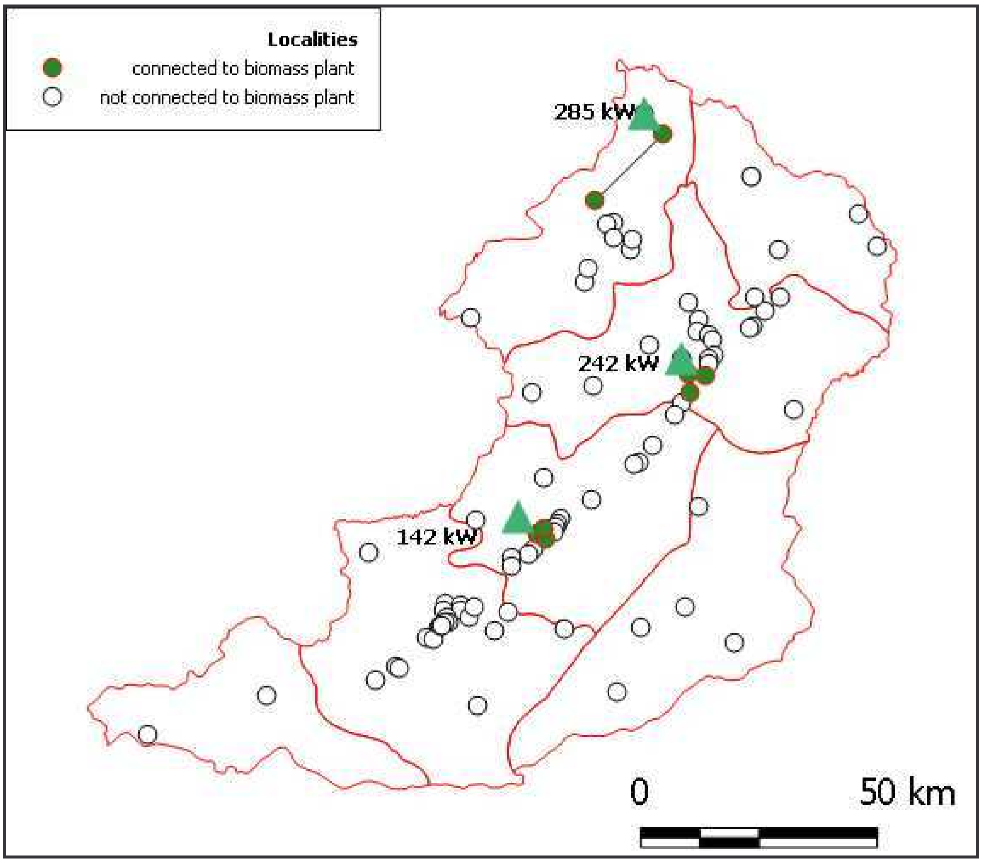
| | |
|---|---|
| **Population in clusters** | **80 569** |

- But one must keep in mind that these systems are not dimensioned to supply the corresponding areas with a continuous service.
- We don't study Nam Phak 12,5 MW plant project here because its capacity is far higher than potential peak demand of the Province. Data on other provinces would be necessary to make estimations. In the same idea, the area selected for Nam Phak 5,1 MW plant is entirely included in Oudomxay Province, what is not necessary the most relevant solution at the country scale.

### 5.3 Biomass plants

Biomass plants are dimensioned as hydro plants: so that supplied clusters have a potential peak demand forecast equal to plant installed capacity by year 10. Unlike hydro plants, biomass plants based on rice residues are able to produce power all along the year. So there is no need to implement diesel plants. But after a few years (between five and fifteen in our cases), biomass plant capacity is not enough anymore to answer whole demand.

The following map represents our three expected places for biomass plants and the clusters they supply:




Economical ananysis for these sites are given in following tables:

## Namo

| | | | |
|---|---|---|---|
| fuel cost (rice husk) | 10 | $/ton of paddy | |
| retail value of ashes | 8 | $/ton of paddy | |
| electricity production | 100 | kWh/ton of pad | |
| computation period | 15 | years | |
| biomass plant life duration | 25 | years | |
| discount rate | 0,08 | - | |
| | | | |
| kWh sold (years 0 to 14) | 12 709 000 | kWh | |
| Investment Cost | 498 750 | $ | |
| Residual Value (year 15) | 199 500 | | |
| Discounted Res Value | 62 891 | | |
| Investment - Disc Res Val | 435 859 | | |
| Fuel & OM Costs | 2,324 | cts/kWh | |
| total discounted O&M costs | 253 856 | $ | |
| Production expenses | 689 715 | $ | |
| **Production Cost** | **5,427** | **USc/kWh** | |
| | | | |
| distribution lines length | 25,8 | km | |
| Investment Cost | 283 800 | $ | |
| Transfo investment costs | 12 000 | | |
| Residual Value of (10) and (11) | 118 320 | | |
| Investment - Disc Res Val | 258 501 | | |
| total discounted O&M costs | 53 071 | $ | |
| **Distribution & transfo Cost** | **2,452** | **USc/kWh** | |
| | | | |
| **TOTAL AVERAGE kWh COST** | **7,879** | **USc/kWh** | |
| | | | |
| Annual Capacity | 1 000 000 | kWh | |
| Consumption year 0 | 728 000 | | 73% |
| Consumption year 5 | 801 000 | | 80% |
| Consumption year 10 | 900 000 | | 90% |
| Consumption year 15 | 1 000 000 | | 100% |
| | | | |
| Power capacity | 285 | | |
| Peak demand forecast year 0 | 152 | | 53% |
| Peak demand forecast year 5 | 173 | | 61% |
| Peak demand forecast year 10 | 205 | | 72% |
| Peak demand forecast year 15 | 232 | | 81% |
| | | | |
| **Population in clusters** | **3 626** | | |

## Xai

| | | | |
|---|---|---|---|
| fuel cost (rice husk) | 10 | $/ton of paddy | |
| retail value of ashes | 8 | $/ton of paddy | |
| electricity production | 100 | kWh/ton of pad | |
| computation period | 15 | years | |
| biomass plant life duration | 25 | years | |
| discount rate | 0,08 | - | |
| | | | |
| kWh sold (years 0 to 14) | 10 997 000 | kWh | |
| Investment Cost | 423 500 | $ | |
| Residual Value (year 15) | 169 400 | | |
| Discounted Res Value | 53 402 | | |
| Investment - Disc Res Val | 370 098 | | |
| Fuel & OM Costs | 2,324 | cts/kWh | |
| total discounted O&M costs | 219 438 | $ | |
| Production expenses | 589 536 | $ | |
| **Production Cost** | **5,361** | **USc/kWh** | |
| | | | |
| distribution lines length | 11 | km | |
| Investment Cost | 121 000 | $ | |
| Transfo investment costs | 18 000 | | |
| Residual Value of (10) and (11) | 55 600 | | |
| Investment - Disc Res Val | 121 473 | | |
| total discounted O&M costs | 22 627 | $ | |
| **Distribution & transfo Cost** | **1,310** | **USc/kWh** | |
| | | | |
| **TOTAL AVERAGE kWh COST** | **6,671** | **USc/kWh** | |
| | | | |
| Annual Capacity | 850 000 | kWh | |
| Consumption year 0 | 545 000 | | 64% |
| Consumption year 5 | 678 000 | | 80% |
| Consumption year 10 | 850 000 | | 100% |
| Consumption year 15 | 850 000 | | 100% |
| | | | |
| Power capacity | 242 | | |
| Peak demand forecast year 0 | 142 | | 59% |
| Peak demand forecast year 5 | 176 | | 73% |
| Peak demand forecast year 10 | 229 | | 95% |
| Peak demand forecast year 15 | 242 | | 100% |
| | | | |
| **Population in clusters** | **3 444** | | |

## Beng

| | | |
|---|---|---|
| fuel cost (rice husk) | 10 | $/ton of paddy |
| retail value of ashes | 8 | $/ton of paddy |
| electricity production | 100 | kWh/ton of pad |
| computation period | 15 | years |
| biomass plant life duration | 25 | years |
| discount rate | 0,08 | - |

| | | |
|---|---|---|
| kWh sold (years 0 to 14) | 7 312 000 | kWh |
| Investment Cost | 248 500 | $ |
| Residual Value (year 15) | 99 400 | |
| Discounted Res Value | 31 335 | |
| Investment - Disc Res Val | 217 165 | |
| Fuel & OM Costs | 2,324 | cts/kWh |
| total discounted O&M costs | 146 288 | $ |
| Production expenses | 363 453 | $ |
| **Production Cost** | **4,971** | **USc/kWh** |

| | | |
|---|---|---|
| distribution lines length | 4 | km |
| Investment Cost | 44 000 | $ |
| Transfo investment costs | 12 000 | |
| Residual Value of (10) and (11) | 22 400 | |
| Investment - Disc Res Val | 48 939 | |
| total discounted O&M costs | 8 228 | $ |
| **Distribution & transfo Cost** | **0,782** | **USc/kWh** |

| | | |
|---|---|---|
| **TOTAL AVERAGE kWh COST** | **5,752** | **USc/kWh** |

| | | |
|---|---|---|
| Annual Capacity | 500 000 | kWh |
| Consumption year 0 | 428 000 | 86% |
| Consumption year 5 | 500 000 | 100% |
| Consumption year 10 | 500 000 | 100% |
| Consumption year 15 | 500 000 | 100% |

| | | |
|---|---|---|
| Power capacity | 142 | |
| Peak demand forecast year 0 | 107 | 75% |
| Peak demand forecast year 5 | 129 | 91% |
| Peak demand forecast year 10 | 142 | 100% |
| Peak demand forecast year 15 | 142 | 100% |

| | |
|---|---|
| **Population in clusters** | **3 385** |

- But these estimations are very dependant on fuel cost and on the retail value of ashes. The cost considered in the upper table is not the paddy cost, but the cost of rice residues corresponding to one ton of paddy.
- The following table gives an idea of the influence of fuel cost and retail value on the life-cycle kWh cost:

| fuel cost | retail value | life-cycle kWh cost |
|---|---|---|
| 10 $/ton | 8 $/ton | 4,97 cts/kWh |
| 10 $/ton | 0 $/ton | 12,64 cts/kWh |
| 50 $/ton | 0 $/ton | 46,29 cts/kWh |
| 0 $/ton | 0 $/ton | 3,25 cts/kWh |

**Table 10: life-cycle kWh cost for Beng site**

## 5.4 Long Term grid extension and minigrids supplied by diesel plants

Main grid extension is often considered as the long term most interesting option, as bulk electricity production offers very cheap energy. The objective of this first part is to determine the ideal extension of the grid if financial capacities were unlimited and if enough power were available from the national grid to answer the whole electricity demand.

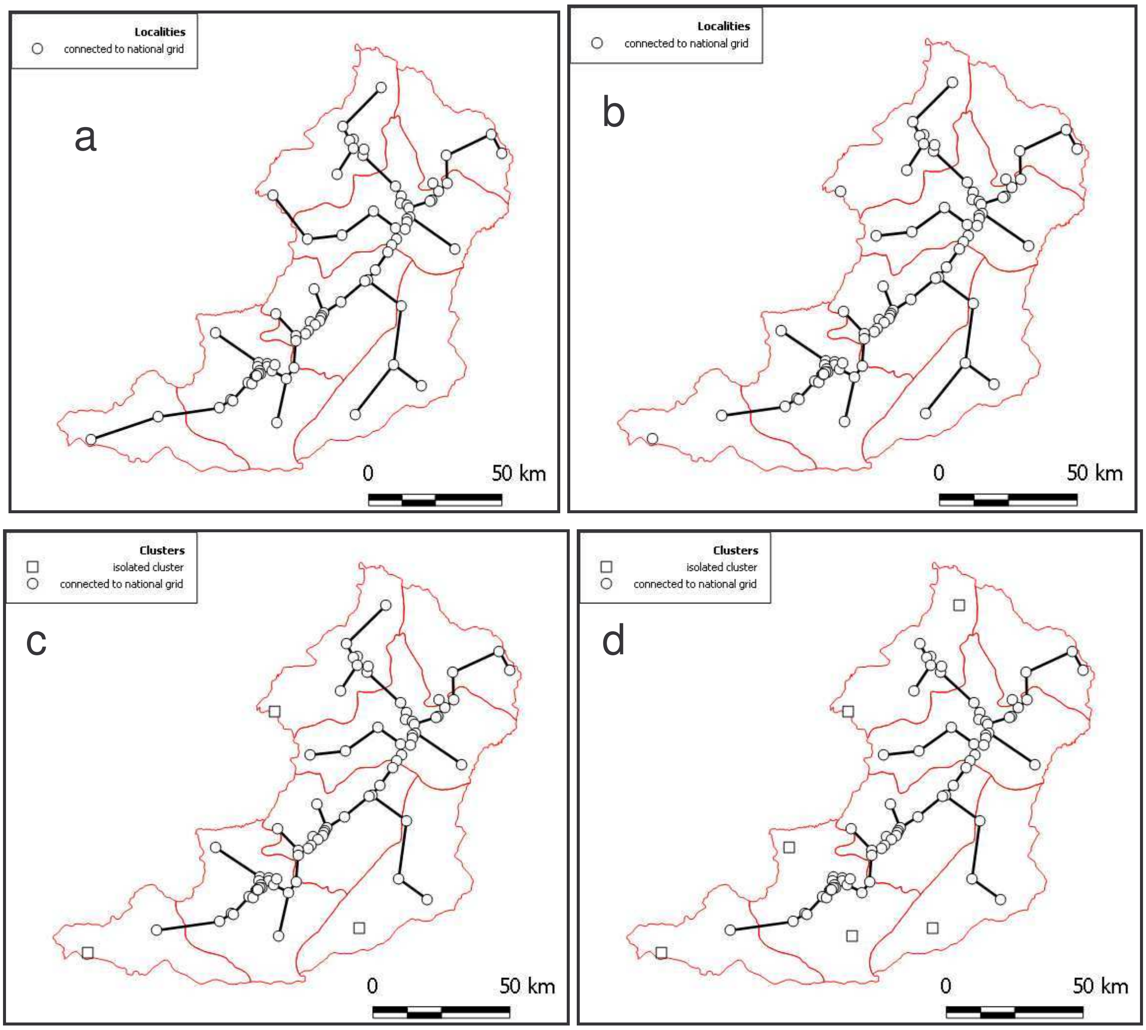
The algorithm connects a cluster to the main grid if the total discounted expenses all over the computation period are lower in the case of a connection (investment costs for lines and transformer, kWh cost at the substation) than in the case of production by a diesel plant. Each locality is thus studied and connected if necessary and the grid thus spreads.

The following figures reminds the parameters used:

**Figure 4: Parameters for long-term grid extension simulation**

| | | |
|---|---|---|
| computation period | 15 | years |
| Discount rate | 0,08 | - |
| diesel plant life duration | 7 | years |
| Operation and Maintenance | 2% of inv /year | |
| transmission line life duration | 25 | years |
| transmission line investment cost | 11000 | $/km |
| diesel plant investment cost | 33000+630*Capacity(kWh) | $ |
| fuel costs | 0,1 | $/kWh |
| transformer cost | 6000 | $ |
| transformer life duration | 25 | years |

- Even if our hypothesis for line costs are $9000/km, we take $11000/km for the simulation to take into account the fact that lines in the reality don't follow straight lines between localities. In the future the user will be able to choose to consider the distance along roads between two localities or the distance following the straight line. This can be done if data on roads grid are not available or to make computation times shorter.
- For lines and transformers, which life durations are longer than computation period, a residual value is taken into account with a linear rule: the residual value at year 15 is equal to ten twenty-fifths of the initial value. This residual value is then discounted and deducted from investment costs.
- Fuel costs are very hard to guess. 0.1 $/kWh is a high but prudent hypothesis.




**Map 12: Grid extensions if kWh cost in Oudomxay substation is 4.3 cts/kWh (a), 5 cts/kWh (b), 5.5 cts/kWh (c) or 6 cts/kWh (c)**

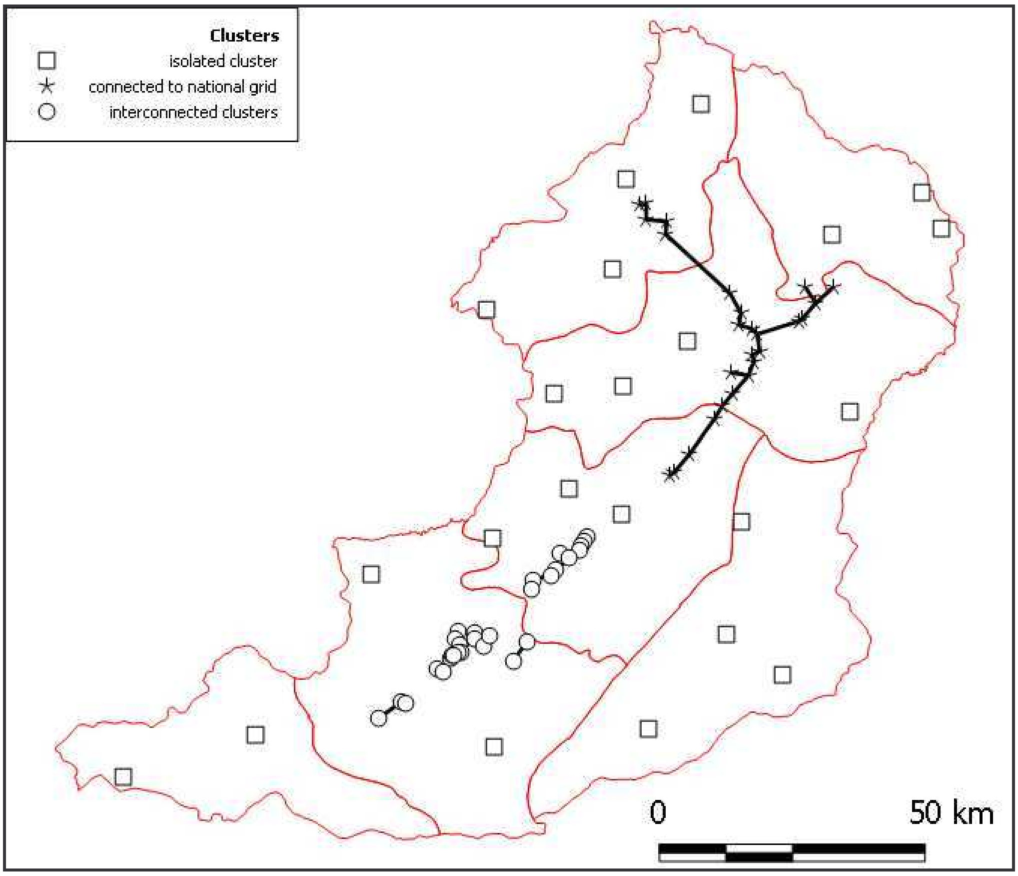
- We notice that connecting to national grid is always very interesting, as we considered a rather low cost for kWh in Oudomxay Substation.

## 5.5 Isolated diesel grids

- Our electricity demand forecasts and EdL planned investments let think that power available from the main grid will be enough to supply the whole province by year 20. However, we have no idea of financial capacities and as situation can change, we study the case of a limitation of power available from the main grid (for technical or financial reasons).
- The REDEO tool allows the user to choose the area that should be connected to the grid. The user can use several indicators such as:
    - IPD of localities
    - Population of localities
    - Distance to the substation…

- For all localities that are not likely to be connected to the national grid before 20 years, the alternative to renewable options are:
  - isolated diesel plant
  - clusters connected together to form a minigrid supplied by a diesel plant.

- The following map illustrates such a case (villages choosen to be supplied by the main grid are represented with crosses). The algorithm used here is similar to this one used to determine the ideal area to be supplied by the main grid if technical and financial capacities are unlimited.

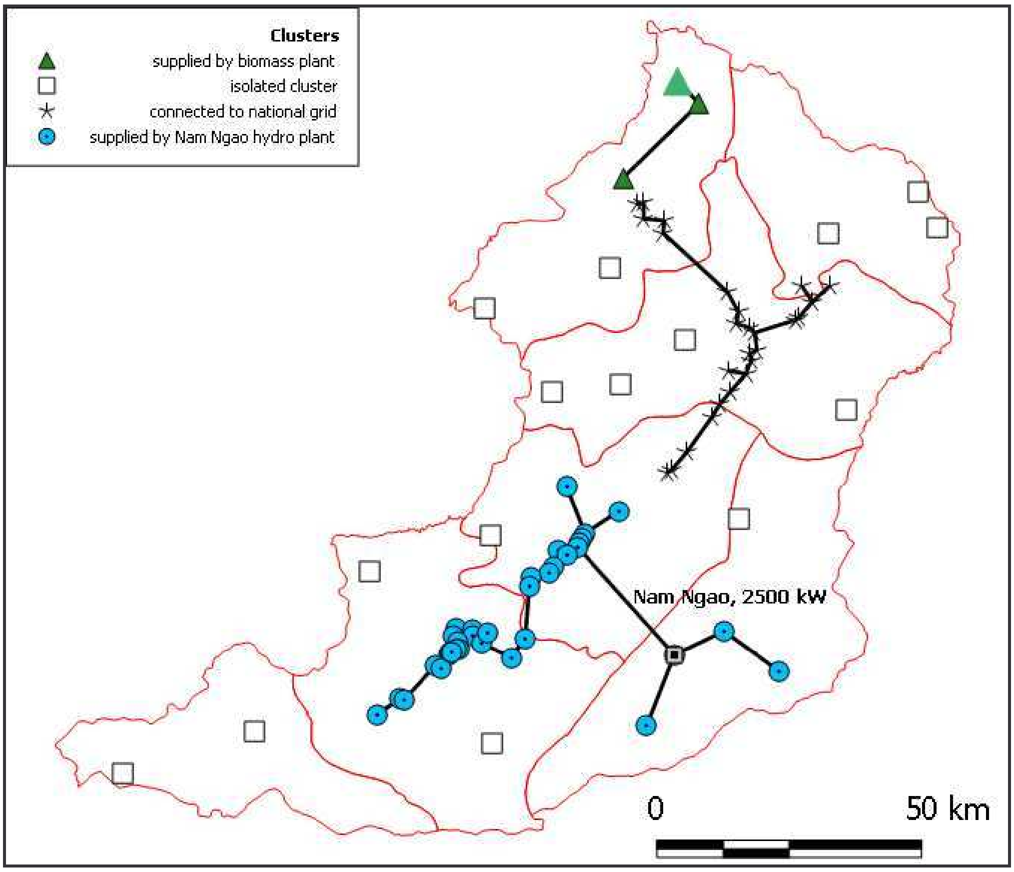


# 6 ECONOMICAL INDICATORS AND IMPACT ON DEVELOPMENT

## 6.1 Fictive scenario

The “electrification scenarios” module gave indicators on projects based on all our production options. The user can then build a scenario based on these projects. His choice can depend on available investment, political objectives, maybe national strategy…

We build an indicative scenario for Oudomxay Province, summarized by the following map.




**Map 13: Fictive electrification scenario**

## 6.2 Indicators by project

| n° | technology | pop. covered | investment cost | kWh life-cycle cost | annual O&M costs (y0) |
|---|---|---|---|---|---|
| 1 | hydro | 45 835 | 6 000 000 | 4,75 | 120 000 |
| 2 | grid extension | 31 255 | 1 201 000 | 4,7 | 11 150 |
| 3 | biomass | 3 626 | 498 750 | 3,708 | 27 000 |
| 4 | isolated clusters | 38 757 | variable | 8-9 cts/kWh | |
| | TOTAL | 119 473 | 7 699 750 | | 158 150 |

**Table 11: Main indicators on selected projects**

- One must here keep in mind that life-cycle cost given for hydro project doesn't include the cost of diesel systems implemented to replace hydro technology during dry season and at peak times after year 10.
- The figures given for population coverage are for year 0 and concern the population living in localities supplied by the corresponding projects. To obtain estimations of population supplied, one have to tak population growth rates and penetration rates into account.

### 6.3 Global indicators

| Category | Sub-category | Indicator | Unit | Formulas | year 0 | year 10 | year 20 |
|---|---|---|---|---|---|---|---|
| Impact on development | Status of electrificati | Households electrification rate | % | Nb of households being electrified / Total number of households | 27% | 46% | 55% |
| | | Localities electrification rate | % | Nb of localities being electrified / Total number of localities | | 71% | |
| | Impact on health | Percentage of health centers being electrified | % | Nb of health centres being electrified / Total number of health centres | | 100% | |
| | | % of population having access to « electrified » health center | % | Nb of people in localities where closest health centre is electrified / Total population | | 100% | |
| | | Mean distance to a non-electrified health center | Km | Sum of distance to a non-electrified health centre for all localities / Total number of localities | | 17,10 | |
| | | Mean distance to an electrified health center | Km | Sum of distance to a electrified health centre for all localities / Total number of localities | | 17,10 | |
| | Impact on education | Percentage of schools being electrified | % | Nb of schools being electrified / Total number of schools | | 71% | |
| | | % of population having access to « electrified » primary school | % | Number of people localities for which closest primary school is electrified / Total population | | 40% | |
| | | Mean distance to a non-electrified primary school | Km | Sum of distance to a non-electrified primary school for all localities / Total number of localities | | 1,16 | |
| | | Mean distance to an electrified primary school | Km | Sum of distance to a electrified primary school for all localities / Total number of localities | | 2,57 | |

**Table 12: impact on development indicators**

- Given households electrification rates take into account population growth rates and penetration rates.
- Figures on electrified health center are not very significative. Only eight health centers are registered in GIS database. The are all concerned by the fictive scenario. Statistics thus indicates that 100% of population have access to electrified health center, because nearest health center is electrified. But the distance to reach this nearest health center can be very long (30 km).

# 7 CONCLUSION AND IMPROVEMENTS

This case study gives a first idea of REDEO decision aid tool possibilities. For Oudomxay Province, it reveals that main grid extension is apparently the best long-term solution for all CHPDs. The fact that localities situated in the neighborhood of CHPDs have systematically been taken into account can explain that potential demand forecast is rather high and that grid extension is interesting. Maybe an other approach only based on biggest cities would have given very different results. However, even if efforts have been done to promote local development, this aspect can considerably be improved by using a precise analysis of industrial potential of each secondary center. By considering those developing centers and by providing them continuous and good-quality electricity services, rural electrification planning can be an effective tool for economical policy and land-use planning.

Except this fundamental aspect, other things can easily be improved, as:

- Taking distance along roads into account

- Considering diesel plants investment costs better adapted to local context, and more generally having better estimates on all costs (kWh from national grid, diesel cost, rice residue costs...).

- Considering other technologies than rice residues for biomass plants

- Having better estimates on future industrial energy consumptions.

# 8 REFERENCES


[1] Power Development Plan 2004-13, EdL, March 2004

[2] North Area Rural Power Distribution Project main report, Acres International (Canada), September 2002

[3] Rural Electrification Frameworks Study, Maunsell, June 2004

[5] The Master Plan Study on small hydropower in Northern Laos, JICA, November 2004

[6] Biomass energy for electricity production: the case, potential, experience and challenges in the ASEAN Region, ICRA-IED, February 2005