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# 1 SREP PROJECT CONTEXT

## 1.1 OBJECTIVES OF THE STUDY AND TARGETS OF THE ROYAL GOVERNMENT OF CAMBODIA

In 2009, MIME approached the French Embassy in Phnom Penh for support in capacity building at the Ministry on rural electrification planning. A work plan was discussed with IED, Innovation Energie Développement, comprising 3 components:

1. Elaboration of Sustainable Rural Electrification Plans, using the GEOSIM tool (www.geosim.fr) for different fund availability options, combining national grid expansion and mini grid options, as well as stand alone options. These results are presented in this report;
2. Training of team of MIME staff on the use of GEOSIM and transfer of the tool and methods to the Ministry, with a hands on approach;
3. Feasibility studies for 3 to 5 renewable energy based mini grids and exploring the possibility of mobilising investors for actual construction of the mini grids, in private public partnership approach.

Upon approval by the Minister of Energy, H.E Tun Lean, general director of Energy department, MIME, signed a Memorandum of Understanding (MoU) with IED on the Ministry's behalf. The MoU is effective since 29th January 2010.

The study was launched in a context of extremely ambitious political targets wherein the current policy objectives are:

- **By 2020, all villages should have access to electricity** of different forms. Electrification is defined here as a village where more than 50% of households receive some form of electricity supply, including from batteries with access to a battery charging system
- **By 2030, 70% of rural households should have access to grid quality service** (24-hour mini-grids or national grid) at acceptable price level and with minimum subsidy from the government.A recent document prepared by EAC has added new targets, which supplement the previous ones, while being slightly more ambitious:
- **By 2020, 80% of villages should have access to the national grid, and the remaining 20% should have access to mini-grids**
- **By 2030, 95% of villages should have access to the national grid**

Moreover, a recent commitment taken as part of the ASEAN aims at **reaching 15% of new and renewable energy by 2015** (every member country took the same comittment). This target does not include large hydro, which implies significant development of medium sized Renewable Energy projects, such as the ones suggested in this study.

In this context, MIME has entered into a collaboration with IED with support of the French Government (FASEP fund), in order to translate these broad and ambitious policy targets for rural electrification into concrete provincial investment plans, supported by maps showing the spatial arrangement of the proposed projects. These investment plans will strengthen the credibility of long term energy policies, and can be used as a tool in negotiations with international donor agencies.

Available financial resources will be matched with the requirements of the policy targets. In a context of constrained budget, the approach will provide insight on the way to prioritise projects: higher preference will be given to those which maximize the impact of social and economic development, i.e. projects supplying "Development Poles", or "Growth Centres" (cf. 2.2 for further details on the specificities of the approach).

Therefore, the present planning study comes as a downstream step of:

- The previous institutional, legal and regulatory projects by the World Bank, which put in place institutions (REF) and guidelines for responsibilities of the various actors (cf. "Rural Electrification Strategy and Implementation Plan")
- The macro-level transmission and regional interconnection projects (e.g. "Power Sector Development Plan"), which left small-scale projects and medium voltage extension issues aside
- The renewable energy potential reviews (e.g. "Master for Rural Electrification from Renewable Energy"), which need to be updated and further detailed with sizing and prioritisation of projects

Moreover, because of uncertainties on forecast assumptions and rapid changes in the situation of the country (for example in the agro-industry sector or grid extension planning, as mentioned above), every planning exercise needs to be updated regularly. That is why the project goes beyond the mere production of a Master Plan document, and strives to transfer the planning tool to MIME. MIME will indeed play a key role in all activities, covering data collection and production of plans as part of Memorandum of Understanding between IED and MIME.

Finally, to better illustrate the transition from the planning exercise to project implementation, feasibility studies are carried out on a few interesting projects identified at planning stage, and possible investors and financing schemes will be sought.

The main components of the Rural Electrification Strategy in Cambodia are:

- Grid expansion from the existing network, with a priority to areas within 40km of the 24 provincial towns (where more than 80% of the population lives)
- Cross-border Power Supply from neighbouring countries (Thailand, Vietnam and Lao PDR)
- Mini-utility systems for remote areas, based on:
    - Diesel gensets (to be phased out in as much as feasible)
    - Decentralized renewable energy (solar, wind, mini-micro hydro, biomass, bio-fuel, etc…)
    - Stand-alone systems (PV, battery charging…) where demand is too low or too scattered
    - Rural Entrepreneurs, NGOs and woman's groups shall be encouraged to participate in the management at the local level. Private participation is encouraged wherever electrification is profitable, otherwise EDC shall come in as public service provider in priority areas.

All these options will be combined in the study to suggest the optimal path to meet government targets. We provide hereafter a brief review of the activities in the work programme, and their current status.

## 1.2 OUTPUTS

The four main outputs of the project are:

- Concrete investment plans, with lists of projects in table and detailed report format allowing actual programming and prioritisation taking into account national and provincial level objectives, physical and financial constraints.
- Trained national MIME staff, which will train in turn provincial authorities on rural electrification planning, using the GEOSIM software tool. National team will be actively involved in all the steps of the planning process, from data collection, practical use of GEOSIM and feasibility studies.
- 2 to 5 feasibility studies for projects with capacities between 50kW and 2MW. Technologies considered are small hydro, bio-electricity (gasification, biogas or co-generation),

geothermal power and hybrid PV/diesel systems. These feasibility studies will be used in mobilisation of private sector to actually implement projects.

- Dissemination of information and mobilisation of private sector to implement projects through drafting of operational business models and organisation of regional events.

## 1.3 ACTIVITIES RELATED TO PROVINCIAL RURAL ELECTRIFICATION PLANS

Rural electrification plans have been made, and are presented in this report. Results at national level are discussed in the first chapters, and province level reports for all provinces, excluding Phnom Penh are provided seperately.

Activities carried out include:

1. Creation of a comprehensive national Geographic Information System (GIS) database, to run the GEOSIM Rural Electrification planning model.
   - Creation of a database, from secondary supplemented with additional data collection in close collaboration with MIME The outcome of data collection activities is explained in more detail further.
   - Data collection at national level.
   - Socio-economic and multisector data (demography, health, education, commerce…), in order to update already available data and select priority localities with high potential for social and economic development (Development Poles). The Ministry of Planning database (former SEILA programme) with detailed socio-economic data from the General Population Census of 2008 has been the main input at this stage.
   - Villages covered and MV lines of existing electricity providers, both REEs (Rural Electrification Enterprises) and EDC, have been collected from EAC and EDC.
   - Final results of national grid extension plans have been collected from EDC for the national grid extension (HV and MV lines, substations) up to 2020.
   - Large businesses, which could benefit from electrification, have been collected from Industry Department of MIME.
   - Location of existing and planned bridges on national rivers have been taken from Ministry of Public Works and Transport (MPWT), important to plan grid network extension across the Mekong and Bassac rivers.
   - Data collection at provincial level.
   - Definition of 4 homogenous study areas (cf. Annexes), with a “regional kick-off workshop” held in each region, so as to explain to provincial authorities (PDIME) the whole approach, get some feedback from them on already collected data, assess the data collection needs and present the method and timeframe to collect remaining data.
   - A nation-wide database of rural industries and agro-industries (about 20,000 businesses), has been established from databases collected from provincial authorities (PDIME). Then the most relevant industries have been selected for field surveys to gather additional data.
   - MIME and PDIME staff have been trained on the survey, and then sent in teams throughout the country, to interview more than 150 industries.
   - Other data collected from PDIME (through databases, workshops and phone interviews) include: validated Development Poles, updated socio-economic data, list of non licensed REEs, number of small businesses, ideas of additional potential hydro and biomass sites to further study.

2. Identification of Decentralised Renewable Energy potential for Rural Electrification, with installed capacities ranging from 50kW to 2MW1.
    - Identification of hydro potential sites (micro and mini hydro) based on previous studies, analysis of maps and hydrology (rainfall and water flow) in 4 priority provinces[2].
    - Summary site visits to produce site identification profiles for planning purposes in the 4 provinces.
    - Identification of biomass to electricity potential sites, which implied detailed information collection on agro industries and their available biomass residues (cf. above).
    - Identification of opportunities for hybrid PV/diesel systems in areas where the hydro and biomass potentials are not sufficient.
3. Review of relevant past and ongoing studies, in order to:
    - Analyse data on end-use consumption.
    - Assess the rural electrification baseline (current situation of access to electricity in the country).
    - Supplement other sources regarding hydro and biomass potential.
4. Definition of planning scenarii.
    - In discussion with Cambodian authorities (EDC, EAC, MIME), 3 scenarii have been defined, corresponding to different level of grid extension over the next 20 years: from the "optimistic" targets of EDC extension plans, to more conservative scenarii.
    - Planning objectives and constraints have thus been reviewed – target connections and villages covered, time horizon, financial constraints, secured financial resources, overall strategy.
    - Development of scenarii with the GEOSIM software to produce operational investment plans for renewables and rural electrification, including programming of investments, maps, investment costing tables as well as GIS database.

[1] The 50kW threshold corresponds to village scale/community systems, and are beyond the scope of a planning exercise at national level. On the other hand, sites above 2MW are relatively large compared to the existing power system, and thus belong to grid generation expansion planning, rather than rural electrification planning.

[2] These 4 provinces have been given by MIME: Mondul Kiri, Rattanak Kiri, Pursat and Battambang.

# 2 METHODOLOGY AND APPROACH

## 2.1 NATIONAL CONTEXT

### 2.1.1 Institutional context

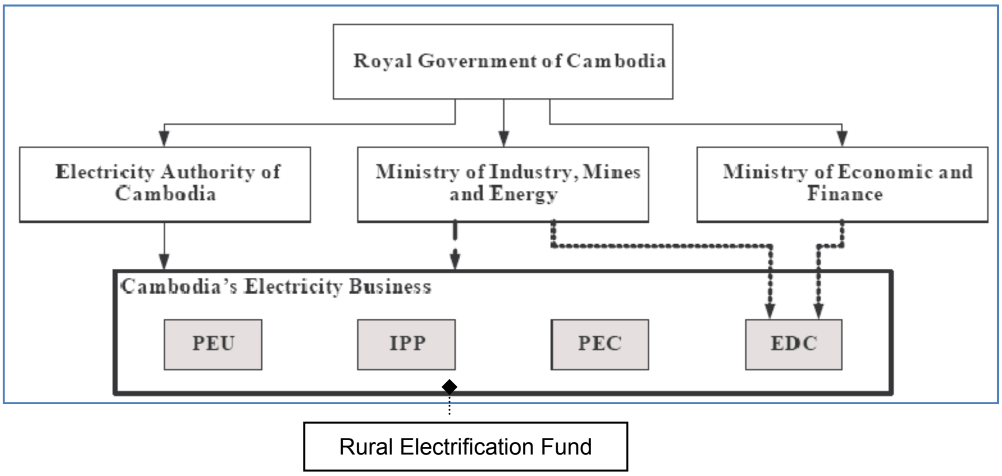
Article 3 of electricity law defines the responsibility between two main institutions: Ministry of Industry, Mines and Energy (MIME) and Electricity Authority of Cambodia (EAC), in the power sector. The roles of the two organisations as well as other institutional arrangements are shown in the following picture.

EDC is a state owned corporation under MIME, which owns and operates the Phnom Penh main generation, transmission and distribution assets, as well as in several provincial towns and accounts for approximately 90% of total electricity consumption of the country, if Independent Power Producers (IPPs) selling power to EDC are included. EDC has a non-exclusive responsibility for generation, transmission, distribution and retail of electricity throughout Cambodia. The remaining electricity consumption is supplied through rural electrification enterprises (REEs) and small generators.

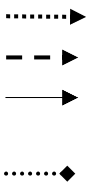
Finally, the recently created Rural Electrification Fund (REF) aims at supporting financially and technically the decentralized rural electrification projects.

At provincial level, the Provincial Departments of Industry, Mines and Energy (PDIME) which depends on MIME and on Provincial authority, plays a key role in implementation of rural electrification programs, but not very actively participate in the formulation of policy and measures.

Figure 1: Current institutional structure of Cambodia energy sector




Note : PEU – public electricity utility; IPP – Independent power producer; PEC – Private electricity company (or REE – Rural Electricity Enterprise); EDC – Electricité du Cambodge



Ownership control of EDC

Policy, strategies planning, development, technical, safety and environmental standards

Regulations, issue licences, review the planned investments, finance & performance, enforce regulation, rules and standards

Provides subsidies and technical assistance for diesel REEs, mini and micro hydro projects and Solar Home Systems (SHS)

### 2.1.2 Status of power sector and rural electrification

The electric power system in Cambodia was reconstructed from the ruins since the 80's. It still consists of isolated systems with the biggest systems in Phnom Penh capital (67% of total energy generated in 2009) and several non-interconnected grid in provincial towns under EDC and many mini-grid systems provided by scattered rural electrification enterprises (REEs, private energy providers). These systems can be grouped into three categories

EDC supply systems (22 not interconnected supply areas in Phnom Penh and provinces). Of the 1100 GWh generated on these networks in 2009 (excluding imports), 89% have been ensured by Independent Power Producers (IPPs), operating mostly fossil fuel thermal power plants. In 2009, there were also 25 private distribution Rural Energy Enterprises (REE) purchasing bulk power from EDC and selling it to their customer,

"Consolidated" (generation and distribution) REEs. At the end of 2009, there were 197 such licensees, mostly mini-grid with diesel systems.

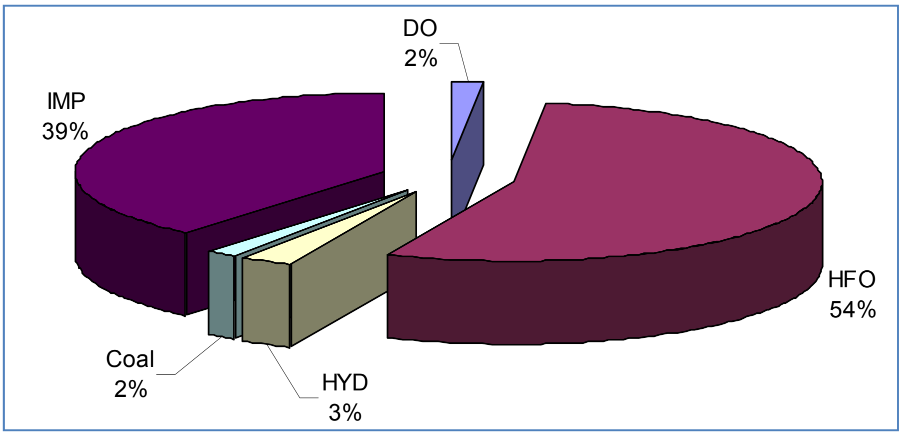
Non-licensed REE power supply systems unknown number, estimated several hundreds (cf. next chapter).

At the end of 2009, the total installed capacity in Cambodia (excluding imports) was about 395 MW, distributed between EDC (77 MW), IPPs (265) and small consolidated licensee (REE, 43 MW).

The electricity prices in Cambodia are currently the highest in the ASEAN region and even the world: up to 17 UScts/kWh for EDC customers, and up to 1 USD/kWh for customers of diesel-based REEs, which must bear significant production costs caused by inefficient second-hand gensets and poorly designed distribution mini-grids. That is why rechargeable car batteries are still commonly used throughout the country (92% of villages according to 2008 village database), even among electrified villages (78% of electrified villages).

The main reason for such high tariffs in EDC areas is the predominance of fossil fuels in the energy mix. National generation without imports is 95% thermal (mostly Heavy Fuel Oil - HFO) with a small share of hydro as shown in Figure 4. In terms of installed capacity, the proportions are the same, with 353 MW of Diesel/HFO, 13.4 MW of hydropower, 13 MW of coal power plant and about 5 MW of wood & biomass power plants.

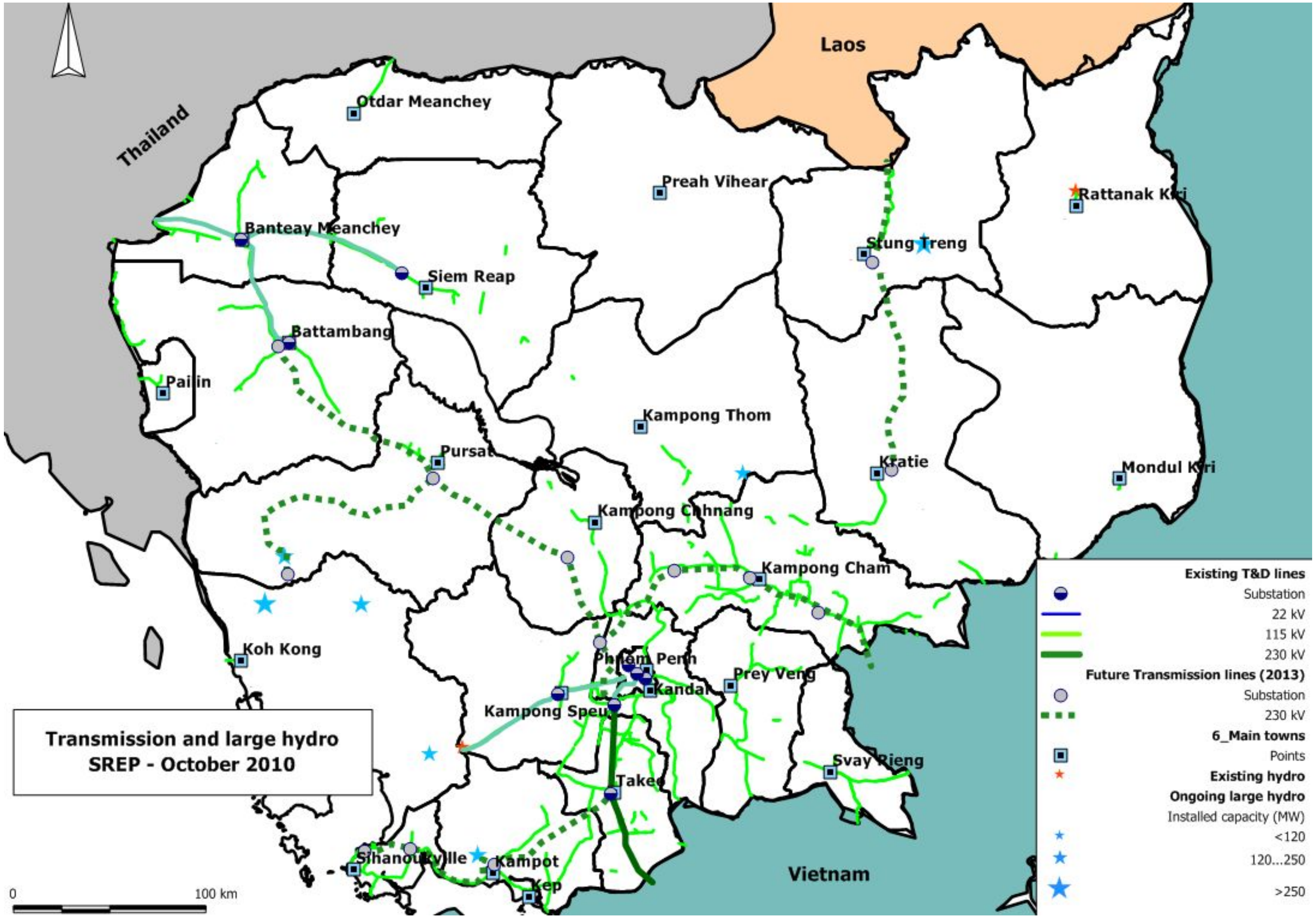
Figure 2: Energy mix for generation in EDC areas in 2009 (Source: EDC, 2010)



The current generation facilities are not only too expensive, but also insufficient to cope with the surging demand. Interconnection of isolated systems and import of electricity from neighbouring countries are thus considered an appropriate short and mid-term strategy to meet surging demand, while also keeping generation costs at reasonable levels (current imports from Vietnam and Thailand are at a price of 7 to 9 UScts per kWh). As shown in Figure 2, 40% of the 1,818 GWh generated in 2009 have been imported (EDC, 2010). Interconnections with neighbouring countries are happening at all voltages levels, from low voltage to high voltage. Recently commissioned high and medium voltages lines are:

- 115 kV line from Thailand to Banteay Meanchey, Siem Reap and Battambang
- 230 kV line from Vietnam to Phnom Penh
- 22 kV line from Laos to Stung Treng
- 35 kV line from Vietnam to Kampong Cham
- Upcoming import transmission lines are:
- 35 kV lines from Vietnam to Mondul Kiri and Rattanak Kiri (2011)
- 230 kV line from Vietnam to Kampong Cham and Phnom Penh (2012)
- 230 kV line from Laos to Stung Treng and possibly Kratie (2013)

Figure 3: Cambodia power system and short term hydropower and transmission plans (source: EAC & EDC, 2010)



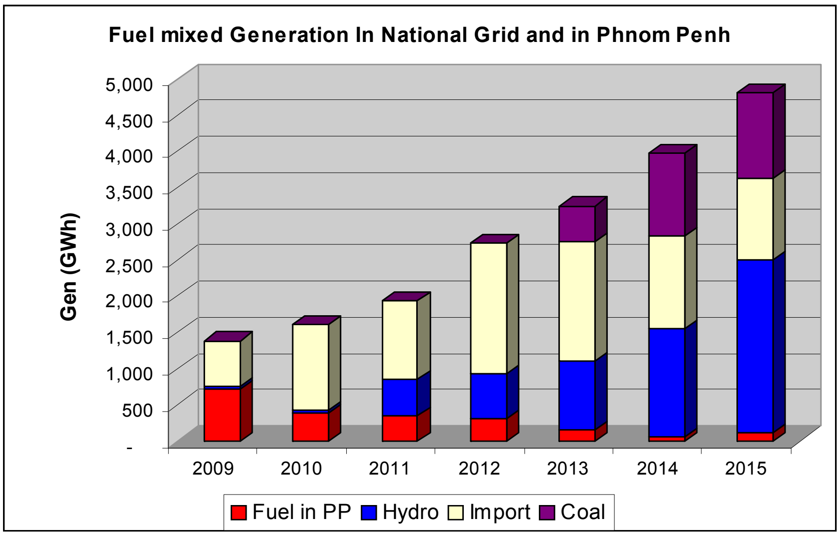
As the power demand is expected to continue its growing trend in the near future, and considering current power shortages in nearby countries, the long term strategy relies on development of local low cost generation capacity, mostly large hydropower projects. Several such projects have indeed been undertaken recently under Chinese financing:

5 hydro projects totalling 900 MW are under construction in the Cardamoms Range (Pursat, Koh Kong and Kampot provinces) and planned for commissioning between 2011 and 2015

Another project of 420 MW is seriously under consideration in Stung Treng

Coal power is also considered to some extent, with a 200 MW coal power plant in Sihanoukville (first 100 MW to be commissed by 2013).

Figure 4: Forecasted evolution of energy mix in EDC areas (source: EDC 2010)

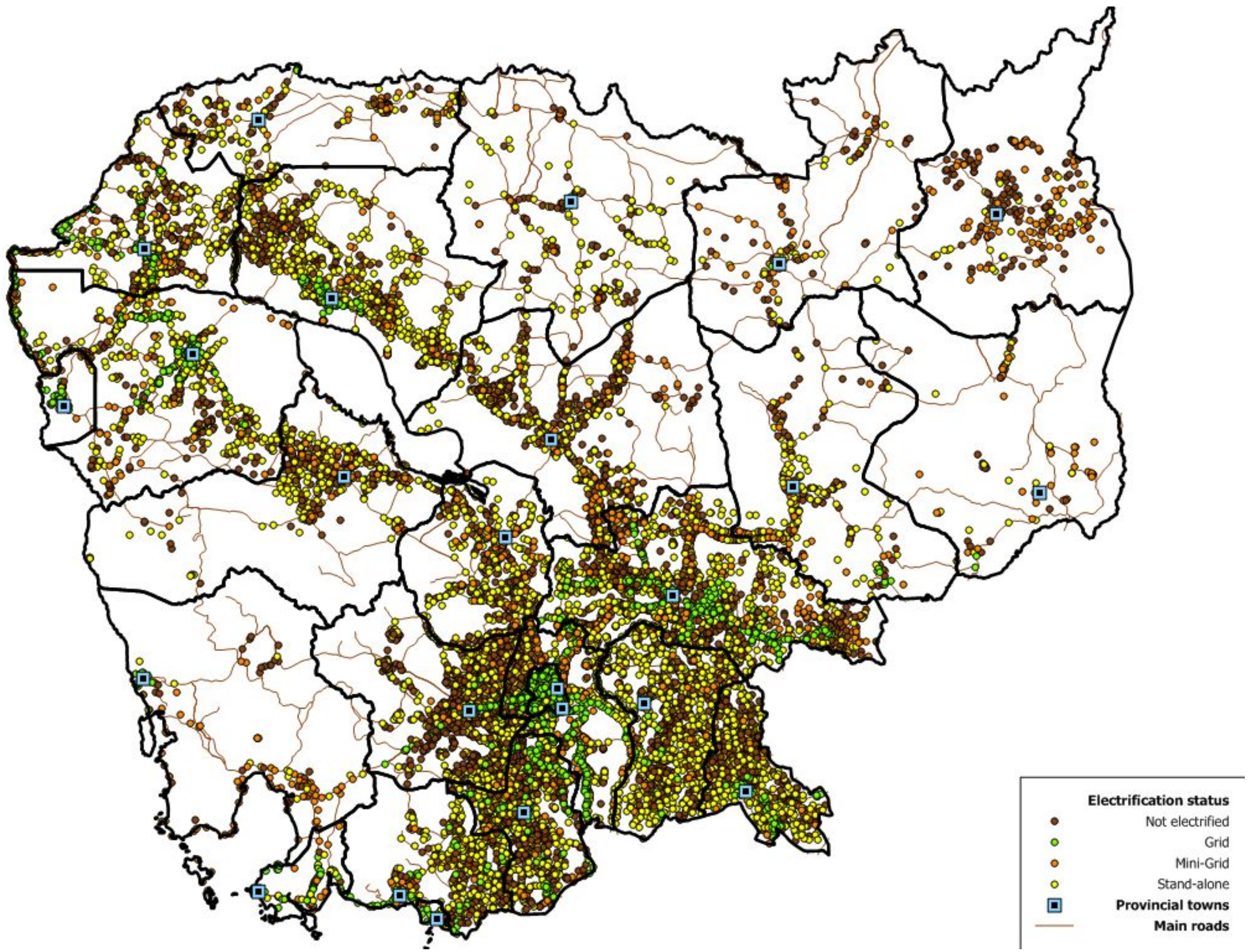



In parallel to these generation expansion activities, interconnection of all major power systems is planned. However, some areas such as Kampong Thom and Preah Vihear will probably remain isolated from the rest of the country for a at least 5 to 10 years.

In the medium-term, all these projects are expected to significantly reduce generation costs on the national grid (from a current average of about **12 UScts/kWh**), and thus the retail tariff to the end-user, allowing even provisions for cross-subsidisation of rural electrification.

However, the issue of actual access to the national grid remains, with only about **25%** of household having access to electricity nationwide, and only half of this from the national grid (the rest being isolated REEs). An ambitious medium voltage extension programme is led by EDC to tackle this issue, tapping resources from various donors (World Bank, ADB, Chinese Exim Bank, AusAid, KfW etc.), but this will take time and the corresponding financial resources are not yet secured. Therefore, off-grid renewable energy-based technologies are believed to have a role to play in the overall strategy to increase access to electricity in the short term.

Figure 5: Electrified villages in Cambodia in 2008. Brown are villages without electricity, yellow are villages with total or partial access to electricity (Source: Village Database 2008 from Ministry of Planning, elaborated by this study)



### 2.1.3 Focus on private rural electricity enterprises

This chapter aims at providing an overview of the REE sector, by combining and analysing data from the following main sources:

- EAC Annual Reports, and the last one in particular, covering the 2009 period
- The SREP database, including GIS data of REE licenses (last updated in October 2010) and GIS data of existing and planned MV lines by EDC

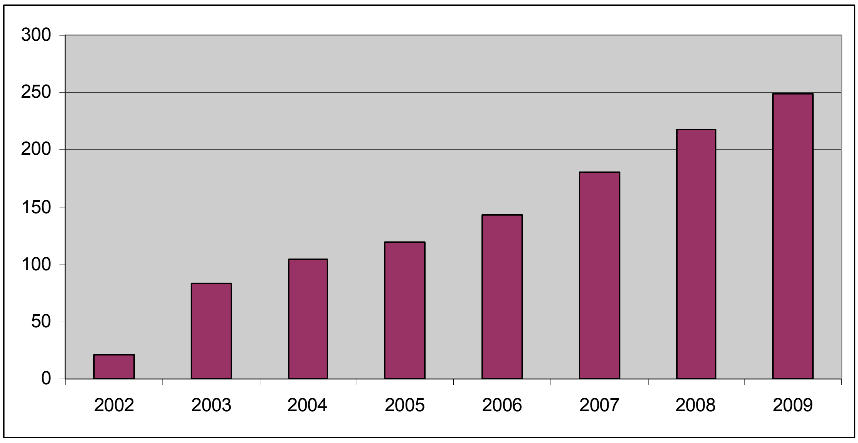
#### 2.1.3.1 Overall picture of the sector and trends

According to the latest EAC Annual Report, at the end of 2009 there were a total of 249 licensed electricity operators, including:

- **25** Distribution Licensees (distributing power purchased from the national grid or another power supplier)
- **197** Consolidated Licensees (generating and distributing power in isolated mini-grid systems)
- The remaining licensees are mostly Generation Licensees (only generating power for one of the interconnected networks) and Transmission Licensees (operating one of the high voltage transmission lines)

Although the official policy of EAC is to try and reduce the number of licensees eventually (through mergers), the historical trend until now has been a steady increase:

Figure 6: Historical trend of total number of licensees



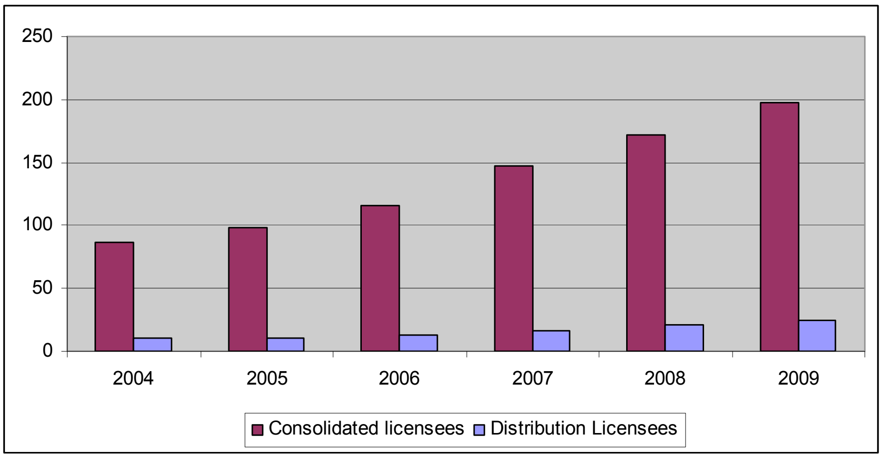

Accurate data for 2010 is missing, but provisional GIS data from October 2010 already shows a total of 267 licensees.

This increase in number of licensees does not necessarily mean they are all newly electrified areas, as there used to be a significant amount of unlicensed operators in the past, which have progressively acquired licenses. Therefore, we can reasonably expect a curb in the increase of new licensed REEs, at least in off-grid areas.

According to the SREP database, there are currently at least **815** villages electrified outside REE license zones, which would amount to about **200** non licensed REEs, assuming a ratio of 4 villages per REE (slightly lower than the average of 7 villages for Consolidated Licensees).

Although the number of Distribution Licensees remains modest, the number of both Distribution and Consolidated Licensees have increased at the same rate until, at 20% per year on average:

Figure 7: Historical trend of number of Consolidated and Distribution Licensees




Following the aggressive grid extension programme, it would seem that most of the licensed REEs will no more be isolated:

- The licensee zone of **96%** of current REEs will intersect with the national grid planned by EDC for 2020
- For Consolidated Licensees, which are not currently interconnected with the national grid, the average year of connection to the grid is **2013** (assuming grid extension happens as quickly as planned)

However, as EDC is not very much interested in taking on the responsibility of distribution and customer management, but interested in being a bulk supplier, the future configuration will probably that of REEs purchasing in bulk from the national grid. This will enable them to have much lower tariffs than currently, as the purchasing price from EDC will be much lower than the cost of diesel generation.

The current number of villages and clients supplied by REEs are given in the table below:

Table 1: Consumption, villages and households covered by licensed REEs in 2009

| | Villages in license zone | Villages connected | Village coverage rate | Number of village per REE |
|---|---|---|---|---|
| Consolidated | 3 267 | 1 183 | 36% | 6,6 |
| Distribution | 1 479 | 623 | 42% | 20,1 |

| | Households in electrified villages | Actual connections | HH connection rate | Number of connection per REE |
|---|---|---|---|---|
| Consolidated | 311 621 | 136 214 | 44% | 765 |
| Distribution | 171 505 | 76 859 | 45% | 2479 |

| | Energy purchased and generated (GWh) | Energy sold (GWh) | Losses | Average consumption per connection (kWh/month) |
|---|---|---|---|---|
| Consolidated | 53 | 42 | 21% | 26 |
| Distribution | 195 | 177 | 10% | 192 |

The above figures reveal that Distribution licensees are much larger on average than Consolidated ones, with 20 villages per licensee instead of 7, and about 2500 customers instead of 765. We can also notice that the connection rate in electrified villages is decent, at almost 50%. Finally, Consolidated licensees have much higher levels of distribution losses (21% against 10%), and lower specific consumption of their customers, which is consistent with the situation in rural areas where Consolidated REEs operate.

The total capacity of consolidated licensees was about **37 MW** at the end of 2009 (calculated from the installed capacities), which is about 10% of the total installed capacity in the country.

### 2.1.3.2 Market segmentation

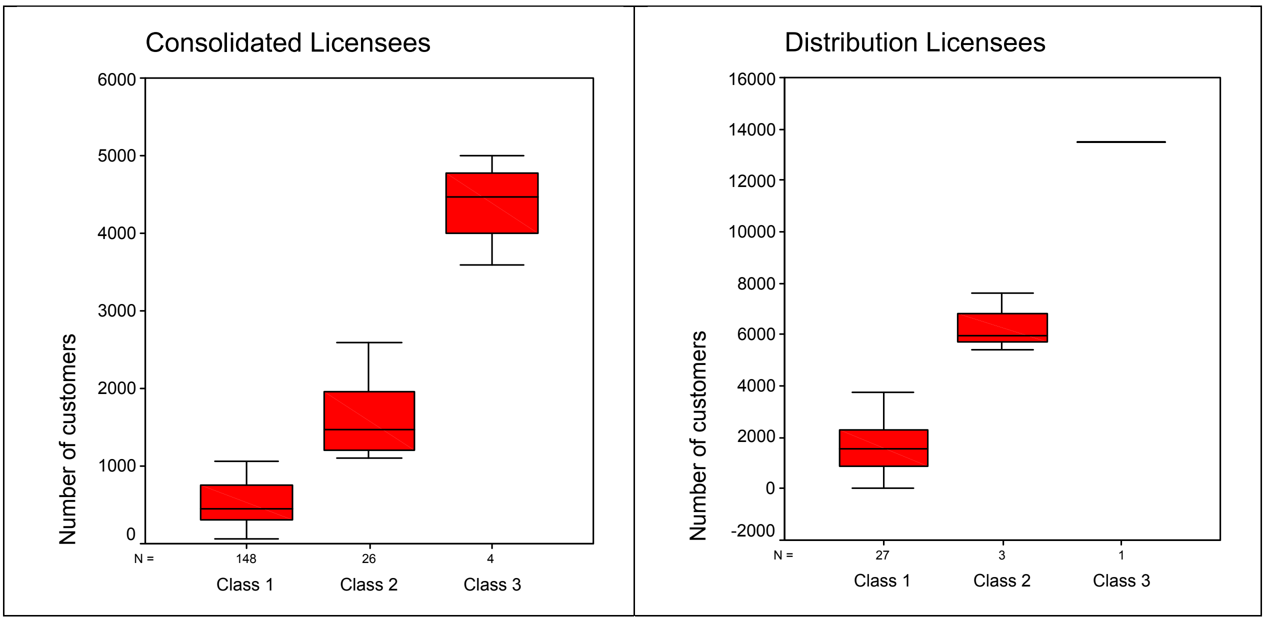
A database of REEs at the end of 2009 has been established (cf. annexes), by combining the different tables of the EAC reports, as well as GIS data from the SREP database. Among the 25 Distribution Licensees and 197 Consolidated Licensee mentioned in the 2009 EAC report, 13 are indicated as not operating and a few Consolidated Licensees seem to be operated as Distribution Licensees (only purchasing power and not generating). Therefore, the final breakdown of REEs suggested by this database is:

- **31** Distribution Licensees
- **178** Consolidated Licensees

From this database, the following market segmentation by number of clients is suggested (using a k-means statistical method):

**Table 2: Market segmentation of REEs, by the number of clients**

| | | Number of REE in class | Min number of clients | Max number of clients | Avg number of clients |
|---|---|---|---|---|---|
| **Consolidated** | Class 1 | 148 | 58 | 1 057 | **516** |
| | Class 2 | 26 | 1 100 | 2 586 | **1 628** |
| | Class 3 | 4 | 3 589 | 5 000 | **4 384** |
| **Distribution** | Class 1 | 26 | 4 | 3 768 | **1 641** |
| | Class 2 | 4 | 5 417 | 7 641 | **6 348** |
| | Class 3 | 1 | 13 506 | 13 506 | **13 506** |



Averages for the main characteristics of each segment are presented in the table below:

Table 3: Main characteristics (averages) of each market segment

| | | Electrified villages | HH conn. rate | Power purchase tariff (USD/kWh) | Retail tariff domestic (USD/kWh) | Installed capacity | Hours of service per day | Load factor while operating | Losses |
|---|---|---|---|---|---|---|---|---|---|
| Consolidated | Class 1 | 6 | 41% | N/A | 0,66 | 180 | 16,9 | 15% | 21,5% |
| | Class 2 | 11 | 58% | N/A | 0,57 | 432 | 23,8 | 18% | 21,8% |
| | Class 3 | 24 | 71% | N/A | 0,38 | 588 | 24,0 | 36% | 21,6% |
| Distribution | Class 1 | 18 | 51% | 0,15 | 0,35 | N/A | 24,0 | N/A | 12,3% |
| | Class 2 | 34 | 47% | 0,18 | 0,27 | N/A | 24,0 | N/A | 12,5% |
| | Class 3 | 31 | 48% | ? | 0,24 | N/A | 24,0 | N/A | 4,0% |

As shown in this table, technical losses are much higher for Consolidated than Distribution licensees, although there is not any difference between different classes inside the two groups.

Smaller Consolidated REEs (class 1) tend to have non continuous service (less than 24h), lower connection rates, lower load factor, and probably much less efficient gensets (although no data can confirm this assumption). All these factors result in much higher retail tariffs for smaller licensees (66 UScts/kWh on average for class 1 Consolidated !).

Obviously, generation costs of Consolidated Licensees being much higher than the power purchase tariff from the grid for Distribution Licensees (15 UScts/kWh for Class 1, and 18 for Class 2), the retail tariff is much lower for Distribution than for Consolidated Licensees.

#### 2.1.3.3 Potential for efficiency gains

Current REEs have very high levels of energy losses:

- At generation level: using old second-hand gensets
- At distribution level: few REEs are using Medium Voltage lines even if their license zone is very spread out, and many distribution mini-grids are poorly designed (unbalanced phases, wrong cable and transformer sizing etc.)

The case study of Chambak REE carried out by SREP (in view of installing a PV/Hybrid system) revealed an extraordinarily high level of distribution losses, at 40%, combined with a diesel specific consumption of 0.43 L/kWh. Following installation of MV lines, as well as improvements on the existing LV lines, distribution losses are expected to drop to 10%, which is the standard set by EAC. Moreover, replacing the existing gensets by efficient ones could lower the specific consumption to 0.3 L/kWh. All these actions would lower the total diesel consumption per kWh sold from 0.72 L to 0.33 L (~50% decrease) !

To assess the potential for efficiency gains at the national level, we can do the following assumptions:

- The current average diesel consumption for Consolidated Licensee can decrease from the current average of 0.35 L/kWh (conservative estimate, suggested by EAC) to 0.3 L/kWh. This would result in 12,000 L of diesel fuel savings per year (14 % of the current total consumption for Consolidated).
- Distribution losses can go down to a maximum of 10% for both Consolidated and Distribution Licensees, resulting in 10,500 MWh of electricity savings per year in total.

To assess the equivalent tons of avoided green house gases, we make the following assumptions:

- The emission factor of the national grid is 0.70 kg$CO_2$eq/kWh (Ministry of Environment, Feb 2011)

- The emission factor of the current Consolidated Licensees is 0.98 kg$CO_2$eq/kWh (corresponding to 0.35 L/kWh) and goes down to 0.84 kg$CO_2$eq/kWh (corresponding to 0.30 L/kWh)

The total corresponding emission reductions would be about 14,000 t$CO_2$eq per year, including 11,400 t$CO_2$eq for Consolidated Licensees and 2,600 t$CO_2$eq for Distribution Licensees.

### 2.1.4 Status of renewable energy development

The rationale for renewable energy as a rural electrification option may be presented in different ways, depending on the context:

On the national grid:

- Medium/large projects (hydro, biomass, and PV in the long term) can reduce overall grid generation costs
- Small/medium projects located close to demand, at the end of the lines, can reduce transmission losses

For mini-grids:

- Small renewable energy projects are usually competitive with current isolated diesel production costs under favourable financing conditions

For stand-alone systems:

- Various applications of solar PV and pico-hydro for remote areas: Battery Charging Stations, Solar Home Systems, bridge lighting, telecommunication systems, pumping…

However, until now the potential for renewable energy has been largely untapped, as revealed by the quick review below.

#### a) Hydro

Technical potential of hydropower in Cambodia is very high (more than 10000 MW for large hydropower and 300MW for small, mini and micro hydropower) but most of this potential has not been developed until now.

As of 2008, there are about 9 hydropower plants in operation in Cambodia with total capacity of 13.2 MW (Kirirom I and O Chum II alone amount to 13.0 MW) and representing about 3% of the total energy output of the country.

As explained in the previous chapters, several large hydropower projects are ongoing, with a combined installed capacity of about 900 MW.

However, excepting a few demonstration facilities powering remote provincial towns (such as Pailin and Sen Monorom), the situation for mini-hydro[3] remains much less dynamic, despite several initiatives such as UNIDO and REF programmes to develop mini-hydro powerplants. In fact, and contrary to large hydropower projects, which can afford to build hundreds of km of high voltage lines to transmit power to demand centre, mini-hydro have to rely exclusively on local demand. Therefore, one of the main challenges for minihydropower development in Cambodia is the very low population density in the areas where there is minihydro potential (mostly mountains in Cardamoms Range and North-Eastern provinces), as highlighted in the planning results of this report.

#### b) Biomass

Biomass resources such as wood (rubber trees, acacia, eucalyptus…) and agricultural residues (mostly rice husk, but also cashew nut shells, peanut shells, palm oil residues, dung…) are

[3] Between 50kW and 2MW

abundant in Cambodia. But similarly to hydropower, this theoretical potential has not been harnessed significantly until now.

Among the three main technologies considered (gasification, cogeneration and biogas), cogeneration and biogas usually require significant biomass input to be technically and economically feasible.

Until recently, few large scale agro-industries existed, and a large part of raw products have been exported to neighbouring countries for further transformation. A number of large existing agro-industries even went bankrupt.

Therefore, the most common biomass technology has been gasification of agricultural residues, either spontaneously (with imported and even locally manufactured equipments) or through international cooperation. A few examples of such projects:

A 200kW rice husk gasification project has been implemented in Battambang province, in a relatively large rice mill (2t rice processed per hour). Investment costs amounted to USUSD75,000 and the payback period was 3 years.

This pilot project has been followed by several other similar projects in rice mills, ice factories, brick factories and garment factories, only for their own consumption until now (about 40 projects commissioned between 150kW and 700kW). Some equipments are imported from India and distributed by a local company (SME Renewables), but there is now a market for locally manufactured gasifiers.

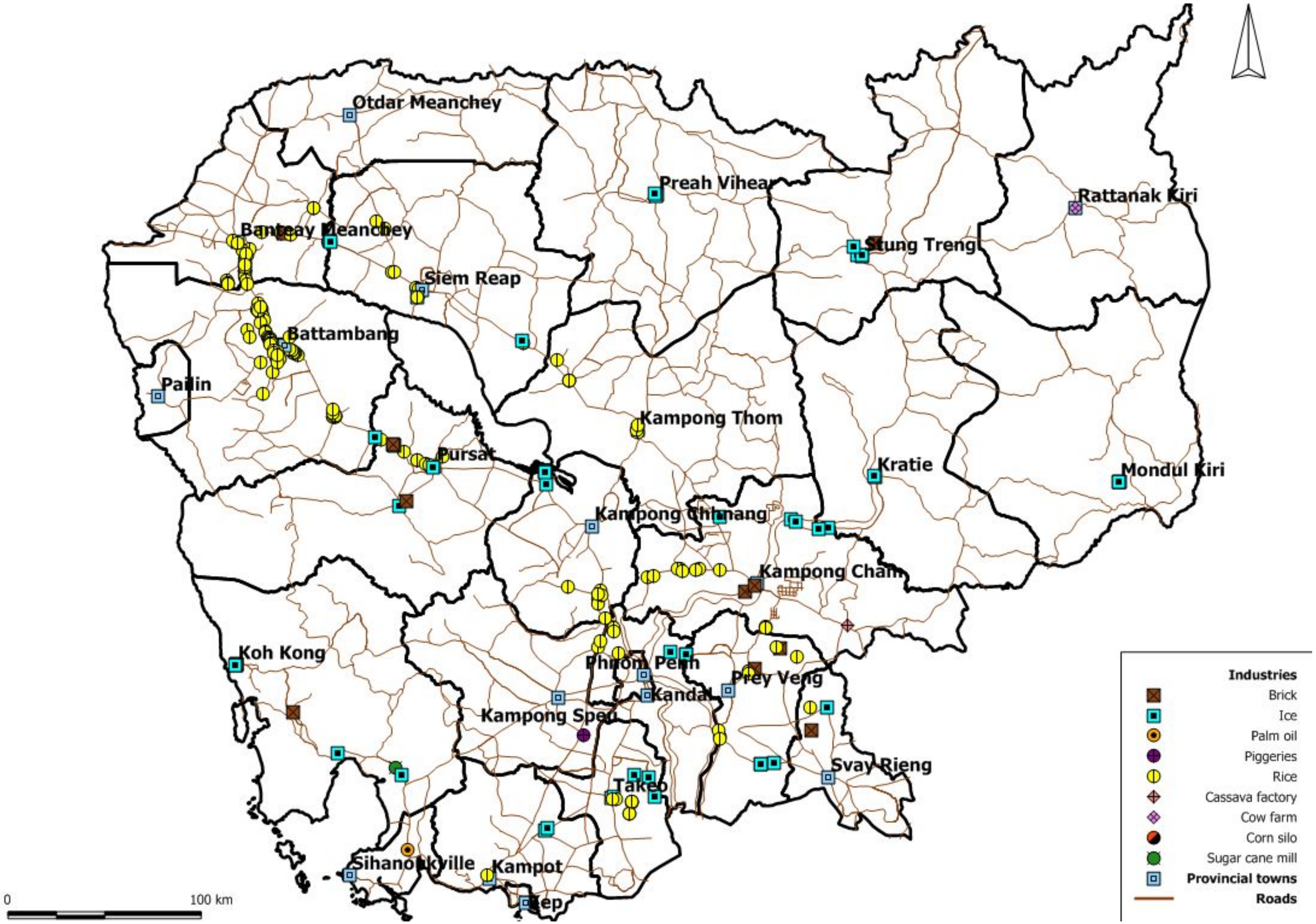
Some other projects tried to use the same technology for rural electrification purposes, such as the Anlong Ta Mei community energy project (9 kW woody biomass in Battambang, now closed because the grid has arrived in the area) and another similar ongoing project by FONDEM in Kampong Thom province. These initiatives rely on community managed fuel wood plantations.

Figure 8: Biomass gasifier in Anlong Tamey

(Source: JICA study of rural electrification by Renewable energy in Cambodia)

However, the situation is changing quickly, and should change even more in the coming years, as a the agro-industry sector becomes more export-oriented (a recent government policy aims at increasing rice exports from its current level of 40,000t/year to 1 Million t/year, through improvement of rice standard and investment in large modern rice mills). Between 5 and 10 rice mills with processing capacities from 10t/h to more than 30t/h are planned, which represent opportunities for cogeneration projects. A first cogeneration power plant has been built in the recently opened Golden Rice mill in Kampong Speu (25 t/h processing capacity). Several large scale sugarcane (about 4) and palm oil plantations are also planned, as well as large pig farms (less than 5).

Figure 9: Map of existing and ongoing biomass projects



Existing projects known to date (combining different technologies and biomass residues, as shown in the figure above) amount to a total of 10.7 MW, mostly for captive use.

Ongoing projects total 87.6 MW, but this time selling excess power is often part of the design for the larger projects, as the agro-industry itself cannot absorb all the power produced. However, many of these projects are still at the plantation stage, with the processing factory still to be built, therefore it is unsure when or even if all these projects will actually be implemented.

#### c) Solar

The data from the JICA master plan study of rural electrification by renewable energy in 2006 has shown an average radiation of 5.1 kWh/m²/day or equivalent of 1860 kWh/m²/y over the country.

According to MIME, as of 2004, more than 204 kWp of PV modules have been installed in the country. They are used to supply power for household lighting and small electric equipment of public and telecommunication facilities. These installations were mostly donation and/or demonstration research projects.

#### d) Wind

All available information indicates that mean wind speeds are low, in the order of 2m/s for much of the country.

The southern part of the great lake Tonle Sap, the mountainous districts in the southwest and the coastal regions have an annual average wind speed of 5m/s or greater; thus the introduction of wind power generation system in these areas is promising. However, to date only one large wind turbine has been installed in Sihanoukville (under Belgian financing).

## 2.2 OVERVIEW OF THE PLANNING APPROACH

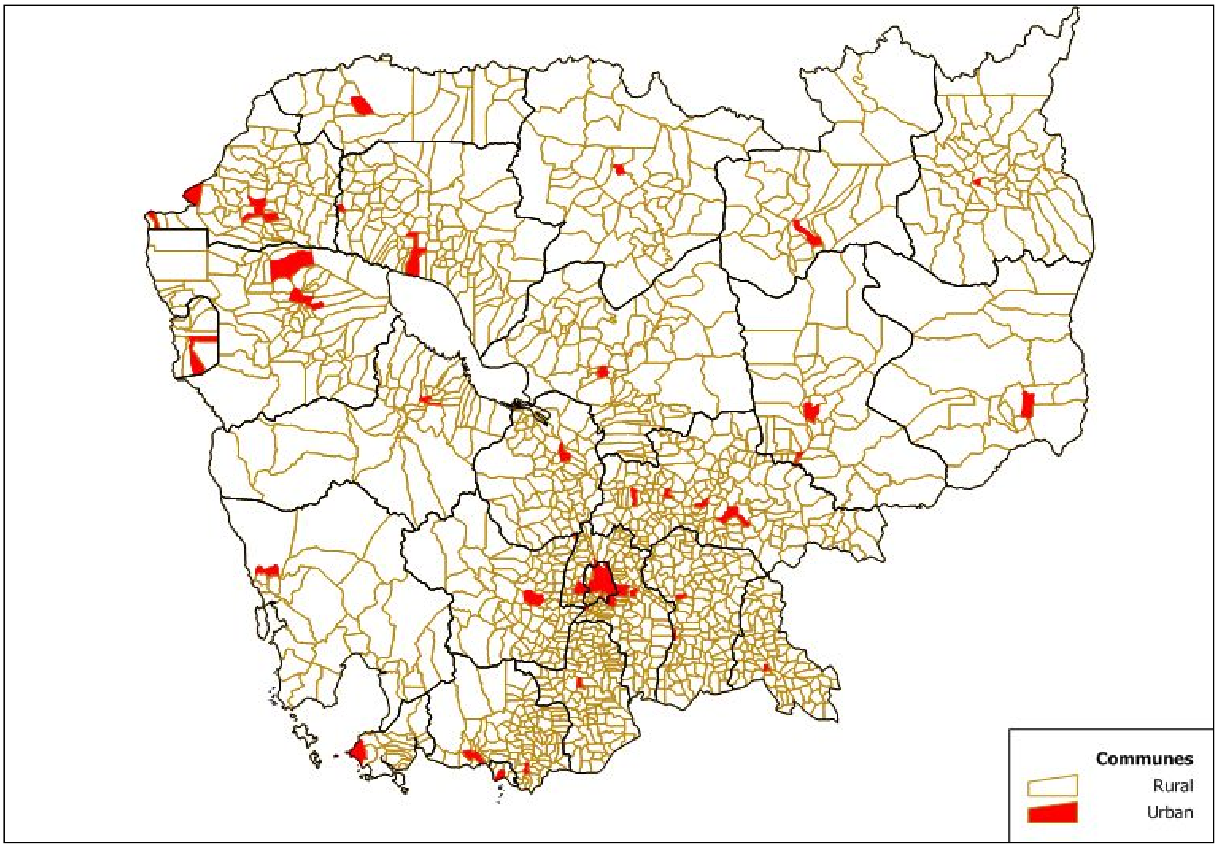
Electrification in Cambodia is still nascent, policy objectives are very ambitious, with 2030 targets aiming at 95% village coverage by the grid and 70% rural households having grid quality service; much remains to be done both in terms of electricity access and renewable energy projects. Although regulatory and financial mechanisms are being created such as REF and EAC, they may lack a clear vision on the medium to long term perspectives to be fully efficient.

### 2.2.1 Rural and urban areas

**All results in this report are about rural areas only, unless it is specifically mentioned to cover urban areas as well.** The definition of “urban” and “rural” communes has been taken from the National Institute of Statistics (NIS):

- Population density >200 inh./km²
- Employment in agriculture <50%
- Total population of commune >2000 inh., see annexes for a detailed list of communes defined as “urban”.

Figure 10: Map of rural and urban communes




### 2.2.2 Current Household and village connection rates

Definition of electrification (according to RE strategy report and RGC policy):

- Electrified household: grid or mini-grid supplied
- Electrified village: at least 50% of households living in the village enjoy grid, mini-grid or other sources of electricity service such as Battery Charging Station (BCS) and PV

Baseline population and electrification figures have been taken from the village and commune database, stemming from 2008 General Population Census. Its results are summarized in the table below:

Table 4: Electrification rates from 2008 General Census[4]

| | Total | | | Urban | | | Rural | | |
|---|---|---|---|---|---|---|---|---|---|
| All households | 2 736 236 | | | 406 761 | | | 2 329 475 | | |
| **Supply source** | **Grid** | **Mini-grid** | **Total** | **Grid** | **Mini-grid** | **Total** | **Grid** | **Mini-grid** | **Total** |
| Electrification rate | 16.6% | 4.2% | 20.8% | 74.3% | 3.7% | 78.0% | 6.5% | 4.3% | 10.8% |
| Electrified households | 453 539 | 114 452 | 567 991 | 302 208 | 15 190 | 317 398 | 151 331 | 99 262 | 250 593 |

4 There may be a few small difference in village and household number with General Census as not all villages could be found in our GIS database (about 100 villages).

There is a difference of 80 565 customers between the total number of electrified households given by the Census (567 991), and the number of customers given by EAC Annual Report 2008. This “error” of 14% may be explained by the following factors:

- Unlicensed REEs not recorded by EAC
- Several households considered as one customer from the point of view of the operator (unofficial connections)

The first explanation is supported by the difference of 78 593 customers (almost all “missing” customers), between the number of rural customers given here (250 593) and the one presented by EAC during the SREP kick-off meeting (172 000).

Figures from 2008 have then been adjusted to 2010:

- Using linear increase of household connection rate in already electrified villages as well as population increase
- Assuming no new village have been connected between 2008 and 2010, as a conservative assumption

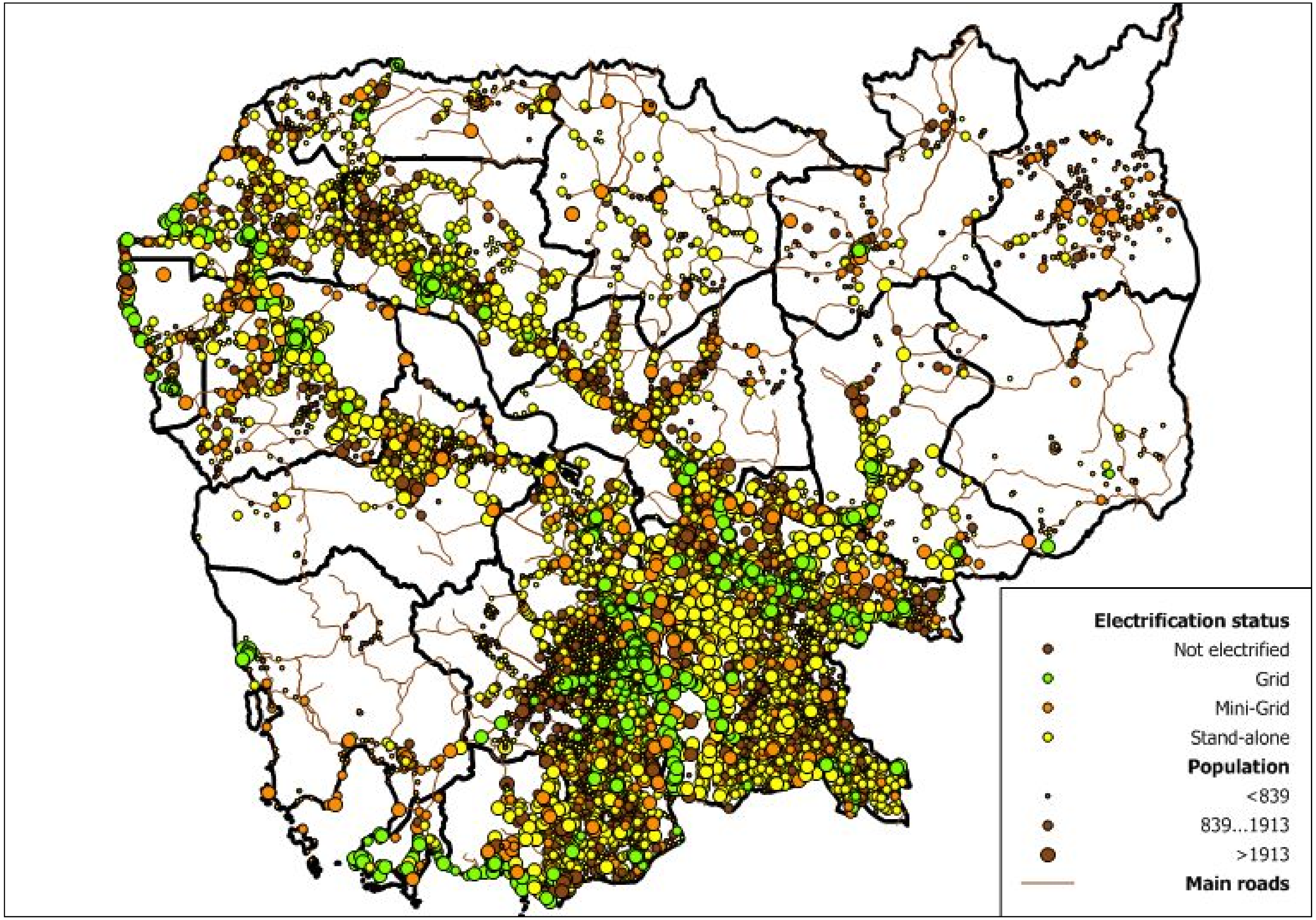
The result is shown on the following map and table.

**Table 5: Electrification rates in 2010, updated from 2008 General Census**

| | Total | | | Urban | | | Rural | | |
|---|---|---|---|---|---|---|---|---|---|
| All households | 2 822 713 | | | 425 435 | | | 2 397 278 | | |
| **Supply source** | **Grid** | **Mini-grid** | **Total** | **Grid** | **Mini-grid** | **Total** | **Grid** | **Mini-grid** | **Total** |
| Electrification rate | 19.1% | 6.1% | 25.2% | 80.9% | 4.3% | 85.2% | 8.1% | 6.4% | 14.6% |
| Electrified households | 539 418 | 172 474 | 711 892 | 344 250 | 18 300 | 362 550 | 195 168 | 154 174 | 349 342 |

The overall electrification rate of **25.2%** comes close to the estimate given by MIME during the SREP kick-off meeting (26%).

Figure 11: Electrification status of villages in 2010



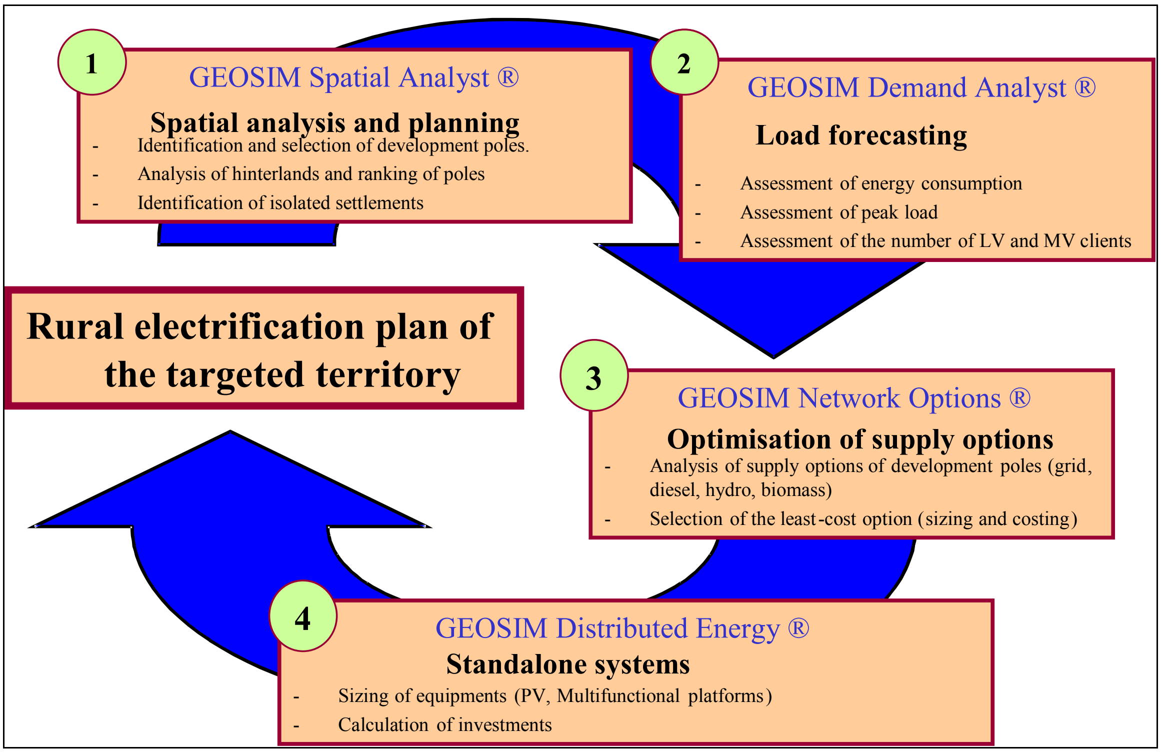
### 2.2.3 GEOSIM: priority to Development impact – selection of development poles

Rational planning approaches using modern tool such as Geographic Information Systems can fill this gap and pave the way for adequate policies and project identification. GEOSIM is thus seen as a relevant answer to these challenges, as it allows planners to quickly simulate sophisticated rural electrification scenarios, harnessing local renewable energy sources and maximising the impact of socio-economic development.

The overall objective of the planning process is indeed to answer the following questions – see annexes for details:

- Which villages should be electrified first to optimise socio-economic development in electrified areas ? *GEOSIM Spatial Analyst®* helps with the identification of priority areas to electrify (Development Poles)
- What is and what will be energy consumption in provinces villages? GEOSIM Demand Analyst® assesses 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® supports identification of supply options to fulfil various scenarios objectives (grid extension, hydro, biomass and diesel options)
- What solutions remain for the villages left without conventional means of access to electricity in the near future? GEOSIM Distributed Energy® helps the planner with sizing and costing of provisional solutions for remote areas (PV kits, battery charging, pico hydro etc.)

Figure 12: GEOSIM planning process



Based on two main inputs from the planner:

- Data collection on grid network, renewable energy potential as well as socio-economic aspects (cf. chapter 2.2 below)
- Clear planning objectives, under different scenarios (cf. chapter 2.3)

The main outputs of the planning study are thus:

- Grid extension strategies and costing within time, resource and physical constraints;
- A list of projects with elements of sizing (installed capacity, energy output over the planning period), costing (investment costs, lifecycle cost) and profitability assessment for a private entrepreneur. This list of project will be used as an operational investment plan and projects will be prioritised according to agreed criteria, so as to identify the most promising projects for further feasibilities, and start negotiations with possible investors.
- An assessment of the direct, as well as indirect beneficiaries of the projects (through increased access to the electricity service in nearby electrified Development Poles).
- Maps showing the location of various projects, allowing the planner to check for the spatial consistence of different scenario

The very novel feature of the GEOSIM approach is that it gives priority status to villages defined as “Development Poles” : the villages have been given an IPD[5] score according to a set of criteria detailed in the related Annex. Then the villages with the highest IPD have been selected. The number of villages selected per province has been adapted to the total number of villages in each province. For most provinces, a proportion of 10% of villages has been considered as Development Pole, according to usual practices in other countries. However, for very small provinces with already high electrification rates, a slightly higher proportion has been taken.

Indeed, the whole idea is that over time, the trend is not for population to remain scattered, but to concentrate in areas and settlements with development potential. Hence, these settlements, which tend to be the larger ones, close to roads and where schools and health infrastructure is planned, where there is potential for income generation, should be given priority in terms of electrification.

A first list of Development Poles has been submitted to PDIMEs and slightly adjusted following their comments (some new Development Poles have been added and their actual electrification status has been updated), cf. list of Development Poles in annex.

Development Poles have then been ranked according to the population of their “hinterland”, i.e. the population, which can benefit indirectly from the electrification of the Development Pole, through improved socio-economic services (electrified schools, health centres and economic activities). This ranking has been used to then prioritise mini-grid projects. Other more traditional ranking criterion could have been investment costs, the levelized cost of kWh or the year of expected connection to the national grid for example.

[5] Indicator for Potential Development, multi-criteria indicator reflecting the quality of socio-economic facilities available within a given village (cf. 2.2).

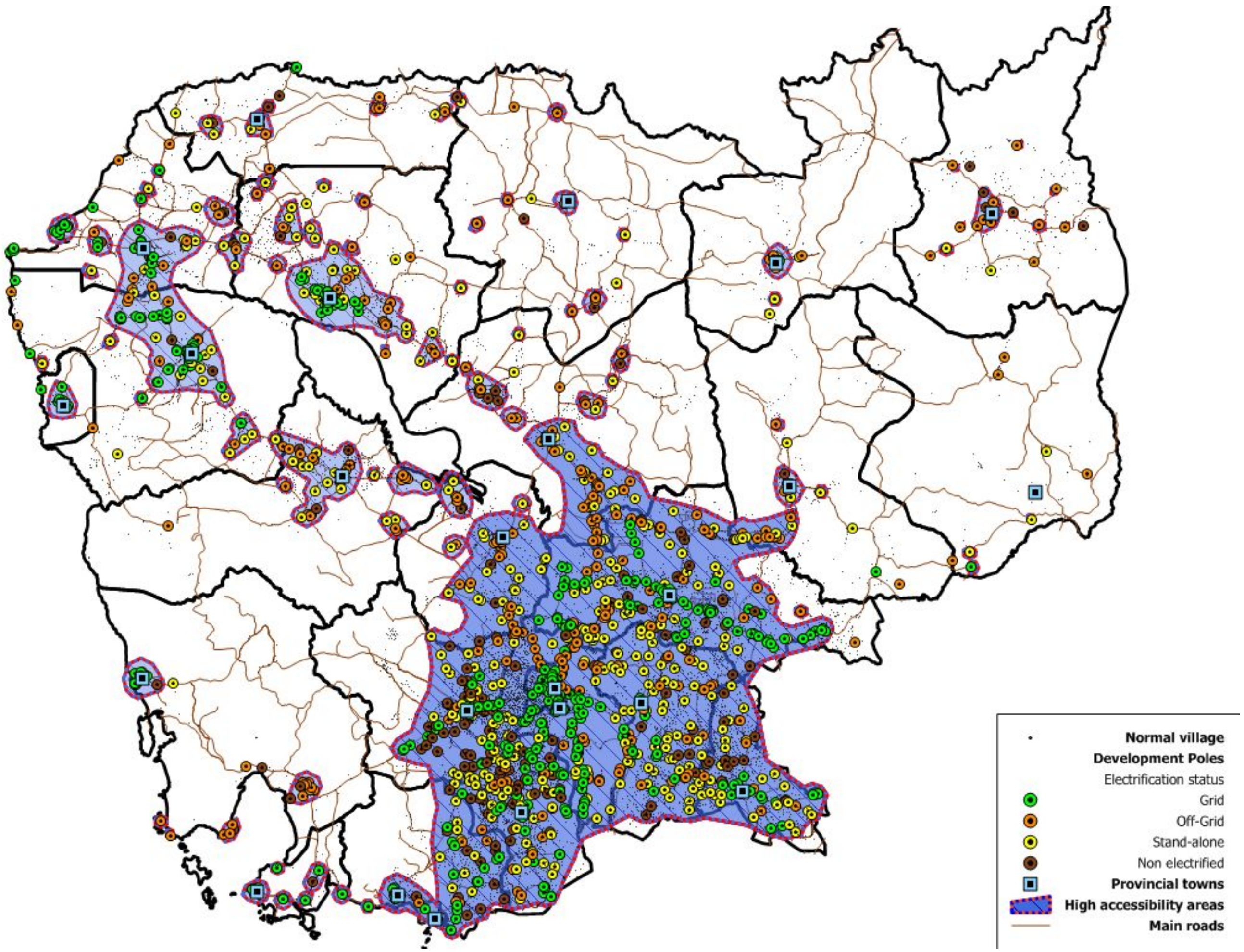
The final number of Development Poles is given in the following table:

**Figure 13: Number of Development poles per province**

| Province | Ratio of DPs selected (%) | Number of DPs kept | Number of rural DPs | Grid electrified rural DPs in 2010 | Off-grid electrified rural DPs in 2010 | Non electrified rural DPs | Rural DPs outside PAGE |
|---|---|---|---|---|---|---|---|
| Kandal | 10 | 108 | **92** | 40 | 30 | 22 | 3 |
| Koh Kong | 30 | 35 | **25** | 6 | 13 | 6 | 13 |
| Preah Vihear | 10 | 21 | **17** | 0 | 10 | 7 | 12 |
| Kampong Cham | 10 | 177 | **159** | 52 | 43 | 64 | 43 |
| Ratanak Kiri | 10 | 24 | **19** | 0 | 12 | 7 | 1 |
| Kampong Thom | 10 | 76 | **70** | 17 | 27 | 26 | 32 |
| Banteay Meanchey | 10 | 63 | **38** | 9 | 16 | 13 | 11 |
| Takeo | 10 | 112 | **108** | 22 | 31 | 55 | 6 |
| Kracheh | 10 | 25 | **18** | 5 | 6 | 7 | 2 |
| Pursat | 10 | 50 | **43** | 0 | 25 | 18 | 3 |
| Siem Reap | 10 | 91 | **69** | 18 | 21 | 30 | 23 |
| Stung Treng | 10 | 13 | **8** | 1 | 3 | 4 | 0 |
| Svay Rieng | 10 | 70 | **62** | 8 | 16 | 38 | 3 |
| Mondul Kiri | 10 | 9 | **9** | 2 | 4 | 3 | 5 |
| Kampong Speu | 10 | 136 | **112** | 19 | 12 | 81 | 1 |
| Phnom Penh | 10 | 69 | **2** | 2 | 0 | 0 | 0 |
| Pailin | 20 | 16 | **9** | 7 | 2 | 0 | 0 |
| Kampong Chhnang | 10 | 56 | **46** | 10 | 7 | 29 | 2 |
| Prey Veng | 10 | 114 | **104** | 5 | 27 | 72 | 7 |
| Battambang | 10 | 74 | **55** | 14 | 23 | 18 | 10 |
| Otdar Meanchey | 10 | 23 | **19** | 2 | 6 | 11 | 9 |
| Kampot | 10 | 48 | **39** | 9 | 10 | 20 | 0 |
| Preah Sihanouk | 10 | 11 | **6** | 5 | 0 | 1 | 0 |
| Kep | 20 | 3 | **3** | 1 | 1 | 1 | 0 |
| **TOTAL** | **10,3%** | **1424** | **1132** | **254** | **345** | **533** | **186** |
| | | | **100%** | **22%** | **30%** | **47%** | |

Figure 14: Location and electrification status of Development Poles.

The "high accessibility area" delineates remote areas, i.e. the 20% of villages located far from all Development Poles and suitable for decentralization electrification technologies (mini-grids or stand-alones).



## 2.3 THE THREE PLANNING SCENARII

The three scenarii aim to reach the policy objective for 2020, i.e. all villages would have access to an electricity service, either national grid, mini-grids or stand-alone systems. The three scenarii follow the same methodology, explained below, their only difference is the assumed speed of national grid expansion (as explained below) , in order to consider different situations of fund mobilisation and actual implementation.

The second main policy objective for 2030 (70% households having access to national grid or mini-grids) is reached only in the baseline scenario, but the two others come relatively close to it.

**Baseline scenario:** in this scenario, the projections made by EDC in terms of number of villages and km of lines are taken for 2015, 2020 and 2030 as achieved. These projections are in line with EAC targets of 80% national grid villages by 2020, and 95% by 2030.

**Intermediate scenario:** this second scenario assumes that the grid extension rate would be half as fast as in the baseline scenario, i.e. whatever villages would be connected in the baseline scenario by 2015 would now be connected by 2020 only. Likewise, villages connected by 2020 in the baseline scenario would be connected by 2030 instead.

**Conservative scenario:** the third scenario assumes an even slower grid extension speed because of limited fund availability, one quarter as fast as the baseline scenario, i.e. villages connected by 2015 would be connected by 2030 only.

Then, once the grid extension has been simulated, least-cost comparison of decentralised mini-grids solutions (mini hydro, biomass, and diesel) is performed in order to supply **all Development Poles** not covered by grid extension before **2015**. Please note that some hydro or biomass projects sometimes do not have any Development Pole in their surroundings, in this case the project is still included in the plan, but does not participate in the above mentioned objective. Hydro or biomass projects located too close (less than 2km) to the forecasted national grid in 2015 will be candidates for Independent Power Producer (IPP) projects, rather than isolated mini-grid projects.

The basis of the calculation principle is that villages continue to be supplied by a given local generation source, as long as the levelized kWh cost continues to decline.

If an existing diesel mini-grid is in conflict with a potential hydro or biomass project, then the latter projects are suggested to replace the previous diesel system. However, new diesel projects are not supposed to replace old ones. For all options, levelized kWh is also a taken into account.

Finally, stand-alone systems (Solar Battery Charging Stations, PV for community facilities and Solar Home Systems) are considered:

- Solar Battery Charging Stations (BCS) will be installed in each village, which are not electrified by national grid or mini-grid projects by 2020, and where no BCS is currently operating. This will ensure that the political objective of 100% village having electricity supply by 2020 is met.
- Likewise, community PV systems are suggested in all villages, which are not electrified by national grid or mini-grid projects by 2020. Targeted facilities are schools, health centres, commune halls and pagodas.
- Finally, all rich households in these villages will be candidates for SHS. The share of rich households in each village varies from one province to another, as explained in 3.1.1.

Deployment of these stand-alone systems is assumed to happen progressively until 2020.

## 2.4 REVIEW OF SURVEYS AND DATA COLLECTION

### 2.4.1 Secondary data collection

A wide range of studies have been reviewed prior to data collection activities, and throughout the project lifetime. Major studies and reports considered include:

- The "Rural Electrification Strategy and Implementation Plan" undertaken by the World Bank to clarify to role of the various stakeholders of rural electrification in Cambodia (2010)
- The "Master Plan for Rural Electrification From Renewable Energy" by the Japanese cooperation (2006)
- Annual reports from EAC and EDC

A detailed list of references used is provided.

The following table summarizes the databases collected and entered into the SREP GIS database.

Given available information on power consumption patterns, socio economic infrastructure (schools, hospitals), population location and income levels, energy expenditures, it was finally not considered necessary to undertake a detailed demand survey. In some instances, a few household level questionnaires were implemented to calibrate and validate demand issues.

### 2.4.2 Agro-industry and rural industry survey

Following the creation of the nation-wide industry database from various sources of data (mostly PDIME databases), a survey has been conducted in agro-industries and rural industries for two purposes:

- To identify possible clients of rural electrification projects ("Special demands")
- To identify possible sources of biomass residues for waste-to-energy (biomass) projects

In order to determine on which industries should the surveying efforts focus, data from the industry database has been validated with the following sources:

- PDIME interviews during regional meetings
- Website listing of land concessions from Ministry of Agriculture (MAFF), cross-checked with phone interview with PDIME, and data from MAFF
- Validation of data from previous surveys (REOREC and COGEN 3 projects) through direct phone calls

Candidates for the survey have been chosen as not directly in national grid areas or very close to it, and close to potential mini-grid renewable energy projects whenever possible

**Table 6: Collected databases**

| Category | Name of data | Format of data | Source |
|---|---|---|---|
| Admin | Province, district and communes boundaries | GIS data | Department of Geography, 2005 |
| Socio-economic | Demographic information | GPS coordinates of villages and population | 08 Socio-economic Village database (MoP) linked to a GIS database established in 98 |
| | Health facilities | GPS coordinates, type (health centre, hospital…), name & villages covered | Ministry of Health (MoH) |
| | Drinking water facitilies | GPS coordinates or village, type (pumped, well, pond...) | Data collected during CAP REDEO project, udpated with 2008 village database |
| | Education facilities | GPS coordinates, type (primary, secondary, high school…), name and villages covered, number of students | Ministry of Education Youth and Sports (MoEYS) |
| | Economic facilities | Location of markets and Micro Finance Institutions (MFIs) | Distance to market & nearest road updated with 2008 village database, location of MFIs collected from ACLEDA and AMRET. |
| | End-user demand data | Household consumption per class, breakdown of classes, productive use consumption, willingness to pay | CAP REDEO survey, supplemented with EAC, EDC, UNDP and NCDD databooks |
| | Special demands: SMEs, industries & agro-industries (power demand above 10kW) | List of about 20,000 businesses with location, type of business, capacity of engine, electrification status, number of staff, capital etc. | Some data from Dep. Of Industry (Phnom Penh), but most from Provincial Dep. Of Industry (PDIMEs).. |
| Power infrastructure | HV and MV lines existing an planned | GIS data, voltage (kV) and expected date of completion for planned lines | Existing MV lines from EAC & EDC<br>Planned MV lines from EDC extension plans (provisional results in 13 provinces)<br>Existing and planned HV from EDC |
| | Substations existing and planned | GPS coordinates, capacity (kVA) and expected date of completion for planned substations | EDC |
| | Rural Electricity Enterprises | GIS data of licensed REE areas and location of non licensed REE + data on number of customers, installed capacity, energy produced, type of engine, tariff etc. | 2010 EAC licensee zones collected in GIS format and additional data taken from EAC annual reports<br>Non licensed REEs collected in 13 provinces from PDIMEs |
| | Electrified areas | List of villages electrified by EDC or REE | Information already included in Socio-economic Village database, and cross checked with feedback from PDIMEs |
| Renewable energy potential | Potential Hydro sites | List of 65 potential hydro sites between 50kW & 2MW, & 90 below 50kW, with GPS coordinates & power output | JICA, MIME, meetings with PDIME and SREP field surveys |
| | Agro-industries able to produce residues for electricity generation | List of agro-industries, including: rice mills, cassava starch factories, palm oil plant, corn silos, sugarcane mills and piggeries | PDIME data (database and phone calls), SREP field survey. Previous projects (COGEN 3 study (2003), CAP REDEO (2008), REOREC (2005))<br>Ministry of Agriculture Fisheries and Forestry (MAFF) - |
| Other | Roads | GIS data with road surface type | JICA / Ministry of Public Works and Transport (MPWT) 2002 |
| | Land mines | GIS data of land mined areas | CMAC |
| | Bridges on main rivers | GIS of existing & planned bridges | MPWT |
| | Water bodies | GIS data | JICA 2002 |
| | Forests and protected areas | GIS data | UN World Database on Protected Areas (WDPA) |

Specific criteria for choosing the different types of activities are:

Ice factories: above 1000t production or 8000 bars (@130kg/bar)

Brick kilns: no threshold could be defined because the production figures in the PDIME database are given in different units, not specified

Rice mills:

- All large rice mills with yearly milled rice production above 2,000 t, except in areas already heavily surveyed by COGEN 3 or REOREC (unless the rice mill is exceptionally large, in which case the rice mill has been surveyed again to check for possible recent evolutions)
- Groups of medium sized rice mills (with production between 200 and 2,000 t), totalling at least 2,000 t/year production

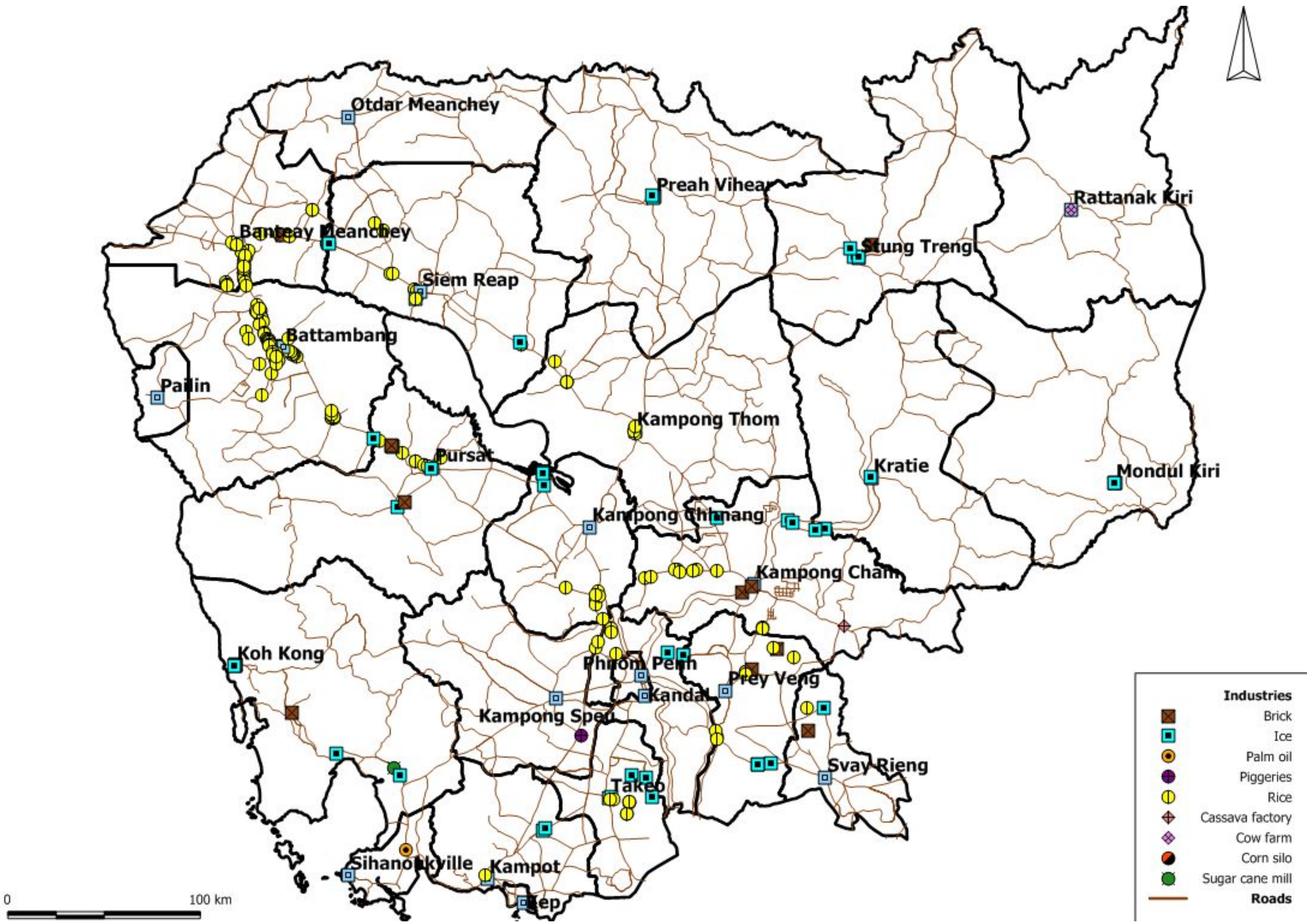
Other agro-industries: given the relatively small number of significant agro-industries outside the rice mill category, all identified agro-industry at the time of the survey have been surveyed whenever possible.

MIME and PDIME staff have been trained on the survey questionnaire on real and fake industries, and then sent in teams throughout the country, to interview more than 160 industries. The breakdown is provided below:

**Table 7: Number of surveyed industries**

| | Activity | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Name of province** | **Rice mill** | **Ice factory** | **Brick making** | **Cassava factory** | **Cow farm** | **Pig farm** | **Sugar cane mill** | **Palm oil factory** |
| Banteay Meanchey | 15 | | 1 | | | | | |
| Battambang | 23 | | | | | | | |
| Kampong Cham | 10 | 5 | 2 | 1 | | | | |
| Kampong Chhnang | 6 | 4 | | | | | | |
| Kampong Speu | 1 | | | | | 1 | | |
| Kampong Thom | 7 | | | | | | | |
| Kampot | 1 | 2 | | | | | | |
| Kandal | 5 | 3 | | | | | | |
| Koh Kong | | 4 | 2 | | | | 1 | |
| Mondul Kiri | | 2 | | | | | | |
| Preah Vihear | | 2 | | | | | | |
| Prey Veng | 8 | 3 | 2 | | | | | |
| Pursat | 8 | 4 | 3 | | | 1 | | |
| Ratanak Kiri | | | | | 1 | | | |
| Siem Reap | 4 | 3 | | | | | | |
| Stung Treng | | 3 | 1 | | | | | |
| Svay Rieng | 1 | 1 | 1 | | | | | |
| Takeo | 7 | 4 | | | | | | |
| Preah Sihanouk | | | | | | | | 1 |
| Siem Riep | 1 | 1 | | | | | | |
| Kratie | | 1 | | | | | | |
| **Total** | **97** | **42** | **12** | **1** | **1** | **2** | **1** | **1** |

Figure 15: Map of surveyed industries



Data from an additional 85 agro-industries (rice mills, corn silos and piggeries) has been analysed too and taken from previous surveys of the REOREC and COGEN 3 projects. The relevance of such data a few years after the surveys has been checked by calling directly each of the surveyed industries.

The results of the survey in terms of special demand and biomass potential assessment are explained further.

### 2.4.3 Data collection from EDC

The following data have been collected from EDC:

- Excel table of investments costs and achievements in terms of connected villages and households, for three periods: 2011-2015, 2016-2020 and 2021-2030. All figures are provided with a breakdown by province and by component (MV, LV, transformers, meters etc.)
- GIS data of existing and planned 22kV lines until 2020, with type of line (main line or sub line) and ownership (EDC or REE)

This data has been very helpful in understanding the scale of the grid extension programme, and to determine which areas are likely to remain left out after it has been carried out. However, a few information were still missing in order to simulate our mini-grid projects:

- The list of villages already connected and to be connected in the future
- Some indication of the priority order of the construction of planned lines (which lines are likely to be commissioned before the others)
- Location of future lines for the 2021-2030 period

These missing elements have been thus simulated with the GEOSIM® software. Efforts have been made to fit to EDC estimates in terms of number of households connected and overall budget, at least for the 2011-2020 phase. As these elements were finalised only after submission of the draft report, we note here the major evolutions in assumptions between the draft and final reports:

- Maximum connection rate reached in a given electrified village decreases from 98% to 70%
- Meter cost has been increased to 50 USD
- LV unit cost has been increased to 15000 USD/km
- Transformers costs have been increased to 46 to 154 USD/kVA (depending on size)
- Customer density after 2020 has been reduced to 50 clients/km LV

However, these assumptions taken individually are not always in line with the ones made by EDC, because of the following reasons:

- Customer density taken by EDC for the whole 2011-2030 period remains roughly around 20 clients/km LV, which is found very low compared to other estimates (66 in remote areas by JICA, about 50 by the WB RE Strategy) and feasibility studies carried out by SREP
- Length of MV lines in Excel tables is found to be slightly higher than the actual length calculated from the GIS data.
- On the other hand, unit costs for LV and MV are found low for utility-grade equipments: at 7700 USD/km and 14700 USD/km respectively (all included).

Nevertheless, some difference remain in our results, mostly for the 2021-2030, because of:

- Very different population growth rates: 3.8% for EDC, 1.2% for SREP (suggested by MIME), to be compared with the historical trend of the past 10 years of 1.5%
- Different lengths of MV lines. The SREP simulation assumed that the national grid would densify (connect villages already close to the grid). Apparently, EDC did not follow this approach, as the additional km of MV to be added in the 2021-2030 phase is found very high.

# 3 DEMAND ASSESSMENT

## 3.1 DEMAND CATEGORIES

In this chapter, main assumptions for the load forecast are presented at the national level (average values). However, most parameters have been set at different values for each province, to better reflect their particularities. Provincial results are summarised at the end of the present report and detailed in a set of annexes.

In a previous study conducted by IED with MIME on European Commission funding, a number of assumptions were discussed and great depth and agreed upon, also based on surveys. For the purpose of the present study, the assumptions were reviewed and broadly taken on board by the Ministry – hence the repeated reference to this study.

### 3.1.1 Domestic market segmentation and demand

In the absence of recent income segmentation study at the national level, the following approach has been chosen:

Three main classes of households are defined: poor (including poor classes 1 & 2 according to the definition of IDpoor project by MoP), medium and rich

Proportion of poor households in rural areas of each province has been determined from Commune level figures extracted from NCDD district data books (NCDD, 2009). These estimates are partly derived from findings of IDpoor project in provinces where it has been conducted, and partly from other socio-economic indicators.

Then the shares of medium and rich households have been determined with the following rule: rich household amount to **15%** of non poor households on average. This is the proportion taken in CAP REDEO project in Kampong Cham (CAP REDEO, 2008). As a comparison, this proportion is 12% in Svay Rieng (UNDP, 2008), 20% in Kampong Speu (UNDP, 2008), 19% in Kampong Thom (PDIME, 2010). NB: definition of households classes from one source to another are not the same, as there is no universally accepted definition for them.The result at national level is as follows:

Table 8: Relative weight of classes in year 1

| | **Poor & very poor households** | **Medium households** | **Rich households** |
|---|---|---|---|
| **National (weighted) average** | 30% | 60% | 11% |
| **Poorest province** | 44% | 69% | 12% |
| **Richest province** | 19% | 47% | 8% |

Then assumptions have been made to determine the evolution of household classes over the planning period. Again, data from NCDD district data books in 2004 have been used, and compared to figures for 2009 to determine the average poverty reduction rate per year, and thus extrapolate poverty levels 20 years in the future. Rich and medium classes have then been calculated using the same assumptions (rich accounting for 15% of non poor households).

Table 9: Relative weight of classes in year 20

| | Poor & very poor households | Medium households | Rich households |
|---|---|---|---|
| National (weighted) average | 13% | 74% | 13% |
| Poorest province | 33% | 82% | 14% |
| Richest province | 4% | 57% | 10% |

Ownership of appliances has been calculated from the CAP REDEO survey and completed with data from the pre-feasibility study in the JICA Master Plan.

**Table 10: Ownership of appliances (average number per household)**

| Appliance | Poor | Medium | Rich | Weighted average[6] |
|---|---|---|---|---|
| Lighting | 1.87 | 3.36 | 4.29 | **3.01** |
| TV & Video-recorder | 0.80 | 1.90 | 2.41 | **1.62** |
| Radio-cassette | 0.80 | 0.90 | 1.10 | **0.89** |
| Rice cooker | 0.08 | 0.11 | 0.13 | **0.10** |
| Iron | 0.00 | 0.18 | 0.50 | **0.16** |
| Fan | 0.00 | 0.77 | 1.90 | **0.66** |
| Refrigerator | 0.00 | 0.09 | 0.26 | **0.08** |

Nominal power ratings[7] are indicated below:

**Table 11: Nominal power rating of appliances**

| Appliance | Power rating (W) |
|---|---|
| Lighting | 16[8] |
| TV & Video-recorder | 100 |
| Radio-cassette | 20 |
| Rice cooker | 300 |
| Iron | 800 |
| Fan | 100 |
| Refrigerator | 150 |

Consumption load curves of appliances have been designed from CAP REDEO survey and adjusted to match the figures of average consumption per household suggested in the SREP project meetings. Resulting demand of each household class is presented in the following table:

**Table 12 : Specific demand of one household for each class**

| | Poor | Medium | Rich | Weighted average |
|---|---|---|---|---|
| Peak demand (W) | 90 | 259 | 470 | **232** |
| Consumption (kWh/month) | **9** | **39** | **75** | **34.1** |
| Consumption with technical losses (kWh/month) | 10 | 43 | 83 | **37.9** |

The peak demand is in line with assumptions currently made by EDC to size its distribution transformers (250 VA per household on average, i.e. about 200 W).

The monthly consumption is slightly lower than JICA and WB Strategy estimates of 50kWh, but constraints on ability to pay show that 34 kWh/month is already difficult to achieve (see 3.4.4). The average consumption per customer including losses was 23kWh in 2008 according to EAC report.

---

6 Average weighted by national average proportion of each household class

7 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.

8 This is the average power rating found during the CAP REDEO survey.

### 3.1.2 Social services

Average number of health centres and schools per rural village have been determined from the commune database integrated into GIS (MoP, 2008). The number of facilities per villages indicated in the table below are national averages, the actual numbers used for each province[9] are provided in the provincial result annexes. The school category covers the following facilities in the database:

- Formal pre-schools
- Primary schools
- Lower secondary schools
- Upper secondary schools
- Private schools

Number of clients for water pumping, and meeting halls has been taken equal to 1 for all villages. However, their specific consumption is proportional to the population of the village.
The resulting number of activities, according to the size of each village, is thus:

Table 13: Number social services per village for different population ranges – national average

| Population range | Water pumping | Meeting hall/Pagoda | Schools | Health centres |
|---|---|---|---|---|
| 500-1000 | 1 | 1 | 0.42 | 0.01 |
| 1000-1500 | 1 | 1 | 0.73 | 0.02 |
| 1500-2000 | 1 | 1 | 1.09 | 0.03 |
| 2000-2500 | 1 | 1 | 1.46 | 0.05 |
| >2500 | 1 | 1 | 1.69 | 0.05 |

The specific consumption of each of these facilities in the 24h supply scenario are:

Table 14: Specific demand of public services, not including distribution losses

| | Water pumping | Meeting hall/Pagoda | Schools | Health centres |
|---|---|---|---|---|
| Monthly consumption | 1200 kWh/1000p | 72 kWh/1000p | 44 kWh/connection | 72 kWh/connection |
| Peak demand | 4000 W/1000p | 400 W/1000p | 150 W/connection | 150 W/connection |

### 3.1.3 Productive uses and small businesses

Average number of small shops and other tourism based activities per rural electrified village have been determined from the commune database (MoP, 2008). This category covers the following activities in the database:

- Bicycle and motorcycle repairs places
- Electronic tool repairs places
- Alcohol refinery places
- Other handicraft places (excluding furniture)
- Small-scale services (hairdresser, phone service, massage, Karaoke…)
- Small-scale food shop businesses (Food, groceries, drink shop…)
- Pharmacies and small drug stores
- Hotels
- Guest houses
- Restaurants

[9] These have been derived from national averages by using a ratio with number of each activity per 1000 inhabitant.

Small industries such as furniture handicraft and metal workshops have been taken from the village database (MoP, 2008), under the category “Other machines” (excluding rice threshers) Likewise, battery charging stations have been taken from the village database (MoP, 2008)

In the case of small rice mills (below 45 HP – average 16 HP or 12 kW), the Commune Database 2008 has been found to be more comprehensive than the industry database (52,190 mills vs. 12,349). Therefore the Commune Database has been used specifically for this category of demand, and the average of 16HP (12kW) has been taken as installed capacity. However, these end-users have not been considered in the study, and the number indicated below are therefore provided for information only.The resulting number of activities, according to the size of each village, is thus:

Table 15: Number of productive uses per village for different population ranges (national average)

| Population range | Misc. shops and tourism activities | Small industry (carpentry, metal works) | Battery charging | Small rice mills (below 45 HP) |
|---|---|---|---|---|
| 500-1000 | 1.58 | 0.43 | 0.30 | 0.30 |
| 1000-1500 | 3.67 | 0.24 | 0.53 | 0.53 |
| 1500-2000 | 5.80 | 0.71 | 0.85 | 0.85 |
| 2000-2500 | 7.94 | 1.07 | 0.98 | 0.98 |
| >2500 | 11.28 | 1.39 | 1.31 | 1.31 |

Specific demand of these productive uses are taken as follows:

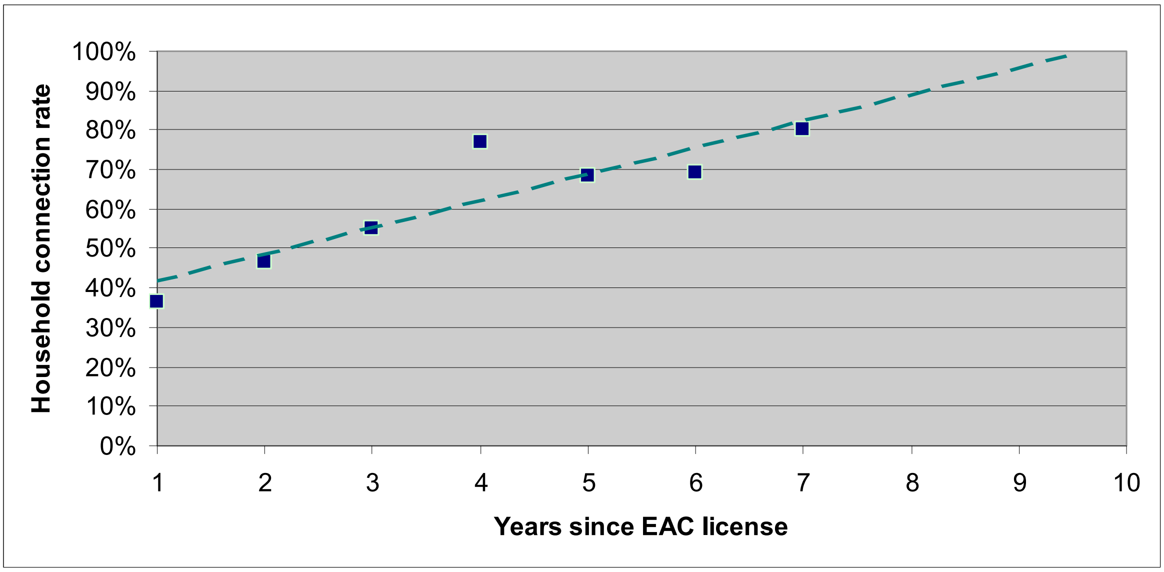
Table 16: Specific demand of productive uses, not including distribution losses

| | Misc. shops and tourism activities (hotels, restaurants) | Small industry (small mills, carpentry, metal works) | Battery Charging | Small rice mills (below 45 HP) |
|---|---|---|---|---|
| Consumption (kWh/month) | 146 | 540 | 360 | 312 |
| Peak demand (W) | 300 | 2 000 | 2000 | 12000 |

## 3.2 HYPOTHESES ON TRENDS

Main assumptions for connection rates and consumption growth rate had been discussed with main power sector stakeholders during the CAP REDEO project. Connection rate assumptions for households have not been changed, as they seem to be confirmed by the figures calculated from the village database, combined with the GIS layer of REE licenses in 2010 from EAC:

Figure 16: Evolution of average household connection rates in rural areas, with the number of years since the EAC license has been granted[10]




The above chart shows a steady increase from 35% to full coverage after 10 years of electrification. For its planning activities, EDC expects 50% connection after 4 years, which is close to the above assumption: 60%. However, the EDC plans expect the connection rate to reach a plateau at about 70%, which appears sensible considering that villages included in the plans are likely to feature a significant proportion of households, which cannot be reached by the grid.

However, consumption growth rates per customer have been slightly reduced to 4% p.a., to fit with current progression calculated from EAC data:

Table 17: Consumption in rural areas (calculated from EAC presentation to SREP kick-off)

| Year | Number of consumers in rural areas | Consumption (MWh) | Average consumption per client (kWh/month) | Average geometric annual growth |
|---|---|---|---|---|
| 2006 | 102400 | 93587 | 76.2 | **3.43%** |
| 2008 | 172000 | 168177 | 81.5 | |

[10] NB: these connection rates may be slightly optimistic, as the actual number of years since electrification may be bigger than the number of years since EAC license (the license may have been granted several years after the REE has started operating)

The previous assumption of 7% growth would be closer to the national average, including urban areas:

Table 18 : Nation-wide consumption figures (calculated from EAC annual reports)

| Year | Number of consumers | Consumption (MWh) | Average consumption per client (kWh/month) | Average geometric annual growth |
|---|---|---|---|---|
| 2005 | 306176 | 858356 | 233.6 | **7.12%** |
| 2006 | 358270 | 1057158 | 245.9 | |
| 2007 | 415141 | 1349122 | 270.8 | |
| 2008 | 487426 | 1664395 | 284.6 | |

Table 19: Growth hypotheses

| **Years** | 1 | 1-10 | 10 | 10-20 | 20 |
|---|---|---|---|---|---|
| **Connection rates** | | | | | |
| Households | 35% | | 70% | | 70% |
| Infrastructures and services | 80% | | 100% | | 100% |
| **Consumption growth rates** | | | | | |
| Households | | 4.00% | | 0.00% | |
| Infrastructures and services | | 4.00% | | 4.00% | |

Villages are considered not scattered, i.e. all households of a village are eligible for connection if the village is electrified.

The population growth rate in rural areas outside Phnom Penh is taken at **1.2% per year as a national average** (actual figures for each province are different). The General Census from 2008 found an average growth rate of 1.5% over the last 10 years, but a new figure of 1.2% has been suggested (MIME 2010). Moreover, some extreme values have been found in some provinces, such as 9.7% in Odtar Meanchey, or 0.46% in Kampong Cham. These figures likely result from migration flows, not demographic growth. Therefore they may not be extrapolated safely for the next 20 years, that is why we decided to divide the distance of each value to the mean (1.2%), by a factor of 4. This results in the same mean value at national level, while still keeping some level of provincial disparities. NB: this average of 1.2% growth rate per year is much lower than then 3.8% taken by EDC, and this will naturally have a significant impact on the planning results.

On average there are **4.95 people per household** in rural areas (Village database, 2010).

Technical losses[11] are set equal to **10%**, as suggested by EAC for well designed systems (with total losses, including non-technical, averaging 15% to 20%). Naturally, actual losses may be higher in existing systems. However, the aim of the load forecast here is to focus on new places to electrify.

[11] Taking into account distribution losses but not commercial losses, due to faulty meters or illegal connections.

### 3.3 LARGE POWER USERS (SPECIAL DEMANDS)

Special demands are defined as large industrial users, which could benefit from Rural Electrification projects (either grid or off-grid), thereby increasing the benefits of electrification and usually improving the economic viability of projects. They may be located inside or outside villages.

A dedicated survey has been conducted to assess the potential electrification or large power users in rural areas, mostly large agro-industries, ice factories and brick kilns. In total, about 160 industries have been surveyed. The following chapters deal with the results of this survey in terms of assessment of special demands throughout the country.

#### e) Number and location of special demands

- Besides surveyed industries, all other industries available in the industry database have been considered as well. A set of screening criteria have been applied to this database, in order to remove unwanted factories:
- They must be still running (the survey revealed quite a number of factories from the PDIME databases, which have been stopped for various reasons)
- They must be located in a rural area (as defined in 2.2.1)
- They must not be already connected to the grid (but the ones connected to mini-grids are accepted). Very few industries fall within this category.
- They must not be one of the potential candidates for captive use biomass projects (
- We must know their geographical coordinates or at least their village
- We must know their peak demand (cf. next chapter)

The resulting number of special demands considered, is thus:

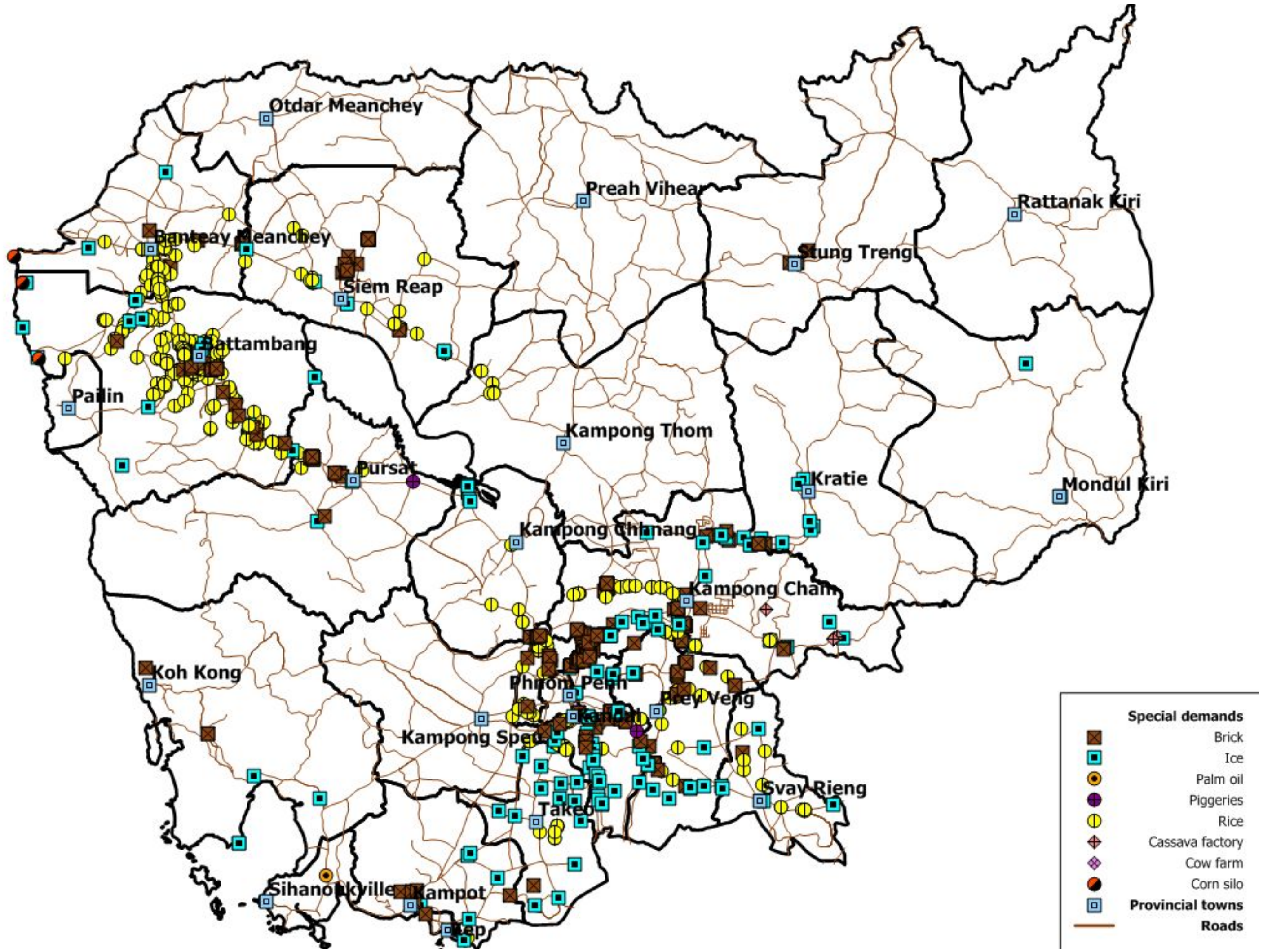
Table 20: Number of activities for different types

| Category | Total number in database | Total number considered after screening |
|---|---|---|
| Rice mills except small | 672[12] | 429 |
| Ice factories | 229 | 148 |
| Brick kilns | 382 | 308 |
| Palm Oil factories | 1 | 1 |
| Cassava | 14 | 11 |
| Corn | 5 | 3 |
| Piggeries | 9 | 7 |

Most special demands identified are rice mills, ice factories and brick kilns, and are located in densely populated areas where the grid is already there or coming soon. Therefore, their impact on off-grid projects is relatively small but can still improve their financial viability in a few cases.The following map shows all special demands identified:

[12] NB: the Commune Database 2008 states that there are in total 1800 large rice mills in the country, which is significantly higher than the figure indicated in this table. However, without a clear definition of "large" rice mills given by the Commune Database, it is not possible to determine whether this discrepancy is abnormal or not.

Figure 17: Map of special demands after screening



## f) Characteristics of special demands

During the field survey, the real peak demand has been estimated (usually lower than installed capacity, as sometimes not all engines are running at the same time, and engines not always deliver their rated capacities), although it is usually hard to define accurately. A simplifying assumption has been made, that the installed capacity indicated in PDIME databases is equivalent to the peak demand (which seems to be generally the case after comparison between survey results and PDIME figures).

All industries have been grouped in categories of similar peak demands. The following table gives the resulting peak demands for the different categories, as well as the cumulated capacity of each category.

Table 21: Peak demands of different categories of special demands

| Type | Category | Total considered | Peak demand (kW) | | | Cumulated peak demand (MW) |
|---|---|---|---|---|---|---|
| | | | Min | Max | Avg | |
| Rice mill | Rice mill 1 | 220 | 38 | 71 | **56** | 12.2 |
| | Rice mill 2 | 111 | 73 | 101 | **88** | 9.8 |
| | Rice mill 3 | 29 | 105 | 128 | **115** | 3.3 |
| | Rice mill 4 | 23 | 135 | 165 | **150** | 3.4 |
| | Rice mill 5 | 10 | 173 | 210 | **196** | 2.0 |
| | Rice mill 6 | 31 | 212 | 270 | **245** | 7.6 |
| | Rice mill 7 | 3 | 278 | 315 | **296** | 0.9 |
| | Rice mill 8 | 2 | 338 | 375 | **356** | 0.7 |
| | **Total rice mill** | **429** | **38** | **375** | **93** | **40.0** |
| Ice factory | Ice factory 1 | 80 | 2 | 99 | **59** | 4.7 |
| | Ice factory 2 | 53 | 109 | 178 | **124** | 6.6 |
| | Ice factory 3 | 9 | 197 | 301 | **254** | 2.3 |
| | Ice factory 4 | 6 | 316 | 392 | **350** | 2.1 |
| | **Total ice factory** | **148** | **2** | **392** | **106** | **15.7** |
| Brick kiln | Brick kiln 1 | 285 | 8 | 18 | **12** | 3.4 |
| | Brick kiln 2 | 11 | 23 | 41 | **30** | 0.3 |
| | Brick kiln 3 | 6 | 45 | 60 | **54** | 0.3 |
| | Brick kiln 4 | 5 | 66 | 75 | **71** | 0.4 |
| | Chhay Eng Brick Kiln | 1 | 127 | 127 | **127** | 0.1 |
| | **Total brick kiln** | **308** | **8** | **127** | **15** | **4.6** |
| Cassava | Cassava 1 | 7 | 11 | 11 | **11** | 0.1 |
| | Cassava 2 | 4 | 18 | 60 | **32** | 0.1 |
| | **Total cassava** | **11** | **11** | **60** | **19** | **0.2** |
| Piggery | Piggery 1 | 3 | 36 | 40 | **38** | 0.1 |
| | Piggery 2 | 4 | 180 | 188 | **184** | 0.7 |
| | **Total piggery** | **7** | **36** | **188** | **121** | **0.9** |
| Corn | Corn silo 1 | 1 | 75 | 113 | **93** | 0.1 |
| | Corn silo 2 | 2 | 240 | 250 | **245** | 0.5 |
| | **Total corn silos** | **3** | **75** | **250** | **194** | **0.6** |
| | MRT Palm Oil | 1 | 784 | 784 | **784** | 0.8 |
| | **Total others** | **1** | **784** | **784** | **784** | **0.8** |

Answers from the surveys allowed detailed assessment of other characteristics of the main types of special demands, beyond the mere peak demand:

- Average load factor during operation hours (%)
- Time of operation (hours in the day)
- Seasonality (months of the year and days of the week)

The summary of average demand characteristics of all industries considered is shown below:

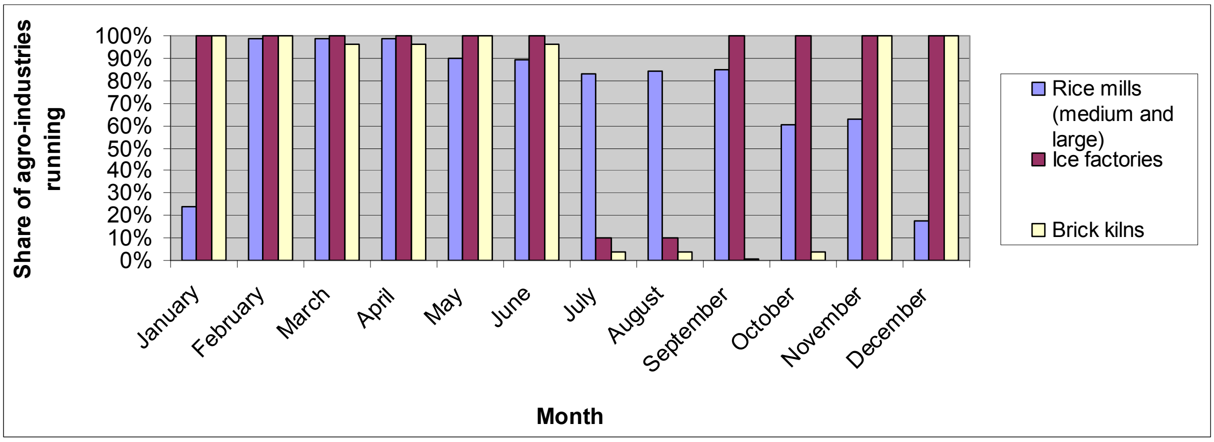
**Table 22: Detailed characteristics of special demands**

| Type | Category | Peak demand (kW) | Avg. load factor during operation hours (%) | Hours of operation per day | Seasonality | |
|---|---|---|---|---|---|---|
| | | | | | Days per week | Months per year |
| Rice mill | Rice mill 1 | 56 | 34% | 7.0 | 6.9 | 9.6 |
| | Rice mill 2 | 88 | 34% | 6.0 | 5.8 | 8.4 |
| | Rice mill 3 | 115 | 34% | 7.2 | 5.8 | 9.8 |
| | Rice mill 4 | 150 | 34% | 7.7 | 5.8 | 10.2 |
| | Rice mill 5 | 196 | 34% | 7.0 | 6.8 | 8.4 |
| | Rice mill 6 | 245 | 34% | 7.0 | 6.3 | 6.5 |
| | Rice mill 7 | 296 | 34% | 6.0 | 5.5 | 6.3 |
| | Rice mill 8 | 356 | 34% | 10.0 | 3.0 | 6.0 |
| | **Total rice mill** | **93** | | | **6.4** | **8.9** |
| Ice factory | Ice factory 1 | 59 | 25% | 20.0 | 6.8 | 10.1 |
| | Ice factory 2 | 124 | 25% | 22.0 | 7.0 | 10.5 |
| | Ice factory 3 | 254 | 25% | 22.0 | 7.0 | 12.0 |
| | Ice factory 4 | 350 | 25% | 24.0 | 7.0 | 12.0 |
| | **Total ice factory** | **106** | | | **6.9** | **10.4** |
| Brick kiln | Brick kiln 1 | 12 | 31% | 9.0 | 6.7 | 7.8 |
| | Brick kiln 2 | 30 | 31% | 6.5 | 7.0 | 9.0 |
| | Brick kiln 3 | 54 | 31% | 8.0 | 6.0 | 7.0 |
| | Brick kiln 4 | 71 | 31% | 8 | 6.0 | 7.0 |
| | Chhay Eng Brick Kiln | 127 | 31% | 8 | 7.0 | 12.0 |
| | **Total brick kiln** | **15** | | | **6.7** | **7.9** |
| Cassava | Cassava 1 | 11 | 20% | 24.0 | 7.0 | 3 |
| | Cassava 2 | 32 | 20% | 24.0 | 7.0 | 3 |
| | **Total cassava** | **19** | | | **7.0** | **3.0** |
| Piggery | Piggery 1 | 38 | 53% | 24.0 | 7.0 | 12.0 |
| | Piggery 2 | 184 | 53% | 24.0 | 7.0 | 12.0 |
| | **Total piggery** | **121** | | | **7.0** | **12.0** |
| Corn | Corn silo 1 | 93 | 40% | 18.0 | 7.0 | 4.0 |
| | Corn silo 2 | 245 | 40% | 18.0 | 7.0 | 4.0 |
| | **Total corn silos** | **194** | | | **7.0** | **4.0** |
| | MRT Palm Oil | 784 | 90% | 24.0 | 7.0 | 12.0 |

All characteristics mentioned in the table above are direct averages from surveys within each category of industry.

The seasonality of rice mills, ice factories and brick kilns is illustrated below:

Figure 18: Seasonality of main special demands throughout the year




All these characteristics have been converted into average daily load curves, and entered into GEOSIM.

Important note on load factors: the load factor indicated in the table above has been calculated from the usual time of engine/genset operation as stated by the respondents (hours per day and days per week), as well as the average monthly consumption of fuel (and electricity if relevant), and the peak demand. To smooth statistical errors linked to the small number of industries surveyed in some categories, averages have sometimes been made over groups of similar industries. In most cases, this figures is found to be very low, even for industries which are supposed to have a constant load close to their peak demand during their time of operation, such as ice factories and rice mills. Two possible explanations may be given:

The schedule of operation provided (hours per day, and days per week) is only indicative, and the industry probably runs for shorter periods of time in reality. This may be especially the case for rice mills, and even more small ones, which do not always manage to get a reliable supply of rice to process (30% of rice millers stated that they do not run regularly throughout the week).

The peak demand, mostly based on installed capacity of engines, may be overestimated. This is caused by oversizing of engines, apparently a regular practice. A survey conducted in large rice mills for the COGEN 3 project found that on average power requirements of rice mills were only **58%** of the installed capacity. Estimating the real peak demand (maximum load of engines or gensets in actual operation) was however outside the scope of the survey, therefore possible errors in estimating this parameter can only be adjusted by using the resulting low load factor in creating our typical daily load curve.

Both factors probably play a role in explaining these results, but their respective importance is hard to assess. If the first one accounts for most of the phenomenon, then it can prove challenging for electricity operators, who will have to size their generation facilities, transformers, conductors etc. according to a very high peak demand, while selling very few kWh to recover their costs.

## 3.4 RESULTS

### 3.4.1 Load forecast results per province

These demand figures are related to rural areas only. Even though special demands (large rural power users) have been included in the calculation, their urban equivalents (such as garment factories) were outside the scope of this study and have thus not been considered. Besides, urban domestic customers have a much higher ability to pay, enjoy lower tariffs, and thus have a higher consumption than in rural areas. Therefore, total demand is expected to be significantly higher.

Overall, in 2030, Provinces are expected to represent the same proportion of national demand as in 2010. Over the 20 year period, demand will be multiplied by 3.3, which means that one will be well beyond the “doubling every ten years” rule of thumb. This is explained by the low level from which one is starting, but of course, will only be achievable in reality if the tariffs and connection fees are affordable...

Table 23: Rural demand per province (GWh/year)

| Province | Rural Population (2008 census) | Demand in 2011 (GWh/year) | Demand in 2030 (GWh/year) |
|---|---|---|---|
| Banteay Meanchey | 533 289 | 42 814 | 140 066 |
| Battambang | 816 895 | 62 571 | 213 577 |
| Kampong Cham | 1 707 950 | 119 892 | 373 638 |
| Kampong Chhnang | 442 484 | 30 939 | 98 497 |
| Kampong Speu | 691 448 | 42 378 | 152 110 |
| Kampong Thom | 639 810 | 44 197 | 143 862 |
| Kampot | 578 698 | 42 154 | 135 727 |
| Kandal | 1 117 681 | 93 351 | 298 842 |
| Koh Kong | 112 100 | 8 809 | 28 110 |
| Kracheh | 284 957 | 25 301 | 86 235 |
| Mondul Kiri | 53 913 | 4 003 | 15 495 |
| Preah Vihear | 164 993 | 10 626 | 37 225 |
| Prey Veng | 1 094 584 | 69 585 | 224 284 |
| Pursat | 384 968 | 23 992 | 78 482 |
| Ratanak Kiri | 130 521 | 9 225 | 33 963 |
| Siem Reap | 738 147 | 56 665 | 182 091 |
| Preah Sihanouk | 103 924 | 12 856 | 42 078 |
| Stung Treng | 93 013 | 6 153 | 22 499 |
| Svay Rieng | 544 871 | 35 194 | 111 845 |
| Takeo | 949 964 | 61 404 | 195 615 |
| Otdar Meanchey | 168 347 | 13 619 | 58 128 |
| Kep | 28 790 | 2 325 | 7 559 |
| Pailin | 52 059 | 4 688 | 24 220 |
| **Total** | **11 433 406** | **822 741** | **2 704 148** |

The following maps illustrate these results at the province and district levels.

Figure 19: Province level demand

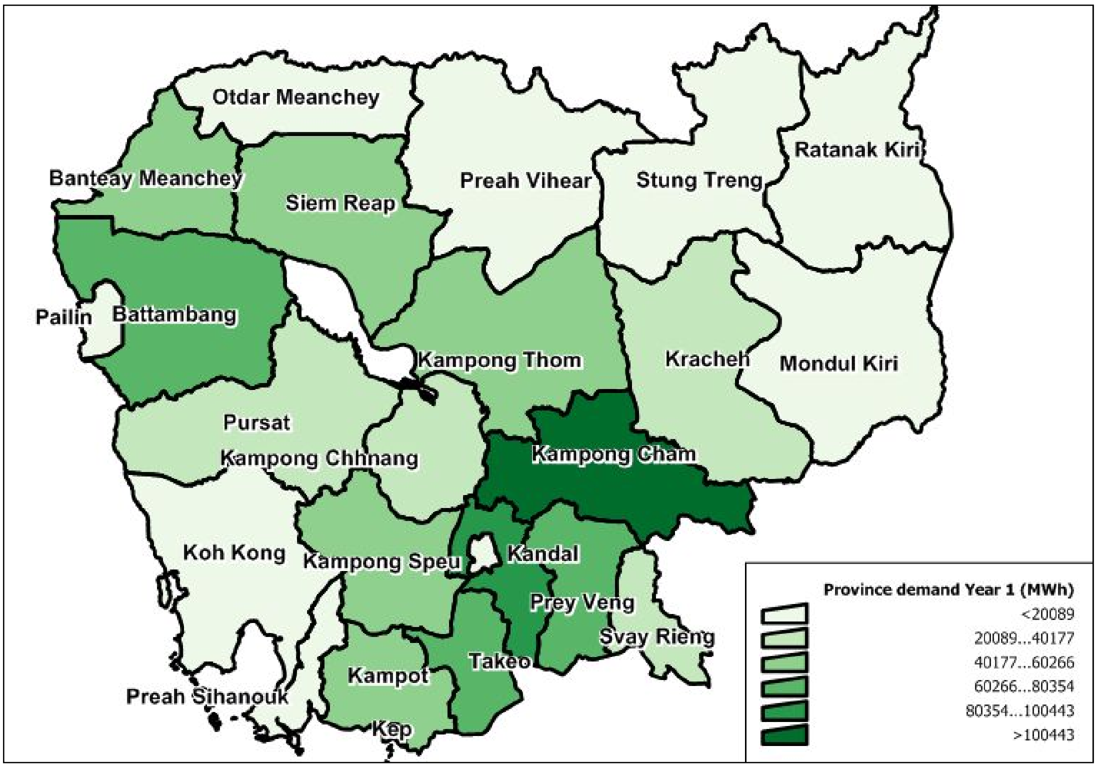
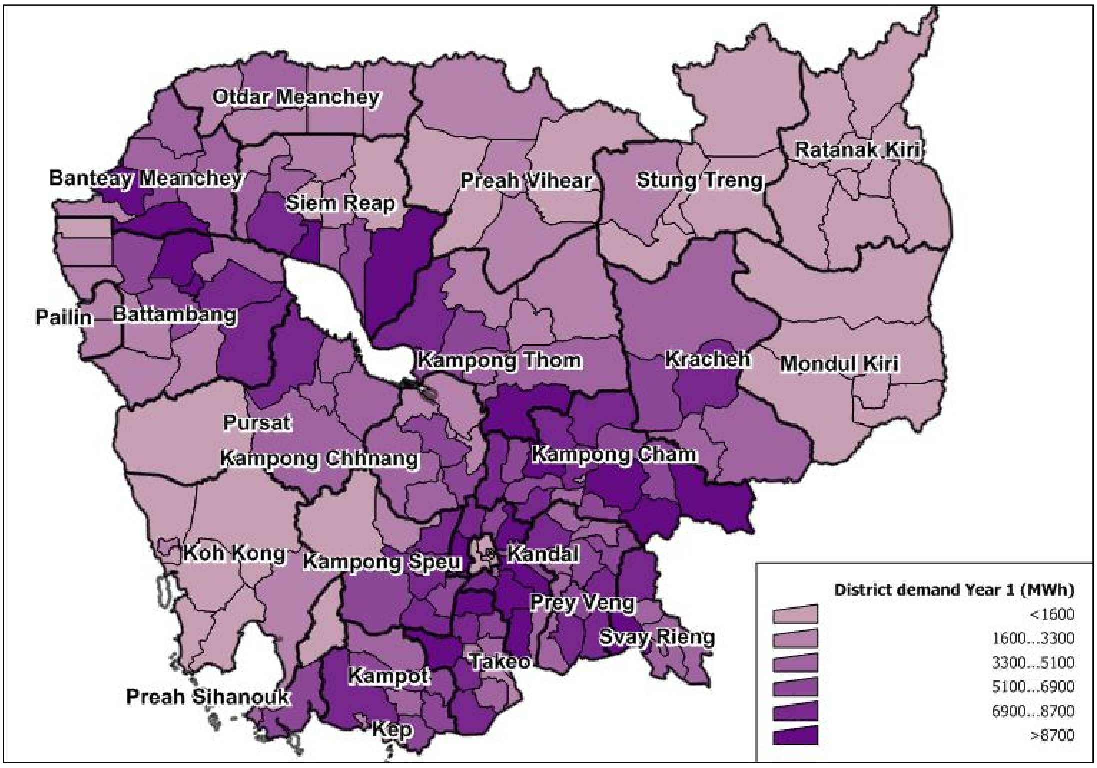



Figure 20: District level demand



The evolution of power consumption for the same size of village in different provinces is shown on the chart ([13]).The differences are caused mostly by two factors:

- Different specific consumptions (average consumption per customer)
- Different numbers of households and services

Having lower living standards, Preah Vihear has naturally lower demand than other provinces, but the difference is not so significant. This is because we are comparing villages of same size, while actually villages of about 1000 inhabitants in Preah Vihear are much less frequent than in Battambang for example. If we compare the results for villages according to the average population size of each provinces, the chart becomes:

Figure 21: Load forecast for villages of 1000 inhabitants in different provinces

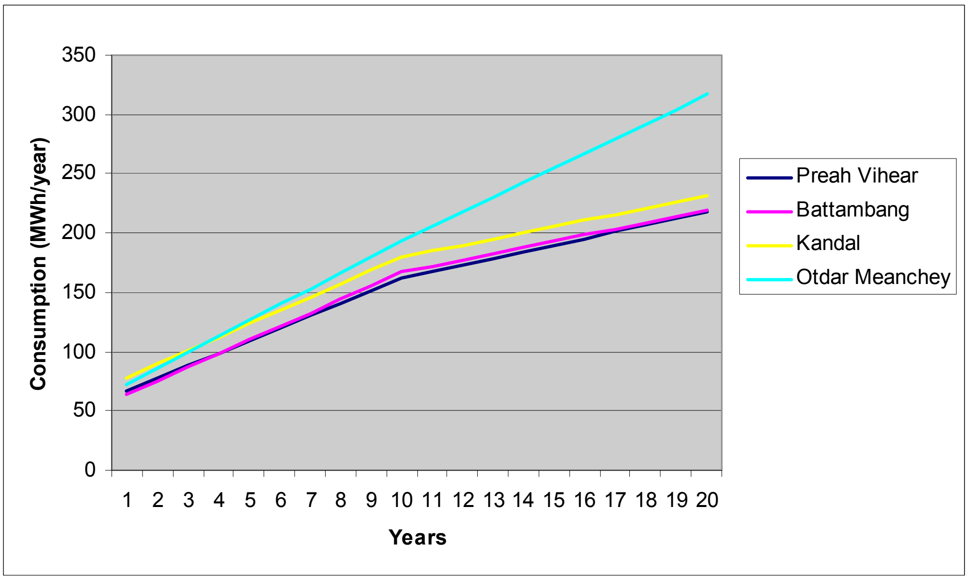
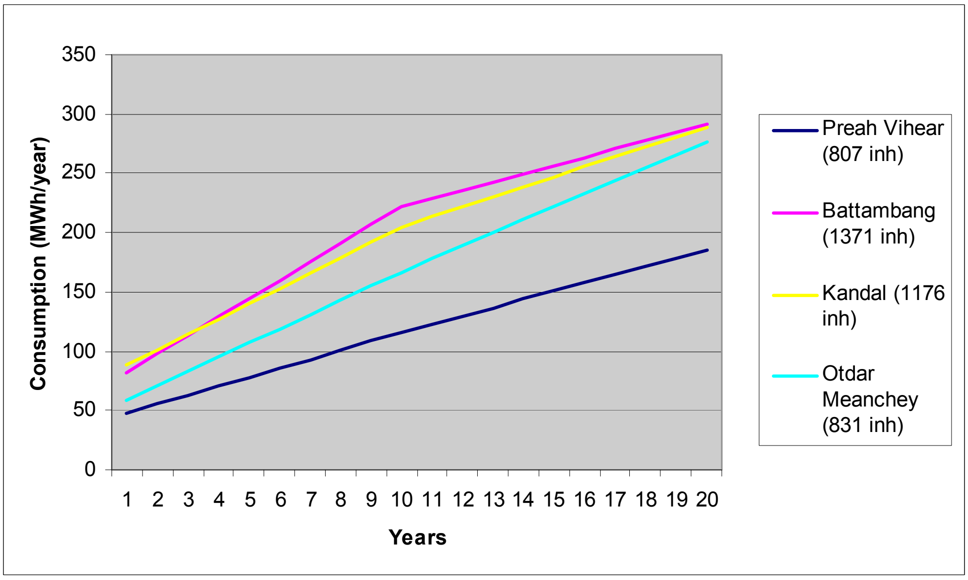


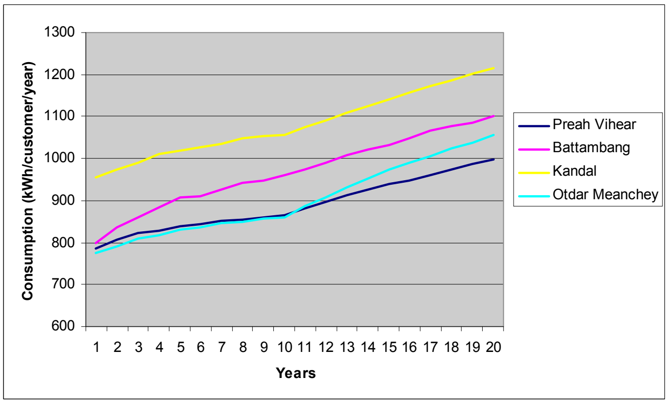

Figure 22: Load forecast for average villages in different provinces, having the average village population in each corresponding province




[13] The results of the load forecast for different sample villages will be shown in this section. All fictional villages feature 1000 inhabitants in 2008 (last census), but they are located in different provinces, so as to assess regional differences.

In the particular case of Otdar Meanchey, demand increases significantly compared to other provinces after year 10, mostly because of relatively higher expected population growth rate. However, in terms of average consumption per customer, the situation is quite different - this chart shows differences between provinces, which are more in line with the differences in living standards.

Figure 23: Average consumption per customer for villages in different provinces with 1000 inhabitants




### 3.4.2 Family scale rice mills

To assess the impact of including small-scale energy intensive productive uses in the load forecast, we will take as an example the load forecast of a 1000 inhabitant village in Preah Vihear, with 50% of family size rice mills (12kW on average) connected to electricity (4 out of 8).

Figure 24: Comparison of consumptions for a village of 1000 inhabitants in Preah Vihear, with and without small rice mills

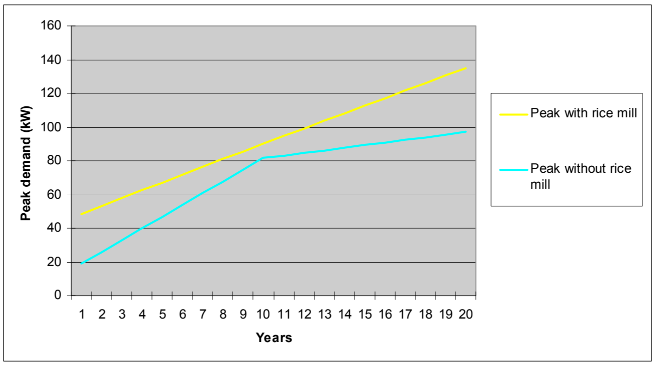
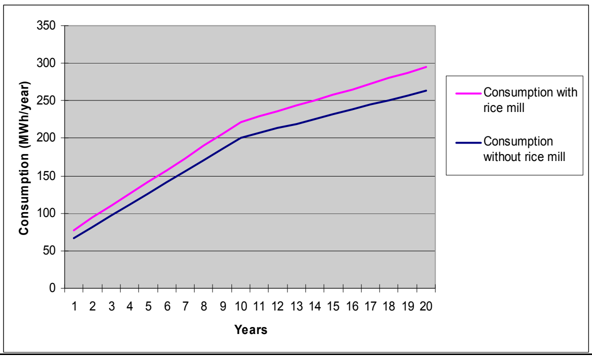



Figure 25: Comparison of peak demands for a village of 1000 inhabitants in Preah Vihear, with and without small rice mills



As shown above, the impact of adding the rice mills is rather small on the overall consumption, but much more significant on peak demand. This is caused by the very low load factor of rice mills. The resulting risk and additional investments involved for the electricity operator (in generation and distribution), and very low associated benefits (energy sales) clearly demonstrate that connecting these small rice mills is not in his interest.

Moreover, the question remains whether all these small rice mills would really switch to electricity, as it would require significant investment costs from them and a sufficiently reliable electricity service.

Therefore, small rice mills will not be considered in the load forecast.

### 3.4.3 Typical daily load curves

Overall, regarding load profiles, one can notice a slight evolution of the shape of the load curve over the planning period. The base load is indeed much higher in proportion during the first year, because of our assumption on connection rates, assuming that non household customers would connect much faster than domestic ones. Therefore, the load factor goes down from **40%** in year 1 to **35%** in year 20, as domestic demand continues to grow.

The following charts show the average daily load curve for a sample village of 1000 inhabitants in Preah Vihear province (the shape does not vary significantly in other provinces).

Of course, what happens in reality will depend on how economic growth will occur in these areas, with industry and services. However, at this point in time, it is difficult to make assumptions other than the ones we have made.

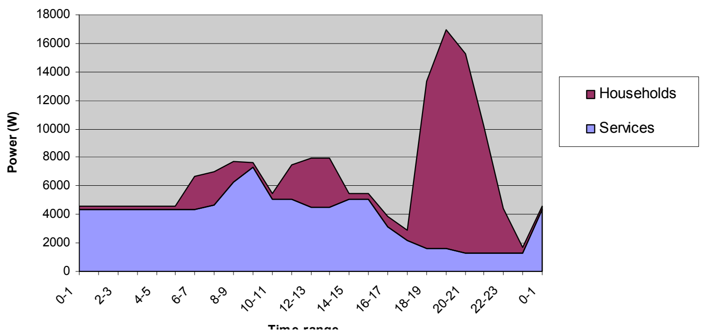



Figure 26: Average daily load curve in year 20 for a village of 1000 inhabitants

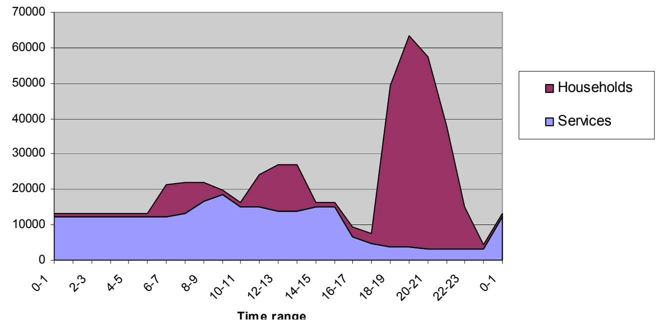



Figure 27: Average daily load curve in year 1 for a village of 1000 inhabitants

### 3.4.4 Discussion on ability to pay and issues for the tariff structure.

Demand in most Cambodian rural areas is usually heavily constrained by the high prices of electricity, i.e. people don't spend on electricity to meet all their needs, but to fit within their allowed budget for the electricity bill. Therefore, the price elasticity is very high, meaning that for example dividing the electricity tariff by two would automatically multiply by two the consumption of households.

Discussions on the ability to pay a certain tariff, or rather the ability to consume a certain amount of electricity, should therefore start from an accurate assessment of the affordable monthly electricity bill.

The UNDP/GERES study in this regard is interesting, as it provides some figures for their four classes of households (based on housing standards) in Kampong Speu and Svay Rieng provinces. There are usually two ways of calculating ability to pay:

- Percentage of total income: a share of 10% is usually taken, although it normally includes other forms of energy (not only electricity). Therefore this method tends to overestimate the real ability to pay.
- Substitutable bill: the expenditure on forms of energy deemed substitutable by electricity, such as kerosene, battery lighting and candles are added to have an estimate of the avoided costs after electrification. Usually, households are willing to spend more than the avoided costs, therefore this method tends to underestimate the real ability to pay.

The resulting figures are as follows:

Table 24: Ability to pay figures from UNDP/GERES study

| Household class | Poor & very poor | Medium | Rich |
|---|---|---|---|
| 10% of household budget (USD) | 2.3 | 4.8 | 9.8 |
| Substitutable bill (USD) | 2.3 | 2.5 | 4.4 |

With the first method and assuming each household class has the same connection rate as the others (which is conservative, as normally richer households have faster access to the electricity service), the average ability to pay would be **4.6 USD/month**.

Other figures given by other sources are:

- JICA Master Plan (2005): **3 to 5** USD/month
- EAC Annual Report for the year 2008: **9** USD/month (calculated average including non household customers as well)
- WB Rural Electrification Strategy (2010): **7.5** USD/month
- SREP survey in villages potentially eligible for hybrid PV/diesel systems: **5** USD/month

By taking an average of all above figures, to 2010 values, it would amount to **6.4 USD/month**. To meet the expected average consumption per month (34.1 kWh/month), the tariff would need to be about **18.7 UScts/kWh**. This is quite in line with the 15 UScts/kWh given by the WB Strategy, and much lower than the current average in rural areas according to data from EAC Annual report (50 UScts/kWh). Moreover, an average growth of household income of **2.5% per year** will be necessary to keep up with the expected growth in consumption, if we assume the tariff remains the same over the next 10 years.

Therefore, if we are really to reach the expect levels of consumption, in the load forecast which is 34,1 kWh / month / household, clear thought will have to be given to the tariff policy.

**Indeed, if average monthly expenditure of 6,4$ works out to a reasonable 18,7 USc/kWh in the Cambodian context, clearly some households would not be able to afford this.**

# 4 ASSESSMENT OF SUPPLY OPTIONS

Generation on the grid will not be covered in this study, as the share of RE in the total system is relatively small , under 10%. The main focus will be on the sub-transmission (medium voltage) network, as it is the determining factor for electricity access in rural areas.

## 4.1 NATIONAL GRID

By combining GIS databases of MV lines from EAC, MIME and EDC planning offices, we have produced the resulting map of existing 22kV and 35kV network. All villages within 2km of these existing lines, which are considered as electrified by the 2008 General Population Census, are considered as interconnected with this network. All electrified villages in Phnom Penh and Kep provinces have been considered interconnected as well.

Data for MV extension plans until 2020 has been collected from EDC, which are considered as high priorities under the ongoing grid extension programme, financed by various donors (ADB, AusAID, China Exim Bank and World Bank +/- 200MUSD committed to date, and a total of +/- 300 MUSD under discussion). Coverage rates have been gathered as well, for different time horizons (2020 and 2030).

All villages within 2km of the planned lines for 2020 have been considered as targeted by the grid extension programme, which was roughly consistent with the number of villages indicated in EDC plans, but slightly lower. The missing 564 villages to reach 80% village coverage in 2020 as stated by EDC and EAC have been simulated using the GEOSIM least-cost optimising algorithm: villages connected first are the ones with the highest Net Present Value over 20 years.

Equation 1: Net Present Value formula for grid extension optimisation

$$NPV = \sum_{i=1}^{20} \frac{Benefits(i) - Costs(i)}{(1+r)^i}$$

With:

Benefits: Energy sold multiplied by 23.4 UScts/kWh (total average cost of grid according to World Bank RE strategy)

Costs: Including cost of generation and transmission (13 UScts/kWh), MV extension (20,000 USD/km), LV lines (15,000 USD/km and a density of 70 customers/km LV line before 2020 and 50 customers/km after 2020), transformers (between 46 to 154 USD/kVA, cf. 4.3) and meters (50 USD/meter). All costs are in constant prices (not escalated with inflation).

r: Discount rate, taken at 6%

This algorithm has then been applied to prioritise the grid extension until 2020, in order to understand which villages are likely to be connected by 2015, an important input to determine our off-grid potential as explained in 2.3.

Beyond 2020, further simulations have been done to reach the 2030 planning target (95% of grid connected villages), using the same optimisation algorithm. This approach tends to favour larger and denser settlements located close to the grid, which may not be in line with the backbone extension plans considered as a short term strategy by EDC. However, since this simulation is applied after the main backbones are extended, it is believed to be an acceptable estimate of grid extension behaviour (after extension of backbones, the utility typically tries to densify its network with profitability in mind). The following maps present:

- Map of the existing 22 kV lines;
- Proposed MV line extensions by EDC;
- Short term transmission and sub-transmission plans;

Figure 28: Map of existing 22kV lines

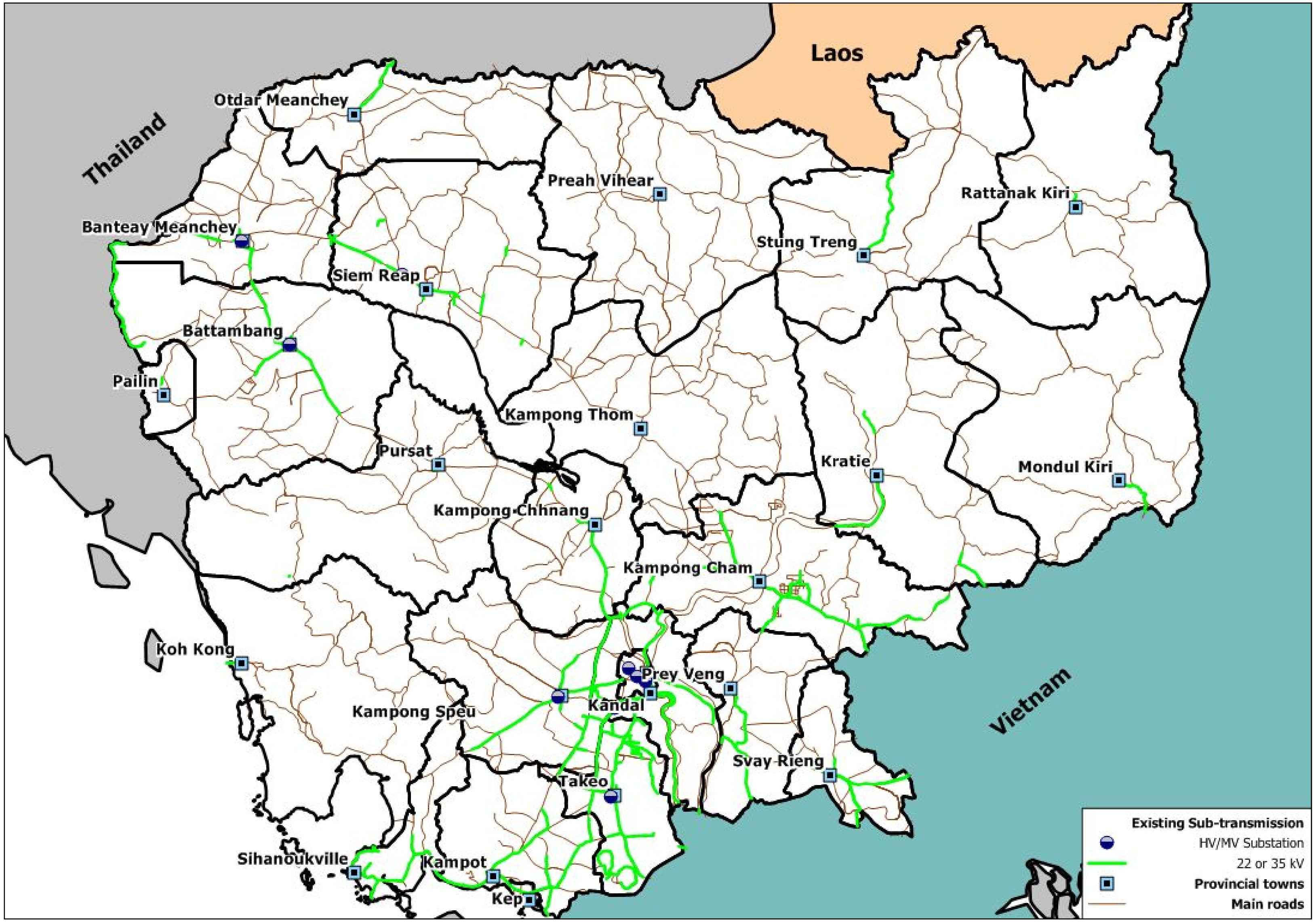


Figure 29: Proposed MV line extensions by EDC

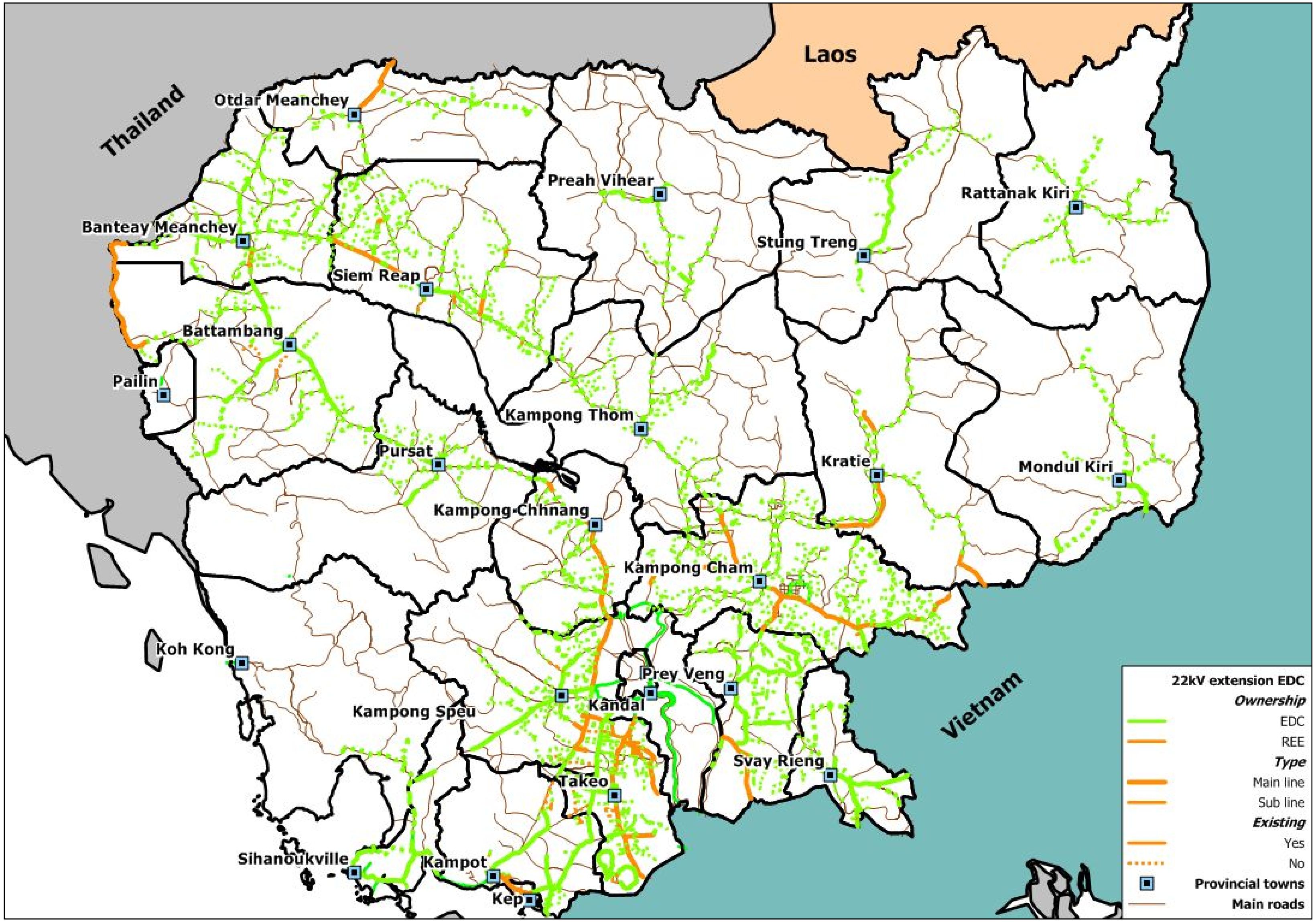
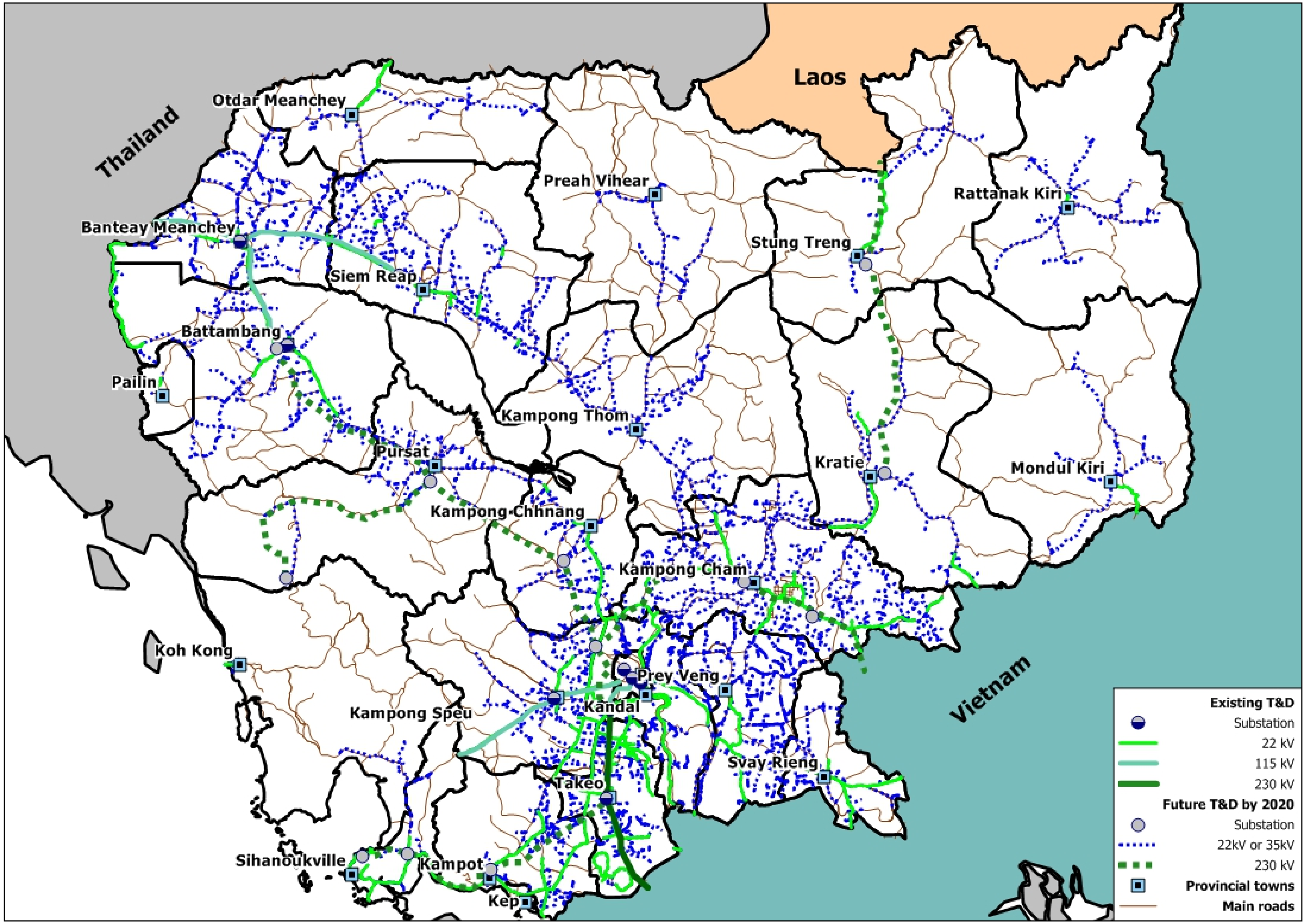


Figure 30: Short term transmission and sub-transmission plans (source: EAC, EDC, MIME, 2010)



## 4.2 OFF-GRID AREAS

As the national grid is expanding quickly, the definition of grid and off-grid areas where mini grid and stand alone options make economic sense in order to avoid leaving out population for a long time, evolves over time. In fact, villages mini grids progressively become “grid connected” as they become integrated in the larger national network. It is therefore important to ensure that the construction standards are compatible and that that remotely located generation can become IPPs. Therefore the definition changes according to the period, as detailed in the following sub-chapters.

The following definition has been agreed as a starting point for the national grid: grid areas are electrified areas which are connected to MV lines (mostly 22kV, but in few cases 35kV) of any of the following networks:

- Phnom Penh, Kandal, Takeo and Kampong Speu (interconnected with Vietnam through high voltage lines)
- Battambang, Sisophon, Siem Reap (each interconnected through high voltage lines from Thailand)
- All border lines with Thailand, Vietnam and Laos. Although not technically “national” grids, these areas belong to much larger networks and therefore behave as if integrated in the national grid from a planning perspective.
- The REE license zones belonging to the interconnected network in 2010 (128 out of 244) are shown on the map below, along with the existing transmission infrastructure

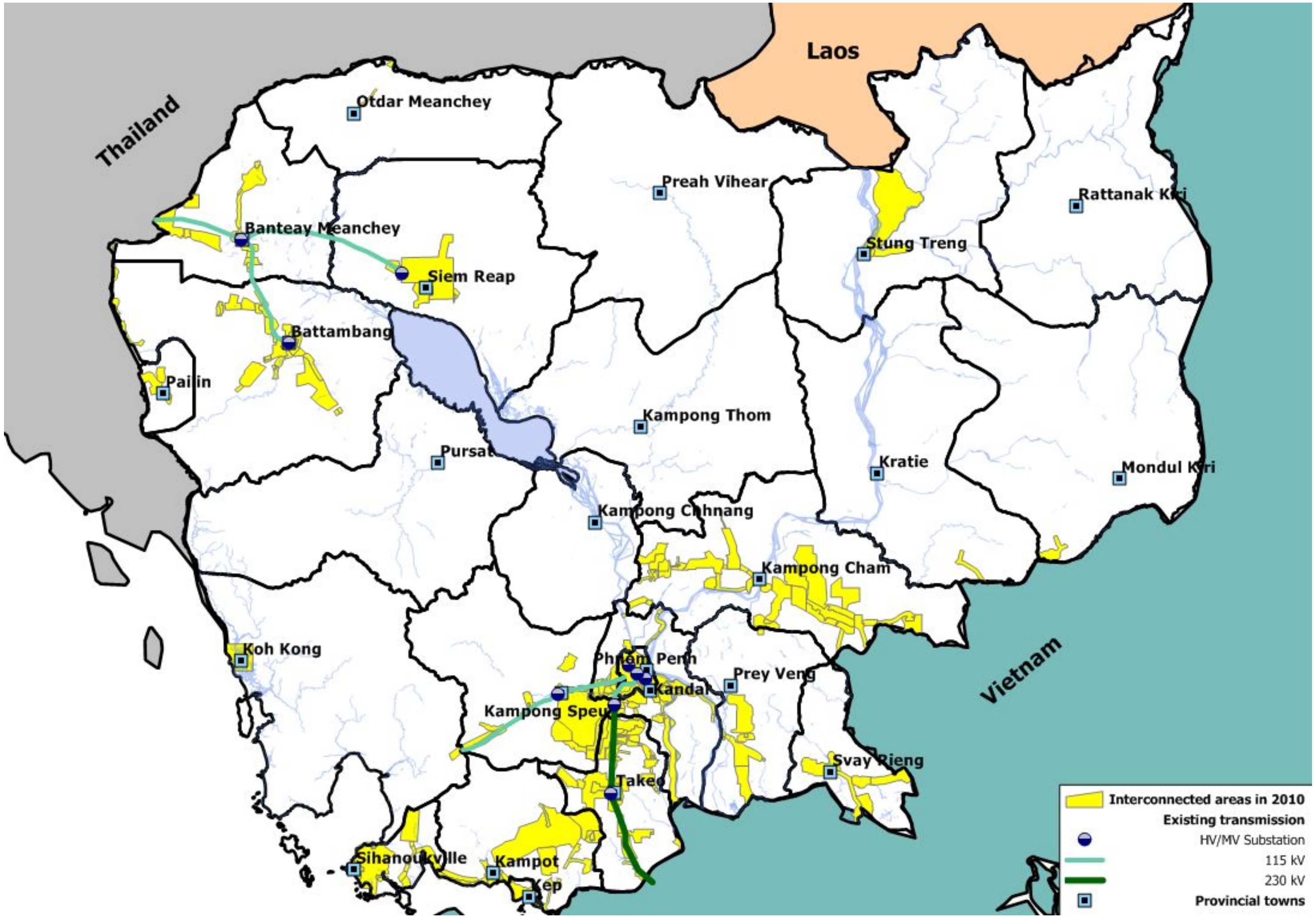
Two short term developments are expected by 2015:

- **The national transmission (HV) network** will interconnect the 3 major networks mentioned in the previous chapter, while expanding the national grid to other provincial towns.
- **The sub-transmission (MV) network** will expand significantly as well, as a result of the ongoing EDc grid extension programme.

As a result, most areas with MV lines will merge into the national interconnected grid (either interconnected to neighbouring countries, or interconnected with other power systems in Cambodia), as shown on the map.

In the longer term, it is understood that Preah Vihear, the last remaining isolated provincial town, will be interconnected with Kampong Thom by 2020.

Figure 31: Map of "grid" areas in 2010



## 4.3 MINI-GRID SUPPLY OPTIONS

### 4.3.1 Principles

This chapter will provide mostly the methodology of mini-grid potential assessment, as well as the main results. More detailed results are available in chapter 5.

The study of off-grid potential focuses on projects ranging from 50kW to 2MW. These projects typically feature a distribution mini-grid and a generation source: either minihydro, biomass (gasification, biogas or cogeneration), or hybrid PV/diesel.

The mini-grid consists of MV (22kV) lines connecting different villages, with LV lines inside each village supplying all customers. The extent of the mini-grid is automatically calculated by the GEOSIM algorithm, starting with the closest Development Pole to the power source, and expanding progressively to nearby villages, until the levelized cost of kWh stops decreasing.

Candidate villages to mini-grid projects are the ones, which are not connected to the national grid by 2015. This time span of 5 years is deemed reasonable, considering the time required to make such projects profitable, and taking into account uncertainties regarding grid extension. All projects are further ranked according to the expected impact on local socio-economic development.

Table 25: Cost of transformers

| Capacity (kVA) | Cost (USD) |
|---|---|
| 30 | 2 935 |
| 50 | 3 339 |
| 100 | 4 787 |
| 160 | 6 377 |
| 250 | 8 260 |
| 315 | 9 499 |
| 400 | 10 630 |
| 500 | 12 430 |
| 630 | 15 145 |
| 800 | 16 770 |
| 1000 | 19 888 |
| 1250 | 23 162 |
| 1500 | 26 440 |
| 800x2 | 33 540 |
| 1500+315 | 35 939 |
| 2000 | 38 117 |

Step-down (three-phase) transformers are sized according to the forecasted demand in each village 5 years ahead. Their cost has been determined in consultation with local suppliers in Phnom Penh; step-up transformers at the generation site are taken as 10% more expensive than step-down transformers of equivalent capacity.

Length of LV lines inside each village is determined with a ratio per customer: **70** customers/km LV line. This parameter is critical in sizing and costing of projects, and naturally depends a lot on the configuration of villages. As a reference, the JICA Master Plan study (2005) assumes a ratio of 66 for off-grid hydro projects . The average LV unit cost is taken at **7,750 USD/km** (EAC, 2010).

Medium voltage lines (22kV) are used to transmit power between different villages. Their path and length is automatically calculated by GEOSIM, using an advanced least-cost path algorithm following roads and avoiding obstacles (forests, rivers, lakes etc.). Moreover, some additional length of MV lines is needed inside villages too. A ratio of **10%** is taken between the MV line length required inside a given village and the calculated length of LV lines. An average unit cost of **10,000 USD/km** is taken (EAC, 2010).

Most customers will use single phase meters, with an estimated cost of **50 USD (including service line)**. The few productive uses using three phase meters will incur a cost of **300 USD**. These costs are included in the overall project costs, as a first assessment of economic costs. However, the customer usually pays at least part of these upfront costs to the operator, therefore the burden may not be on the operator.

According to EAC regulation on depreciation, an economic lifetime of 30 years is taken for all equipments, except transformers with 25 years. Operation and maintenance costs of all distribution equipments is taken at **1%** of investments costs per year.

The 3 main generation technologies studied to power these mini-grids (minihydro, biomass and hybrid PV/Diesel) are detailed below.

### 4.3.2 Mini Hydropower

The first step of the assessment consisted in compiling recent studies on hydro potential in Cambodia including:

- **2006: Master Plan of Rural Electrification from Renewable Energy** (JICA): 145 sites identified from map survey, 66 sites screened, about 28 sites visited and pre-sized, 3 pre FS from 45 to 180 kW
- 2006: Identification of Technically Suitable Micro Hydropower Site in Cambodia for the Purpose of Energy Services (UNIDO): 5 sites visited and one kept for feasibility study and implementation (still pending)
- **REAP**: 6 pre FS 0.65-4MW
- **2006: KEPCO Master Plan for EDC**: 14 sites above 24 MW (outside the scope of the project)
- **2005: Hydro Master Plan** (JICA): 29 sites above 24 MW (ditto)
- **2003: Pre-Investment Study of Community Scale Hydro Projects** (NZ Ministry of Foreign Affaires & Trade & Meritec, 2003). 45 locations identified by desk screening in nine provinces. 6 locations were selected as priority communities for site and socio-economic survey. Pre-F/S for 10 schemes.
- 1995: Review and Assessment of Water Resources for Hydropower and Identification of Priority Projects (Chao Praya Engineering Consortium, Vienna)
- 1971: Inventory of Promising Tributary Projects in the Lower Mekong Basin (Mekong Secretariat, Bangkok)

After analysis, it was decided to start from the long list of JICA sites (145), which is currently the most comprehensive list for the targeted power range, and then to supplement it with other sources, such as MIME, UNIDO, Meritec, as well as SREP field visits on about 10 sites.

A first list has been presented to MIME and PDIME officials during 4 regional meetings in April 2010, in order to have their comments on the list of potential, and also add new ones.

After combining these different sources, and applying screening criteria, the resulting list of potential hydro projects features **65** sites. Please refer to the annexes for a detailed explanation of the method used to create this list. In particular, as we are addressing the issue of off grid electrification, we had to combine basically a reasonably costed site located close to demand – population. In the context of Cambodia, this combination has proven rather difficult.

Since the hydropower sites come from different sources, their sizing assumptions (installed capacity) may differ from one another. For example, JICA sites (the majority of sites) have been sized with isolated rural electrification projects in mind, therefore they tend to have much lower capacities than MERITEC estimates, which are usually sized at the mean annual flow. Whenever two estimates of installed capacity were available for the same site, preference has been given to JICA sizing when assessing potential for mini-grid projects, and to the MERITEC one when assessing potential for injection on a larger grid. The 65 sites have a total installed capacity of **17** MW.

After a first round of simulation in GEOSIM, it has been found some of the 65 sites were competing for the same demand and some didn't have any significant demand nearby. Therefore, only the best sites have been kept, on the basis of the lowest levelized cost of kWh. Sites removed in this way may be candidates for IPP project, provided demand is sufficient and generation & transmissions costs are acceptable for the operator. Final number of sites for each scenarii is given below:

Table 26: Mini-hydro projects for each scenarii

| | Baseline scenario | Intermediate scenario | Conservative scenario |
|---|---|---|---|
| Number of projects kept | 33 | 35 | 38 |
| Cumulated installed capacity (kW) | 6 449 | 6 639 | 7 309 |

Installed capacity is not the only important characteristics of a potential mini hydro project. The GEOSIM model also requires information on the guaranteed capacity (dry season output in kW) and the yearly energy production (in MWh). Therefore, formula had to be used to define these missing parameters. Whenever estimates of investment costs were not available, the following unit costs for hydropower plant have been applied, taken from the two main sources:

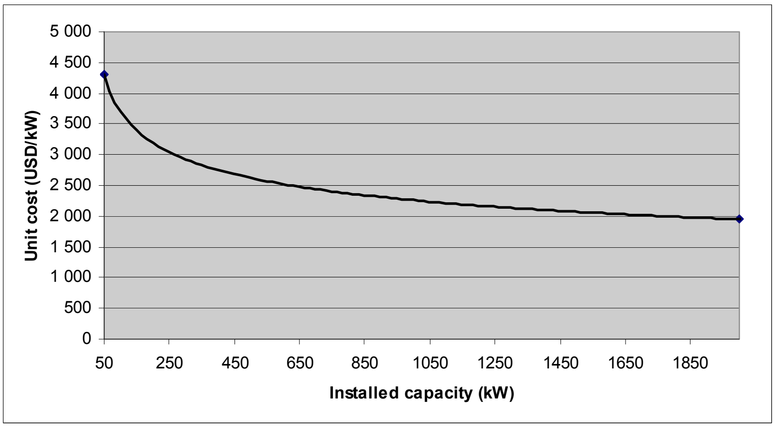
- **JICA**: average cost of 4300 USD/kW, for systems around 50kW
- **Meritec**: average cost of 1947 USD/kW, for systems around 2MW

Values for sites between 50kW and 2MW have then been interpolated using the following power law:

Equation 2 Hydro unit cost formula

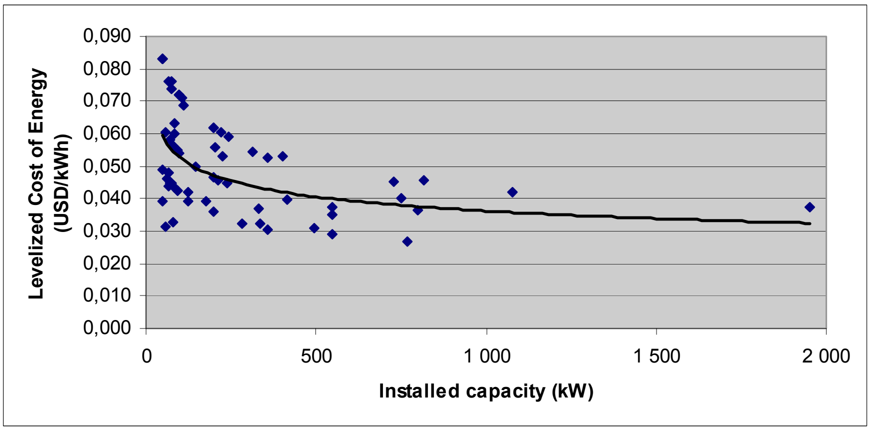
$$UnitCost(USD/kW) = 9963 \times Capacity(kW)^{-0.2148}$$

Figure 32: Evolution of unit costs with installed capacity



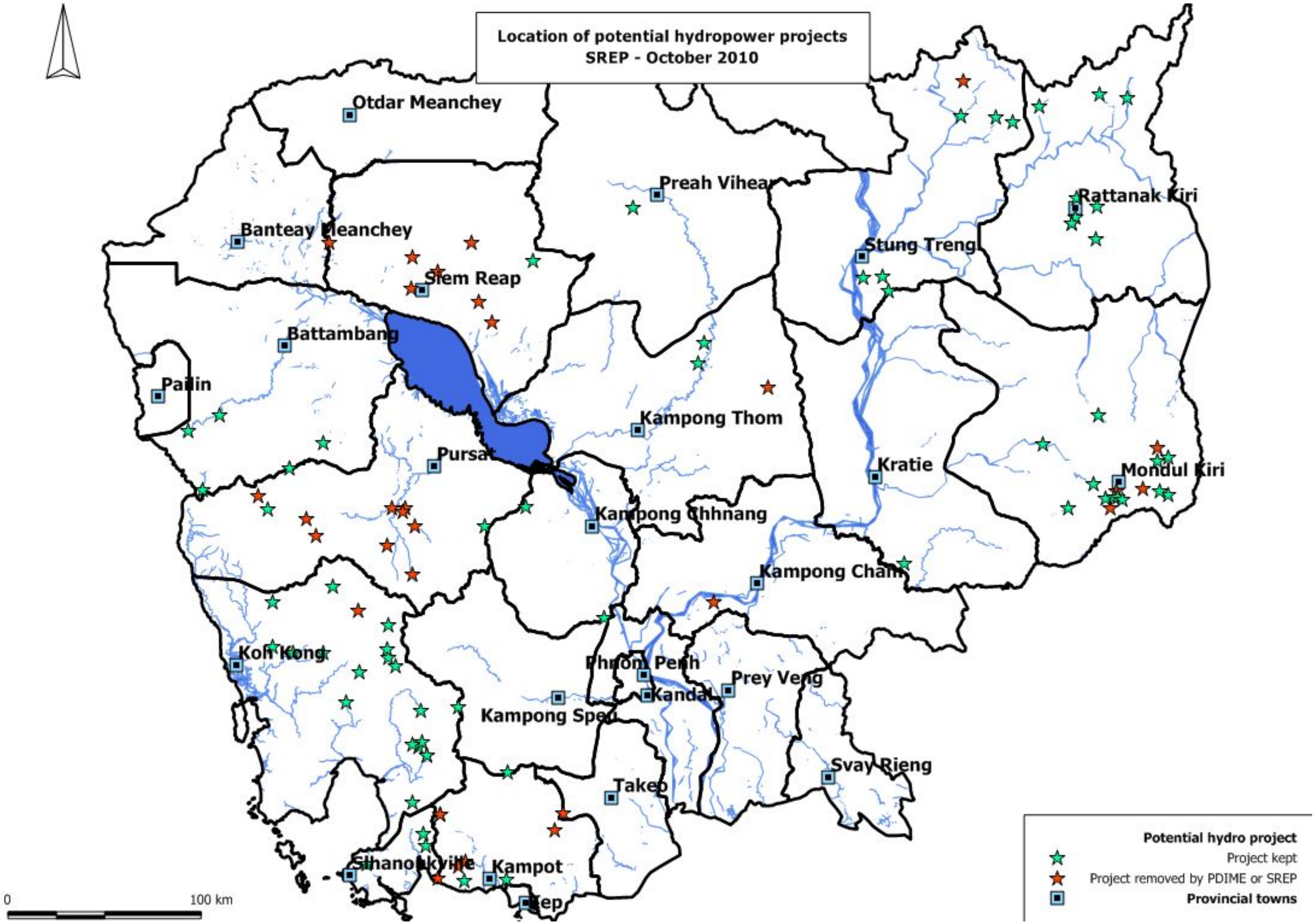

According to EAC regulation on depreciation, an economic lifetime of **30 years** is taken for all hydropower equipments. Operation and maintenance costs of all distribution equipments is taken at **2%** of investments costs per year (in line with assumptions from JICA Master Plan). From these assumptions, the raw generation cost of hydropower projects can be calculated, using the Levelized Cost of Energy (LCOE) approach, with a 6% discount rate and constant prices:

Figure 33: Raw hydro project generation costs




Naturally, the cost of transmission, distribution, taxes and the profit margin for the operator will have to be added to estimate the real tariff to the end-user, but this already provides an indication of the competitiveness of this solution for off-grid and grid connected purposes. NB: This calculation also assumes that all power generated can be sold, which is not always the case in both grid and off-grid cases, as it will be explained in the planning scenarii results (see chapter 5). Moreover, the cost in isolated mini-grid mode is usually much higher than this, as the seasonality of hydro supply makes a diesel genset backup mandatory (simulated by GEOSIM on a case by case basis, depending on the characteristics of the hydro site and its nearby demand).

Figure 34: Map of identified hydro potential projects



### 4.3.3 Biomass mini grids options

Projects falling under the biomass family may be very different from each other and are usually defined by the three following characteristics:

Type of biomass resources: three main categories of biomass resources exist:

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

It has been decided to focus on agro-industrial residues for several reasons, and more specifically on rice husks and bagasse from sugarcane as a first step (the final planning report may include some other more recent agro-industries under development, such as palm factories, piggeries and cassava starch factories).

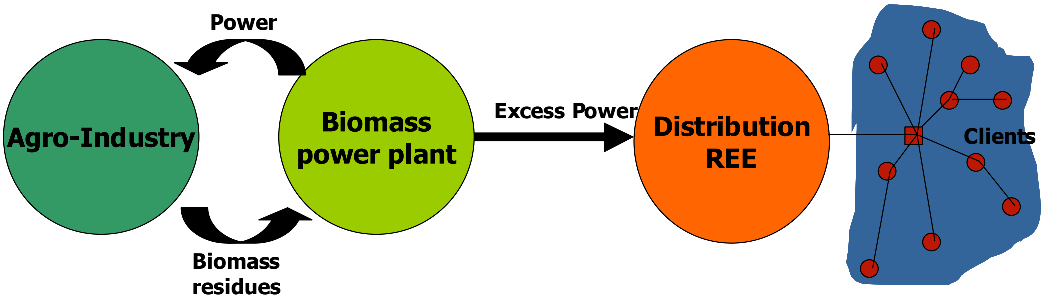
Technology used to convert the biomass resources into electricity: again, three technologies have been considered:

- Biogas (anaerobic fermentation): To date, there are very few large agro-industries in the country having the quantity of humid waste required for biogas. There are only about 5 pig farms which could be potentials for such units in the Medium term.
- Cogeneration (combined production of heat and power from a boiler): again requires fairly large units, which also need the heat. Until recently, relevant agro-industries (large rice mills, sugar production) were not large enough to offer such opportunities. However, a few (5 to 10) such investments are being prepared in Cambodia, mostly sugarcane mills and rice mills.
- Gasification: usually uses the same types of residues than cogeneration, but it is more suitable whenever power output is less than 1MW and when heat is not so much needed by the agro-industry (which is usually the case for medium sized rice mills). This technology currently offers more potential – some 90 rice mills of suitable size have been identified and SME Cambodia has been selling and installing gasifiers which have a fairly good track record, however mostly for captive use until now.

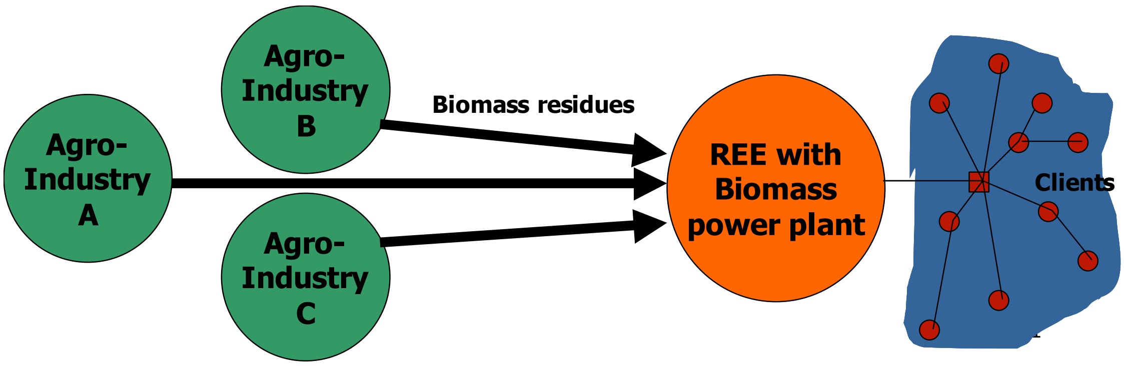
Figure 35: Workers shoveling rice husks coming out of a rice mill

Business model: two main types of models associating agro-industries with rural electrification may be considered:

"Captive use projects": projects where biomass facility is in the agro-industry compound, and a part of the generated electricity/steam is consumed by the agro-industry (captive use), the rest being supplied either to a mini-grid or the national grid or both. For example, rice mills typically consume only 30% of the husk for their own consumption and hence the balance could be used to sell to a local (diesel) REE, bearing very high production costs.




"Clusters": projects where agro-industrial residues are purchased and transported from several medium sized agro-industries, which individually wouldn't have the critical size for a single biomass project.




Please see refer to the annexes for a detailed review of these different elements, and the reasons for the choices among all the possibilities. After combining the above three main characteristics, four main types of projects have emerged:

**Table 27: 4 main types of biomass projects**

| | Residue | Technology | Business model | Production range |
|---|---|---|---|---|
| A | Rice husk | Gasifier with dual fuel genset | Cluster | Each industry between 200 and 2,000 t rice/year, total of 2,000 t rice/year for the cluster |
| B | Rice husk | Gasifier with dual fuel genset | Captive | 2,000-10,000 t rice/year |
| C | Rice husk | Cogeneration | Captive | >10,000 t rice/year |
| D | Bagasse | Cogeneration | Captive | All sugarcane mills |

As shown in the table below, the survey conducted under SREP provided rather optimistic perspectives for at least the two first types of projects. Regarding the second type of project, there also will probably be an important potential, but in the medium term: the agro industrial sector is made of SMEs in Cambodia and large agro-industries are still at the inception stage. Willingness of small rice millers to sell excess power or act as REEs was found not to be an issue, since the proposed business model for their category would be to sell directly rice husks to a dedicated gasifier purchasing from several rice mills.

**Table 28: Results of the SREP survey on small and medium rice mills**

| Production range | Type of project | Surveyed by SREP | Knowledge of biomass technology | Interest in technology | Already equipped with biomass | Willing to sell excess power | Willing to act as REE | Excess husk availability (avg of % total residues) |
|---|---|---|---|---|---|---|---|---|
| 200-2000 t rice/year | Clusters of rice mill (A) | 69 | **84%** | **85%** | **10%** | **36%** | **19%** | **46%** |
| >2000 t rice/year | Medium rice mill (B) | 27 | **100%** | **96%** | **7%** | **72%** | **72%** | **73%** |

We have assumed that the cogeneration projects, with installed capacities often in the range of several tens of megawatts, would provide 500kW to 2MW for local mini-grid electrification, the rest being used for own consumption or selling to the grid (located close to the agro-industry in all cases ). This excess capacity for rural electrification has been sized depending on actual forecasted demand in the vicinity of the power plant, and thus depends on the scenario.

For the detailed methodology and assumptions made to create the list of potential biomass projects in GEOSIM is explained in annexes. The resulting number of projects and installed capacity for each scenario is:

**Table 29: Number of identified potential projects**

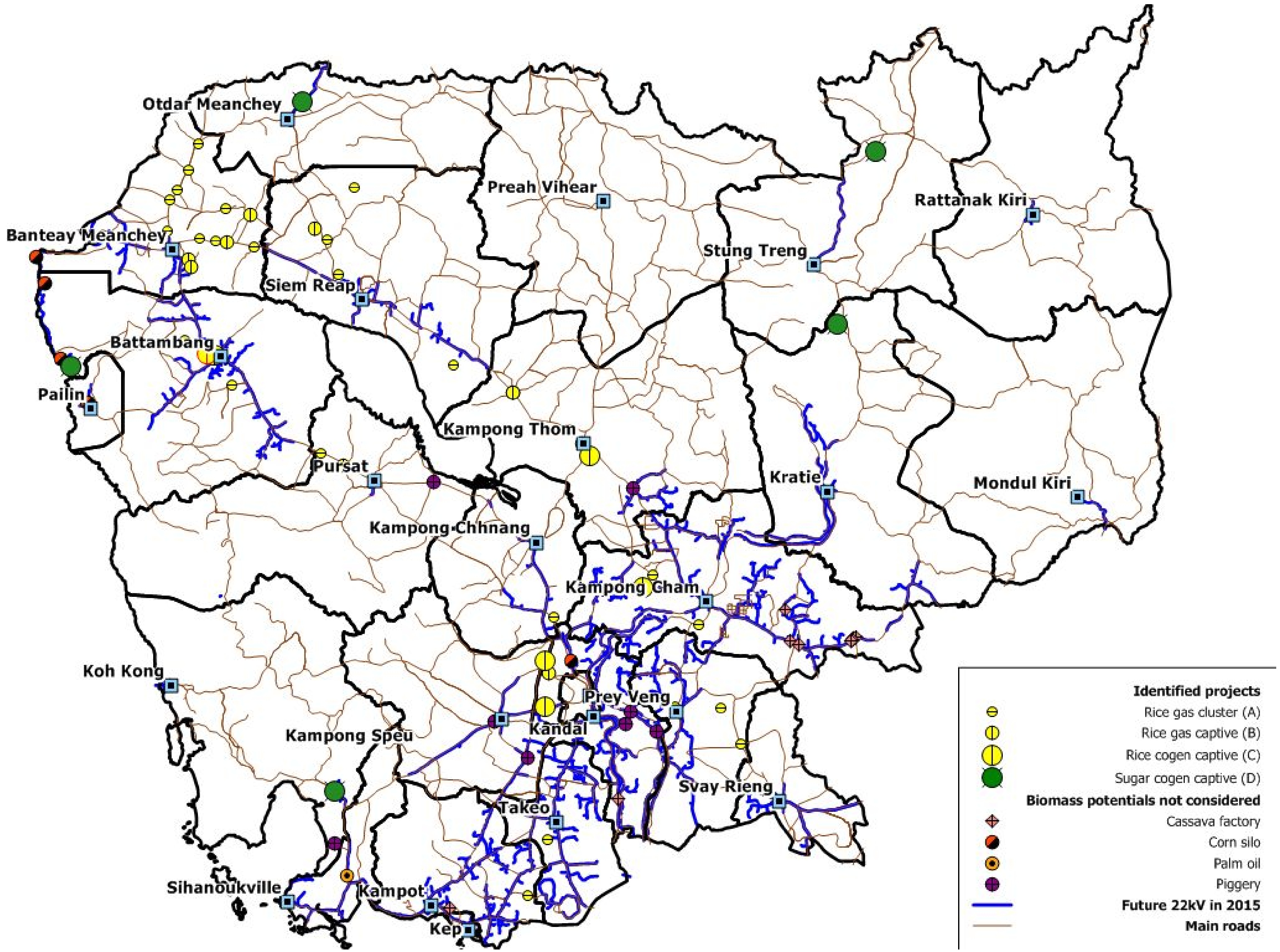
| | Type of project | Baseline scenario | | Intermediate scenario | | Conservative scenario | |
|---|---|---|---|---|---|---|---|
| | | Number of projects | Cumulated installed capacity (kW) | Number of projects | Cumulated installed capacity (MW) | Number of projects | Cumulated installed capacity (kW) |
| A | Rice cluster | 12 | 2096 | 20 | 3544 | 28 | 4728 |
| B | Rice captive gasifier | 2 | 321 | 7 | 1488 | 10 | 2078 |
| C | Rice captive cogeneration | 6 | 4200 | 6 | 4350 | 6 | 4150 |
| D | Sugarcane | 5 | 3700 | 5 | 4450 | 5 | 5250 |
| | **Total** | **25** | **10317** | **38** | **13832** | **49** | **16207** |

Please note that the above projects will definitely not be carried out for rural electrification purposes only. Many more projects would be possible as pure IPP projects (direct injection on the national grid), as it already happens in a few cases, where the REE runs its gasifier in the day and purchases power from the grid at night time when demand is too low for the gasifier to run properly. Total number of biomass projects including IPP is about **120**.

The following map shows all biomass potentials identified (conservative scenario), as well as some others not considered in the rural electrification plan, but which could be of interest for direct injection to the grid.

However, these projects will not emerge unless there are considerable policy evolutions and a clear regulatory and incentives framework provided: to date, there has been no systematic work done on small scale independent power production and the framework for grid connection, and power purchase agreements depending on the technology, firm / non firm power, seasonality etc... It is obvious that large agro industry will limit co-generation to captive use unless it is attractive enough to sell excess power to the national grid.

Figure 36: Map of identified biomass projects (conservative scenario)



### 4.3.4 Diesel mini grids

| Capacity (kW) | Total cost (USD) | Unit cost (USD/kW) |
|---|---|---|
| 5 | 1 200 | 240 |
| 10 | 3 000 | 300 |
| 20 | 9 000 | 450 |
| 30 | 10 100 | 337 |
| 40 | 11 824 | 296 |
| 50 | 13 549 | 271 |
| 60 | 15 273 | 255 |
| 70 | 16 573 | 237 |
| 80 | 17 456 | 218 |
| 90 | 18 339 | 204 |
| 100 | 19 221 | 192 |
| 150 | 23 636 | 158 |
| 200 | 28 050 | 140 |
| 250 | 32 464 | 130 |
| 300 | 36 878 | 123 |
| 400 | 45 707 | 114 |
| 500 | 57 000 | 114 |
| 600 | 68 400 | 114 |
| 700 | 79 800 | 114 |
| 800 | 91 200 | 114 |
| 900 | 102 600 | 114 |
| 1000 | 114 000 | 114 |
| 1200 | 136 800 | 114 |
| 1500 | 171 000 | 114 |

As a conservative move, the simulations have been run assuming that all new diesel mini-grid projects would be purely diesel based. However, potential for hybrid PV/diesel will be discussed briefly in the next chapter.

For all new diesel projects, it is assumed that 2 generators are operated to ensure 24h supply: one during evening peak demand, and another during the day, when demand is lower. The average lifetime of gensets is taken at **5** years, although the current practice for REEs seems to largely exceed this value, resulting in drastically reduced efficiency. Average specific fuel consumption is thus assumed to be **0.35 L/kWh**.

Unit costs vary between **115** and **450 USD/kW**, depending on the installed capacity.

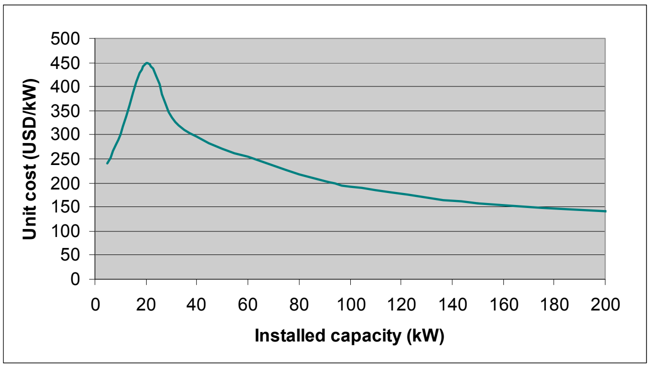



Table 30: Cost of diesel gensets

The above costs are found slightly higher than quotations given by suppliers in Phnom Penh. However, these quotations are mostly for second-hand material, and therefore should not be used as a reference for sustainable projects.

Operation and maintenance costs of all distribution equipments is taken at **5%** of investments costs per year.

The number of sites and capacity for each scenarii is given below:

Table 31: Diesel projects for each scenarii

| | Baseline scenario | Intermediate scenario | Conservative scenario |
|---|---|---|---|
| Number of projects | 150 | 233 | 289 |
| Cumulated installed capacity (kW) | 21 663 | 34 701 | 46 833 |

The number of diesel projects is significantly higher than biomass and hydro projects, thereby justifying the need for innovative solutions to make them more economically and environmentally sustainable, such as hybridisation with PV.

### 4.3.5 Hybrid PV/Diesel

International experience now shows that with the dropping of PV panel prices and the increase in reliability of technology, the PV production cost, with financing available over 15 years, could be between 20 and 70 UScents/kWh:

- The lowest range being for large (3 MW and above) units feeding into the grid without any battery storage
- Mid range being for smaller capacities and feeding into a diesel grid typically, still without storage
- The most costly being for very small units and with up to 100% battery storage, the PV power being produced during the day, stored and then consumed in the night time.

Most new diesel mini-grid projects proposed under the rural electrification plan belong to the third category. Therefore, the cost are expected to be slightly high, even compared to diesel standards. However, some sites may still prove competitive, for example is sufficient demand exists during the day (several mobile phone antennas and other productive uses), and if adequate sources of financing are available. Besides, with economic development and further activities, load factors will improve, and direct injection of PV without battery storage should prove to become an option. Although careful optimisation will need to be carried out on a case by case basis (cf. the 3 feasibility studies undertaken as part of SREP activities), we will provide here an estimate of the potential market size in Cambodia using the following assumptions:

- PV productivity: 5.3 kWh/m²/day, 80% overall conversion efficiency[14]
- Lifetime of equipments: 20 years for panels and electronics, 5 years for batteries
- Unit costs: 3.3 USD/Wp for panels, 1.0 USD/Wp for inverters, 1.0 USD/Wp for battery charge controllers, 140 USD/kWh for batteries
- Installation and contingencies: 10% investment costs
- Discount rate: 6% (excluding inflation, calculation is done in constant prices). This means that access to soft loans is possible.

This results in the following levelized costs:

- Project with 100% battery storage (no demand during the day): **42 UScts/kWh**
- Project with 50% battery storage: **34 UScts/kWh**
- Project with 0% battery storage: **27 UScts/kWh**

These figures are to be compared with diesel generation costs, using the assumptions detailed in the previous chapter. Since the unit costs vary with the installed capacity, the generation costs are slightly different between small and large scale:

- Small-scale projects (~20 kW): **39 UScts/kWh**
- Large-scale projects (>400 kW): **36 UScts/kWh**

However, investment costs of diesel are marginal in the cost of kWh. The real parameters are the diesel specific consumption (taken here as 0.35 L/kWh on average) and the diesel price (1 USD/L). If we assume that small-scale projects use very inefficient second-hand gensets consuming 0.4 L/kWh, while large-scale projects go down to 0.27 L/kWh, the range of generation costs becomes:

[14] Taking into account losses in the inverter, batteries, and the panels at high temperature.

Table 32: Diesel generation costs for different capacities of diesel gensets, and associated competitive PV/hybrid option

| Capacity (kW) | Unit cost (USD/kW) | Specific consumption (L/kWh) | Diesel generation cost (Uscts/kWh) | Competitive PV/Hybrid option |
|---|---|---|---|---|
| **20** | 450 | 0.40 | **44** | **100% storage (42 UScts/kWh)** |
| **30** | 337 | 0.38 | **42** | |
| **40** | 296 | 0.37 | **40** | **50% storage (34 UScts/kWh)** |
| **50** | 271 | 0.36 | **39** | |
| **60** | 255 | 0.35 | **38** | |
| **70** | 237 | 0.35 | **37** | |
| **80** | 218 | 0.34 | **36** | |
| **90** | 204 | 0.33 | **35** | |
| **100** | 192 | 0.33 | **35** | |
| **150** | 158 | 0.31 | **33** | **0% storage (27 UScts/kWh)** |
| **200** | 140 | 0.30 | **31** | |
| **250** | 130 | 0.29 | **30** | |
| **300** | 123 | 0.28 | **29** | |
| **400** | 114 | 0.27 | **28** | |

The above table reveals that projects below 30 kW can be equipped with 100% storage systems, projects between 30 and 100 kW can have a maximum of 50% storage, and projects above 100 kW would need to work with no storage at all. This is relatively consistent with the daily load patterns, as small-scale projects tend to have demand only in the evening (thereby requiring 100% storage of PV power, to be delivered at night), while larger projects can include daytime productive uses absorbing directly PV power without going through a battery system.

As a first estimate, 20% is suggested as a reasonable penetration rate of PV, i.e. for a 100 kW diesel system, 20 kWp would be installed. This is to minimise power distribution stability issues, and ensure enough power can be absorbed at the time of PV production. The results in terms of sizing and investment costs are detailed in the planning results (chapter 5).

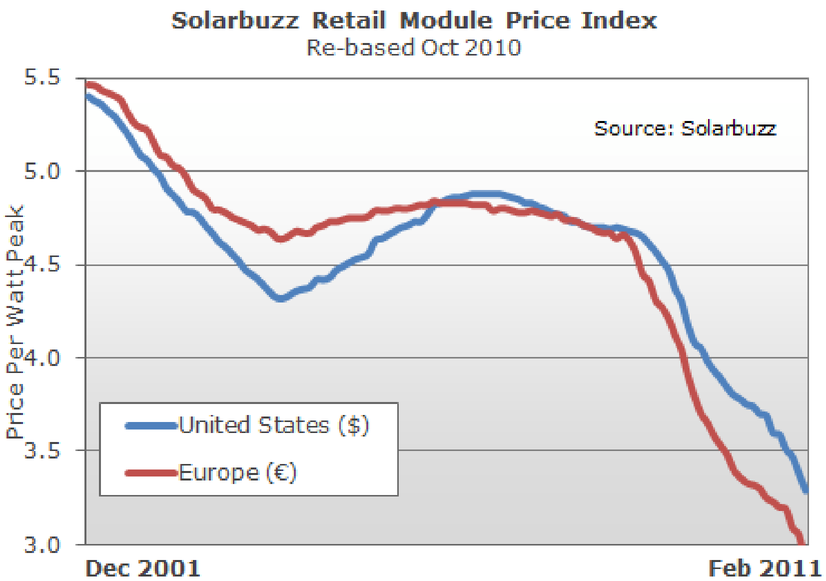



Figure 37: Historical evolution of PV panel unit prices for the past decade

In the longer term, it can be expected that, given the depth of the market of diesel operators, and further cost reduction at the global stage, as well as rising fuel prices, even projects where the suggested PV option is difficult to implement may become eligible for hybridisation.

Therefore, sensitivities have been carried out on diesel fuel prices (increased to 1.3 USD/L) and PV panel unit costs (decreased to 2.2 USD/Wp). The 0% storage solution would then decrease to about 20 UScts/kWh, making it significantly cheaper than any diesel project. As seen in the table below, even large-scale projects would become competitive with a 100% storage PV/diesel hybrid.

Table 33: Diesel generation costs and associated competitive PV/hybrid option with higher diesel price and lower PV unit costs

| Capacity (kW) | Unit cost (USD/kW) | Specific consumption (L/kWh) | Diesel generation cost (Uscts/kWh) | Competitive PV/Hybrid option |
|---|---|---|---|---|
| 20 | 450 | 0.40 | **56** | **100% storage (35 UScts/kWh)** |
| 30 | 337 | 0.38 | **53** | |
| 40 | 296 | 0.37 | **51** | |
| 50 | 271 | 0.36 | **49** | |
| 60 | 255 | 0.35 | **48** | |
| 70 | 237 | 0.35 | **47** | |
| 80 | 218 | 0.34 | **46** | |
| 90 | 204 | 0.33 | **46** | |
| 100 | 192 | 0.33 | **45** | |
| 150 | 158 | 0.31 | **42** | |
| 200 | 140 | 0.30 | **41** | |
| 250 | 130 | 0.29 | **39** | |
| 300 | 123 | 0.28 | **38** | |
| 400 | 114 | 0.27 | **36** | |

The overall conclusion is that there is a significant potential for PV/diesel hybrids in Cambodia but as a prerequisite, there definitely is a need for:

- pilot projects to demonstrate the technical feasibility of projects in a Cambodian context, particularly in consideration for the most appropriate electronics;
- Capacity building on the technology.

An appropriate policy and financial support framework is definitely required, ensuring that:

- Tax and duty issues do not unduly increase project costs;
- Long term soft loan financing with a part of grants is available, whether provided by the Rural Electrification fund or commercial banks, which is far from being the case today due to lack of understanding of the technology and limited credit worthiness of the project sponsors;
- The regulator encourages these schemes through appropriate regulatory frameworks and PPAs.

### 4.4 STAND-ALONE SYSTEMS

The main components of the approach are:

- Solar Battery Charging Stations (BCS) will be installed in each village, which are not electrified by national grid or mini-grid projects by 2020, and where no BCS is currently operating. This will ensure that the political objective of 100% village having electricity supply by 2020 is met.
- Likewise, community PV systems are suggested in all villages, which are not electrified by national grid or mini-grid projects by 2020. Targeted facilities are schools, health centres, commune halls[15] and pagodas.
- Finally, all rich households in these villages will be candidates for Solar Home Systems (SHS). The share of rich households in each village varies from one province to another, as explained in 3.1.1.

Level of services suggested are:

- Community PV
  - Schools & Health Centres: **700 Wp**
  - Pagoda and commune hall: **200 Wp**
- Solar BCS: equivalent of **40 Wp/customer**
- SHS: 100 Wp

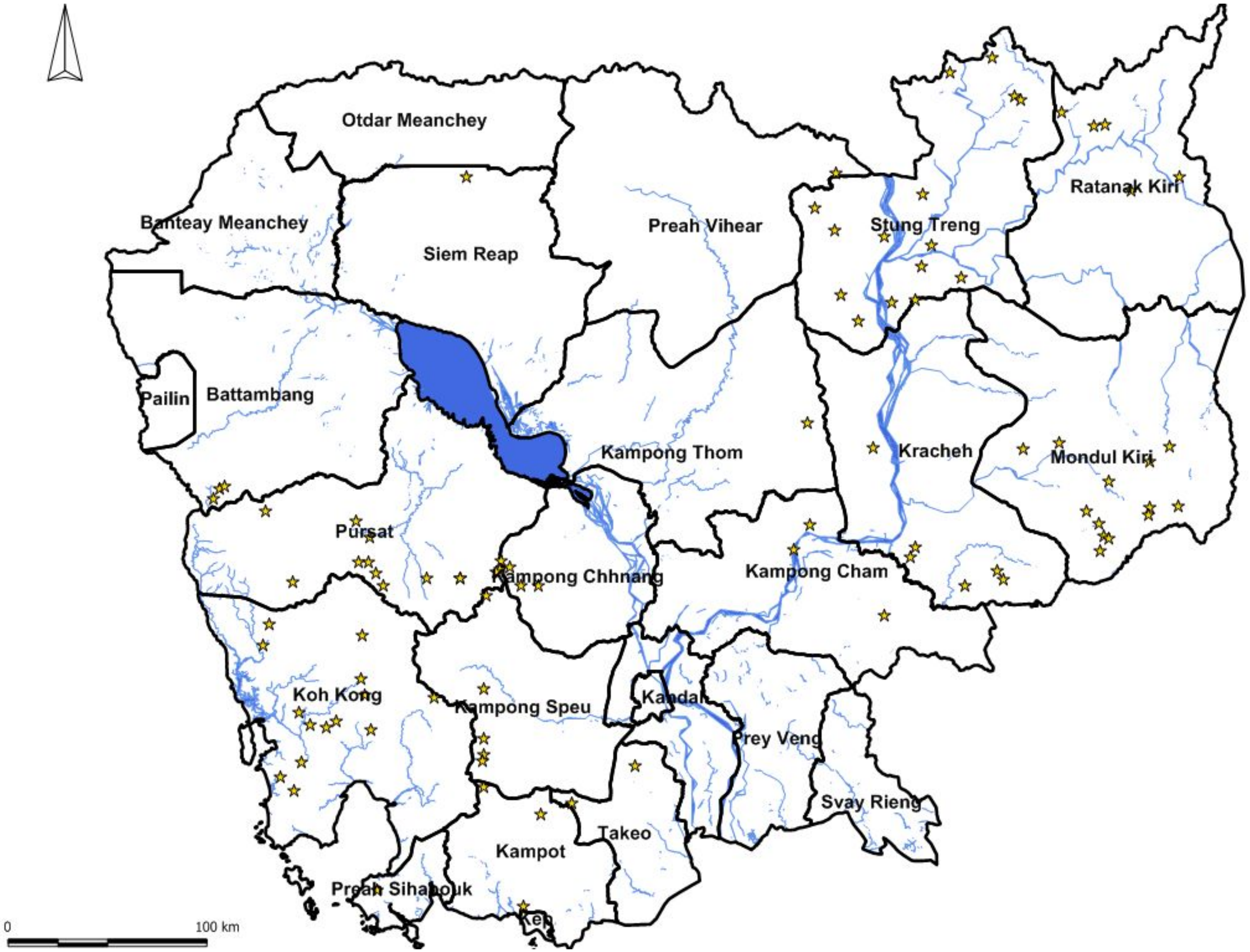
Regarding investment costs, the following assumptions have been made (inclusive of transport and installation):

- **3 USD/Wp** for Solar BCS, plus an additional 30 USD per customer for the battery itself
- **4 USD/Wp** for SHS and community PV systems

Deployment of these stand-alone systems is assumed to happen progressively until 2020. Pico-hydro systems could be added, but they are very site specific, and usually cannot be identified from a map study given that the smallest scale available in Cambodia is 1:50,000. Therefore, extensive field surveys would be required to identify suitable places. Nevertheless, a map of sites found to be smaller than 50kW after the JICA study is shown below:

[15] As the location of each commune village was not available from the GIS database, it has been assumed that the commune hall is located in the largest village of each commune (in terms of population).

Figure 38: Location of possible picohydro projects



# 5 RESULTS OF THE THREE PLANNING SCENARII

## 5.1 REMINDER OF OBJECTIVES AND APPROACH, SENSITIVITY ANALYSIS

The three scenarii aim to reach the policy objective for 2020, i.e. all villages would have access to an electricity service, either national grid, mini-grids or stand-alone systems. The three scenarii follow the same methodology, explained below, their only difference is the assumed speed of national grid expansion (as explained below).

The second main policy objective for 2030 (70% households having access to national grid or mini-grids) is reached only in the baseline scenario, but the two others come relatively close to it.

**Step 1: grid expansion**

The scenarii differ on the speed at which the national grid will expand to rural areas making different assumptions in terms of achievements by 2015, 2020 and 2030, in order to consider different situations of fund mobilisation and actual implementation.

- **Baseline scenario:** the projections made by EDC in terms of number of villages and km of lines are taken for 2015, 2020 and 2030 as achieved. These projections are in line with EAC targets of 80% national grid villages by 2020, and 95% by 2030.
- **Intermediate scenario:** this second scenario assumes that the grid extension rate would be half as fast as in the baseline scenario, i.e. whatever villages would be connected in the baseline scenario by 2015 would now be connected by 2020 only. Likewise, villages connected by 2020 in the baseline scenario would be connected by 2030 instead.
- **Conservative scenario:** the third scenario assumes an even slower grid extension speed because of limited fund availability, one quarter as fast as the baseline scenario, i.e. villages connected by 2015 would be connected by 2030 only.

**Step 2 : off grid households and villages**

Least-cost comparison of decentralised mini-grids solutions (mini hydro, biomass, and diesel) is performed in order to supply **all Development Poles** not covered by grid extension before **2015**.

Finally, stand-alone systems are considered:

- Solar Battery Charging Stations (BCS) to ensure that the political objective of 100% village having electricity supply by 2020 is met
- Community PV systems (schools, health centres, commune halls and pagodas) for all non electrified villages
- All rich households in non electrified (grid or mini grid) villages will be candidates for Solar Home Systems (SHS)

**Demand**

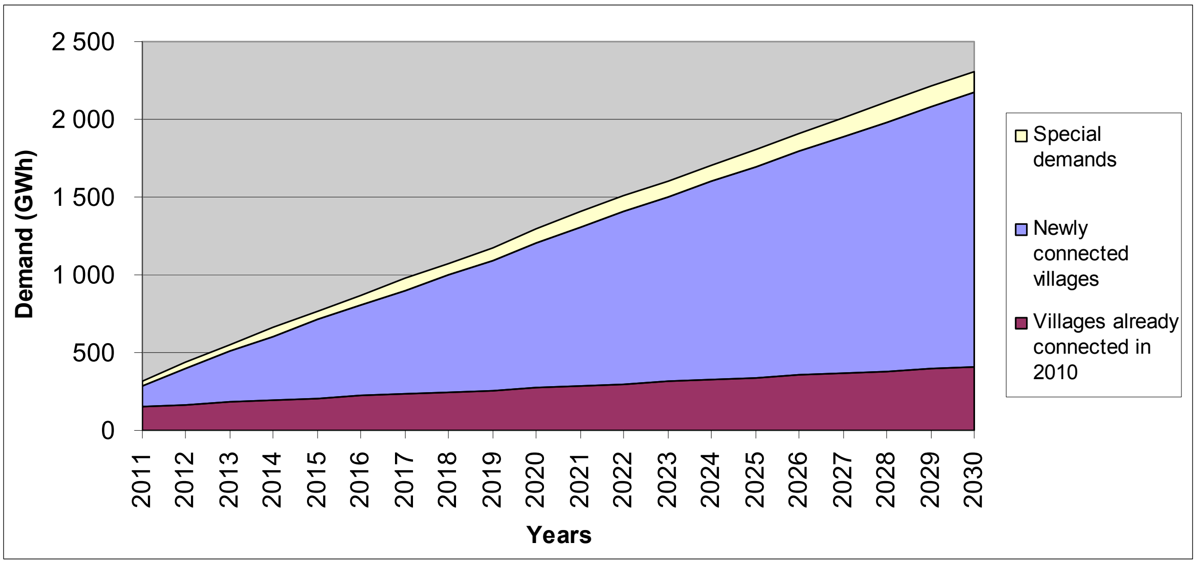
In the baseline scenario, which has the maximum number of grid connected villages, rural demand as per our simulations will amount to 2,310 GWh/year in 2030, compared to 21,000 GWh/year for the whole country including urban and large industrial customers (Power Sector Development Plan). This is slightly above 10% of total demand, hence it is obvious that rural demand will not be constrained by energy production.

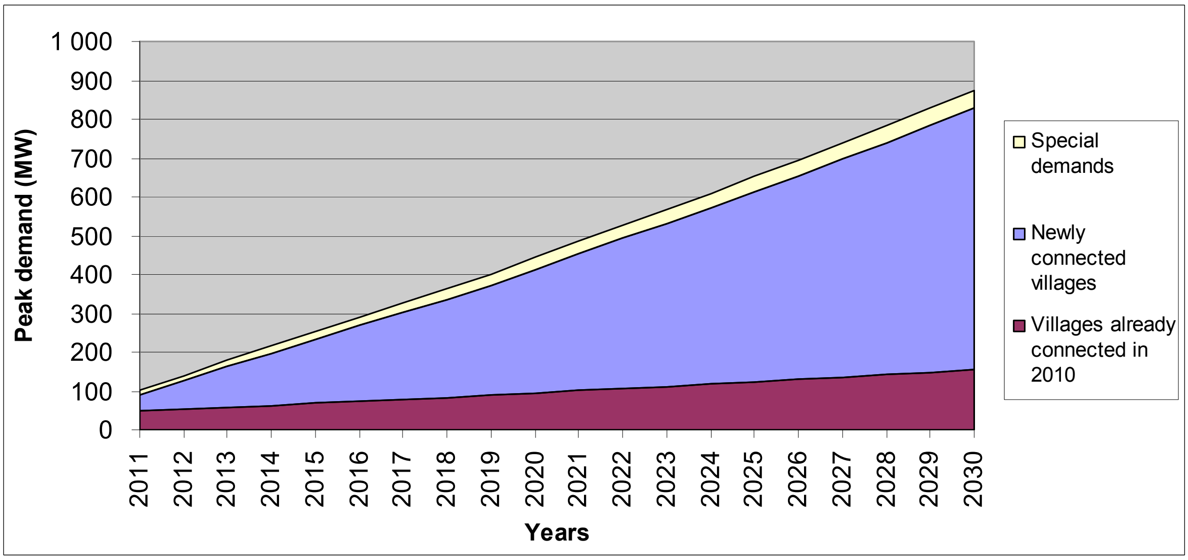
Peak demand for rural grid customers amounts to about 873 MW in 2030, but most of this demand is expected to happen in the evening, contrary to the current peak on the grid, which is mostly in the afternoon (linked to AC use). Therefore, rural electrification being much smaller in volume, its impact on total installed capacity will be negligible.

Therefore, we have not conducted any sensitivity analysis to demand, which does not mean that this should not be refined when moving to the more detailed assessment of off grid / mini grid options, on the contrary, as the level of demand and placed energy impacts significantly the kWh cost.

The following charts display the evolution of rural demand on the grid, with a breakdown of villages already connected to the grid, and the ones connected after year 2011.

Figure 39: Rural demand grid connected villages – energy and peak load.



## 5.2 BASELINE SCENARIO

### 5.2.1 Key results

#### g) Share of grid and off grid

Grid extension has the lion's share of rural electrification efforts, in a very clear "explosion" from 2010. Second and third solutions are Solar Battery Charging Stations and new diesel mini-grids (possibly hybrid PV/diesel):

- In 2010, National grid covers 7% of total HH and 10% of villages, and only 11% HH and 57% villages are covered by all technologies. Regarding village coverage, stand alone and mini grid options play a very important role;
- By 2030, 100% villages are covered, of which 95% through the national grid; and 67%[16] HH of which almost the totality by the national grid.

The graph below clearly shows this dramatic rise in the share of the national grid, which is further detailed in the table.

#### h) Financing requirements

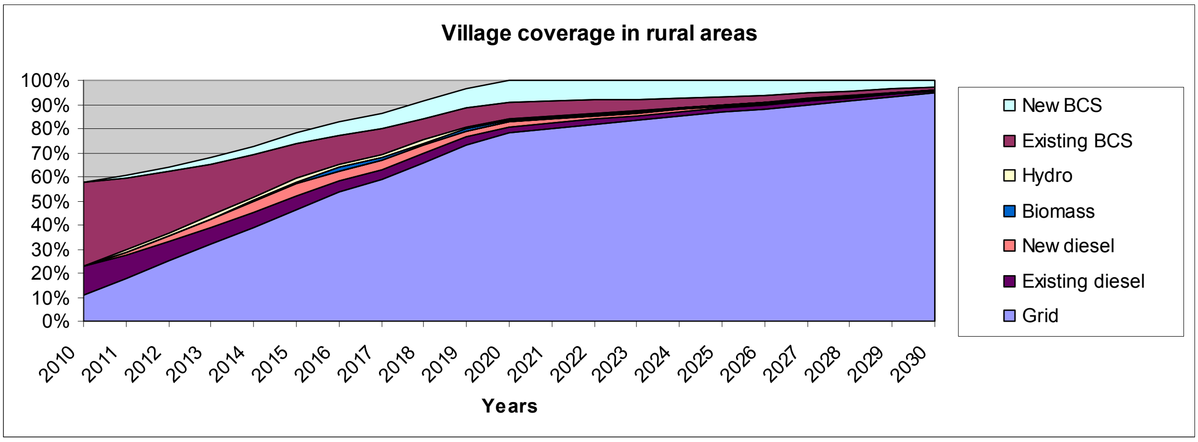
This of course now raises the question as to whether the required funds will be available to reach the grid objectives and whether it will be physically possible. Indeed, the investment requirements amount to:

- By 2015:
  - **143MUSD for MV (107MUSD according to EDC)**, which will essentially have to be EDC borrowings or RGC allocations, as REEs can contribute but only marginally to the effort;
  - **184MUSD for distribution (222MUSD according to EDC)**, necessary to connect HH in the villages. It does not seem likely that REEs alone would be mobilise these funds, so the question of developing a financing mechanism to support REE borrowings is essential (long term, low interest) - and the REF could definitely be an option. EDC currently is not willing to borrow for distribution, but only to implement grants allocated.
  - **72MUSD requirement for mini grids**. At present, there is no public mechanism to finance this, as the REF has but this on hold. It seems very ambitious to imagine that the private sector could mobilise this amount in the coming 5 years. Besides, longer term issues such as integration with the national grid as IPPs once the national grid arrives, still need to be resolved.
  - **19MUSD will have to be mobilised for stand alone** (essentially PV) options during this first period.
  - Therefore, **418 MUSD worth of rural electrification investments** have to be executed during the coming 5 years, in order to meet the RGC targets

- Over the 20 year period to 2030, the targets are no less ambitious, with about 1 BlUSD having to be mobilised over 20 years to reach the target of 100% village coverage and 70% HH connections, the detailed breakdown of which is provided in the following table.

[16] The estimate of the draft rural electrification plans of 88% was based on the optimistic assumption that all electrified village would reach a connection rate of 98% of households. This has been slightly decreased to a more reasonable 70%, in line with EDC assumptions and field surveys carried out by SREP.

Figure 40: Evolution of village coverage for different technologies




| Coverage for rural areas | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 6,9% | 29,1% | 47,4% | 66,2% |
| | Hydro mini-grid | 0,0% | 0,6% | 0,3% | 0,1% |
| | Biomass mini-grid | 0,0% | 0,4% | 0,3% | 0,0% |
| | Existing diesel mini-grid | 4,4% | 1,9% | 1,4% | 0,6% |
| | New diesel mini-grid | 0,0% | 1,9% | 1,2% | 0,1% |
| | Solar home systems | 0,0% | 0,7% | 1,4% | 0,2% |
| | **Total percentage of rural households** | **11%** | **34%** | **52%** | **67%** |
| Village coverage | National grid | 10,9% | 46,1% | 78,3% | 94,8% |
| | Hydro mini-grid | 0,0% | 1,5% | 0,6% | 0,2% |
| | Biomass mini-grid | 0,0% | 1,2% | 0,7% | 0,1% |
| | Existing diesel mini-grid | 11,9% | 5,4% | 2,7% | 0,9% |
| | New diesel mini-grid | 0,0% | 5,1% | 1,9% | 0,1% |
| | Existing battery charging stations | 34,7% | 14,3% | 6,8% | 1,3% |
| | Solar battery charging stations | 0,0% | 4,5% | 9,0% | 2,6% |
| | **Total percentage of rural villages** | **57%** | **78%** | **100%** | **100%** |

| Investment costs in rural areas ('000 USD) | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 143 429 | 118 203 | 83 282 |
| Distribution (transformers, LV, meters) | 183 994 | 158 735 | 203 490 |
| **Subtotal grid extension** | **327 423** | **276 938** | **286 772** |
| Hydro mini-grid | 31 492 | 861 | 233 |
| Biomass mini-grid | 16 363 | 581 | 171 |
| New diesel mini-grid | 23 906 | 2 382 | 392 |
| **Subtotal mini-grid projects** | **71 761** | **3 824** | **796** |
| Solar home systems | 6 698 | 8 272 | 0 |
| Community PV | 2 190 | 2 190 | 0 |
| Solar battery charging stations | 10 368 | 10 564 | 0 |
| **Subtotal stand-alone systems** | **19 255** | **21 025** | **0** |
| **Total** | **418 440** | **301 787** | **287 568** |

Table 34 : Investment costs for all technologies in rural areas (baseline scenario, in thousands of USD)

The situation status map in 2015, illustrates the point made above which is that there will still be substantial investment required in diesel mini grids and solar battery charging stations. As can be seen on the map, some of these investments will located in remote areas of the North or North Eastern Cambodia, but most will still be in the south and south East , where there is lot of population and where the grid will not have reached. Indeed, MV lines will also be expanding North West, as EDC's policy is to set up a back bone infrastructure and not necessarily to focus only on the very dense areas. The proximity of the proposed mini-grid projects with the national grid still represents a serious issue, as it may be perceived as an unbearable risk by potential project developers.

The grid extension map provides insight on the different phases of grid extension. The first phase from 2011 to 2020 follows EDC's objective of providing a back bone infrastructure, the second phase from 2021 to 2030 tries to densify the network (connect villages close to the backbone).

Figure 41:  Map of grid extension by 2015, mini-grid projects and stand-alone candidates (baseline scenario)

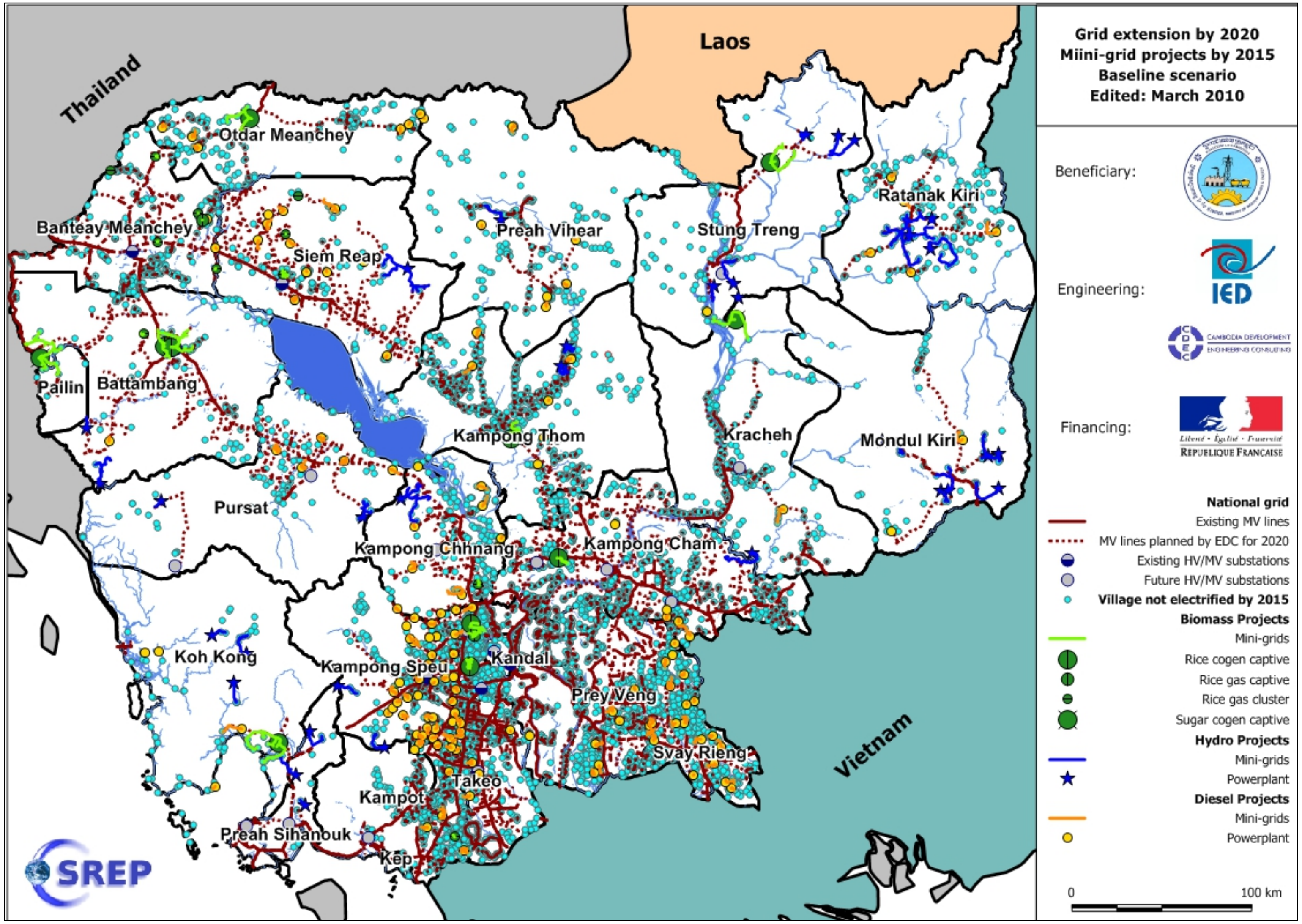
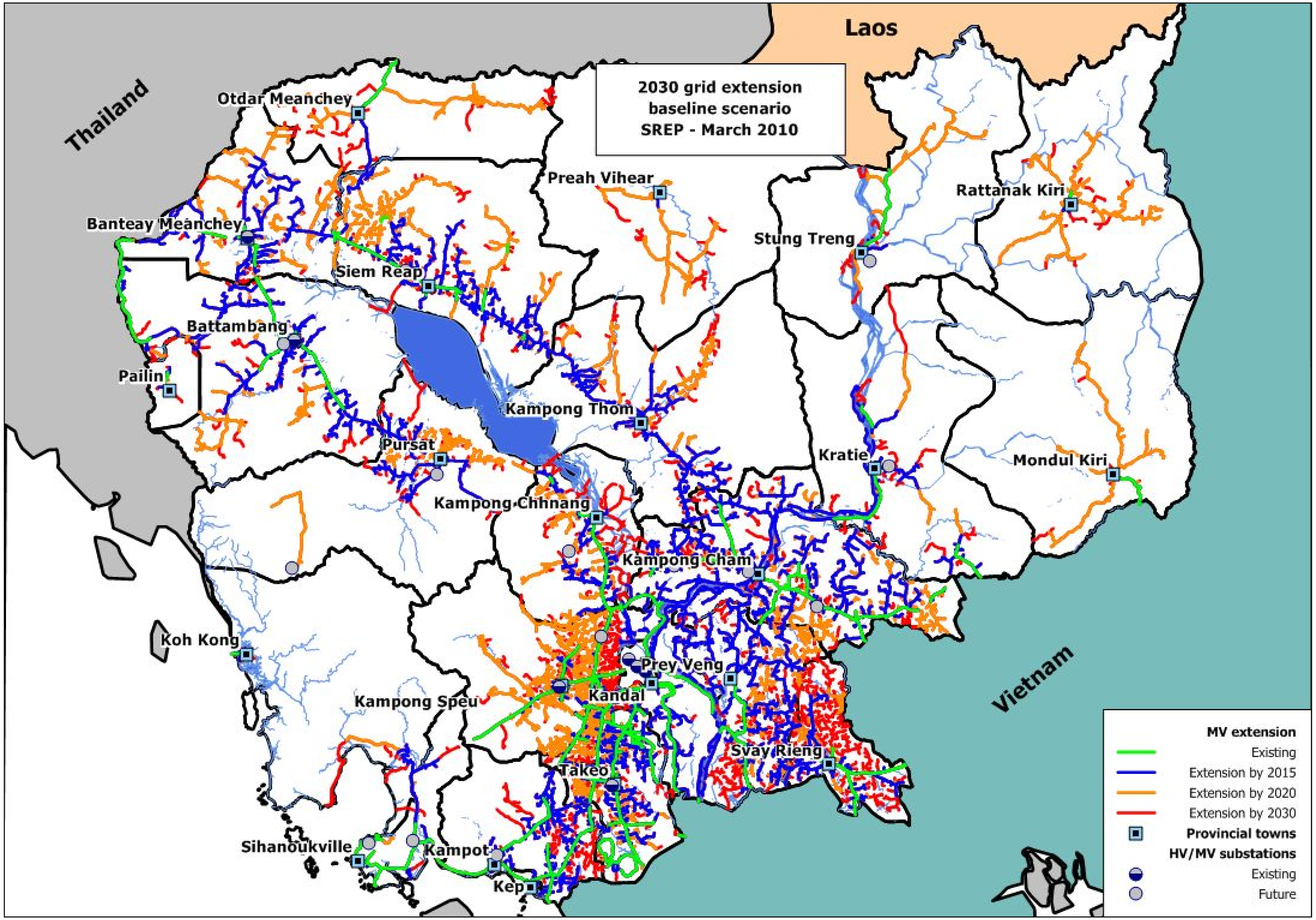


Figure 42 : 2030 Map of grid extension (baseline scenario)



## i) Comparison of all technology economics over the planning period to 2030

Though the number of non national grid villages is marginal percentage wise, the investment figures in mini grids is far from negligible as we have seen, and the following table does show that we are facing a situation where :

- about 1000 villages have to be covered by mini grids over the next 5 years
- about as many villages to be equipped with solar battery charging stations over the next 10 years
- and 2000 odd community PV systems have to be installed over the next 10 years

How realistic this is a real question, all the more so given the related investment requirements.

Cost per village is also interesting to compare: though the fact that the investment cost of a "hydro" village is about double that of a "grid" village may seem worrying at the outset, it is not at all so, as for grid villages, this is the average cost, and the hydro options typically are for the remoter locations, which are at the tail end of the grid and with a much higher marginal cost. As for biomass, even though they are usually located much closer to the national grid, and do have slightly higher investment costs per village, the long term kWh cost proves to be rather on par with the grid because of low O&M costs.

Interesting to analyse is the cost per household, which remains high for off grid options as unfortunately those remote villages tend to be little populated.

A generation and transmission cost of grid electricity of 13 USCts/kWh has been taken (for grid connection), and all calculations have been made with a 6% discount rate. ([17]). All off grid options compare favourably to diesel (at +/- 38 USc) and it must be born in mind that in the GEOSIM scenarios, a scenario of explosion of fossil fuel prices has not been simulated; and that further, the cost of PV for instance is expected to decrease.

| | | No villages | 000 HH | Invest (MUSD) | Cost/ village USD | Cost /HH USD | kWh (USDc) |
|---|---|---|---|---|---|---|---|
| Grid | | 10 572 | 1 838 | 891 | 84 292 | 485 | 21.0 |
| Mini-grids | Hydro | 193 | 15 | 33 | 168 842 | 2 244 | 26.3 |
| | Biomass | 157 | 9 | 17 | 109 012 | 1 853 | 24.2 |
| | Diesel | 643 | 47 | 27 | 41 495 | 565 | 38.4 |
| Stand-alone | Solar BCS | 1 138 | 131 | 20,9 | 18 393 | 160 | 36.3 |
| | Community PV | 1 994 | - | 4,4 | 2 196 | - | - |
| | SHS | - | 37 | 15,0 | - | 400 | 39.7 |

[17] The numbers are not meant to be added up. The number of villages and households served by all technologies is higher than the total number of villages and households in Cambodia, as some villages and households may very well start being connected to a mini-grid or stand-alone project, and then become connected to the national grid later on.

Figure 43: Evolution of household connection rates for mini-grid technologies

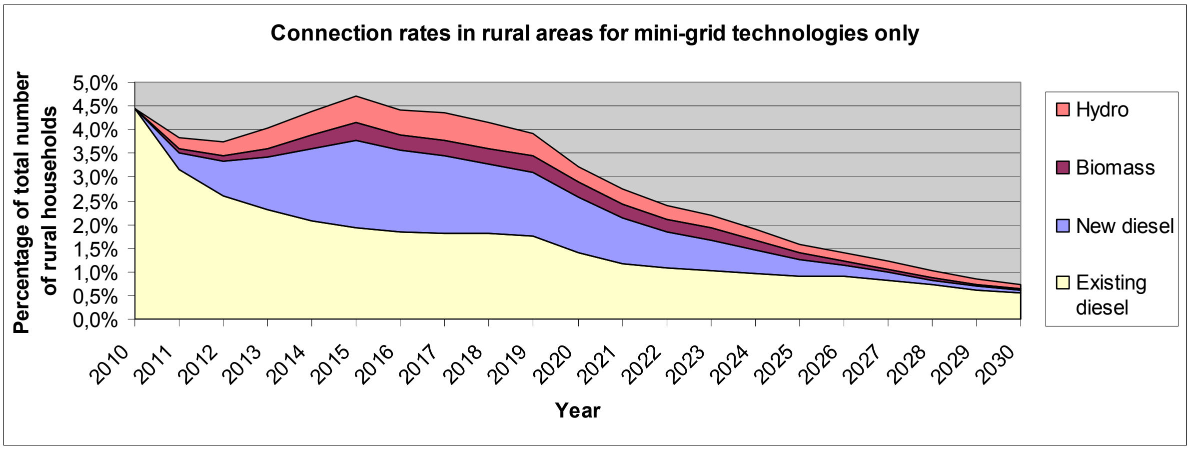



Figure 44: Yearly investment for all technologies in rural areas

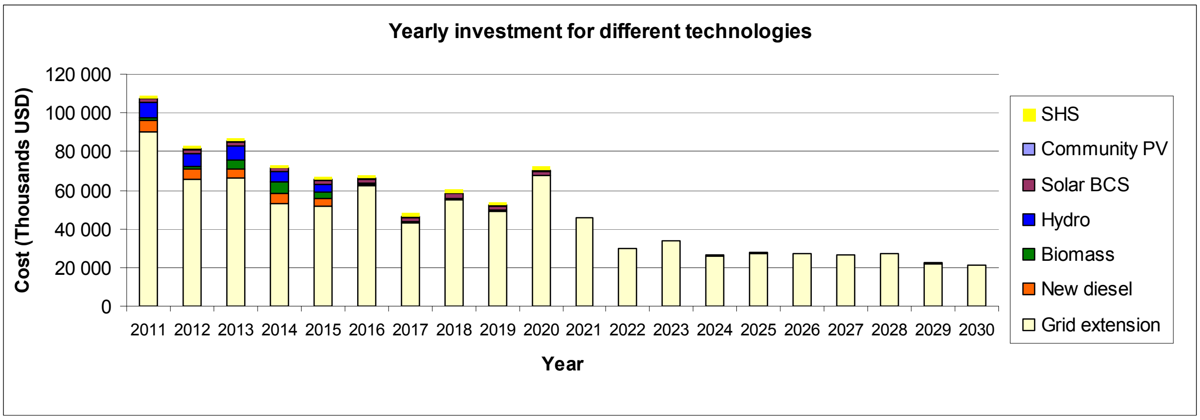
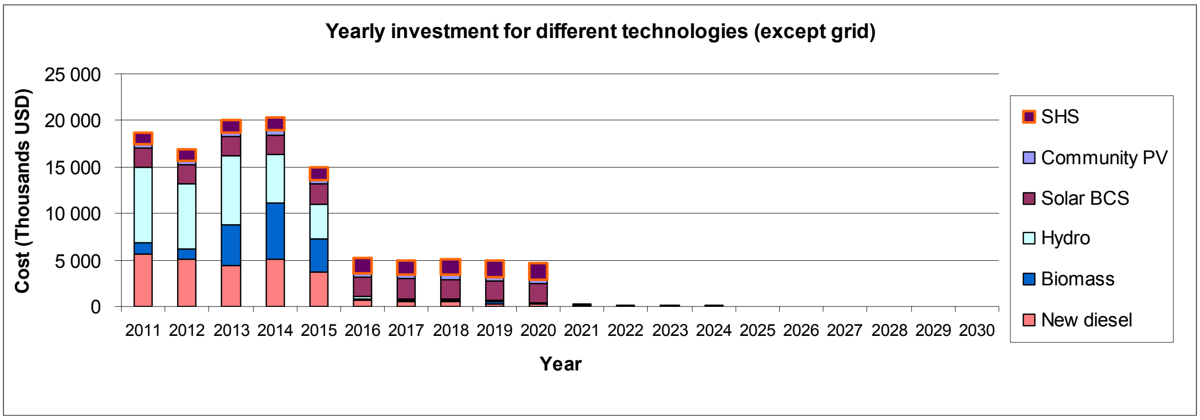



Figure 45 : Yearly investment for mini-grid and stand-alone technologies in rural areas



### 5.2.2 Detailed analysis for grid expansion component

**Important note**: All the numbers and investments in this chapter are provided for the *new* villages and households to be connected in *rural* areas.

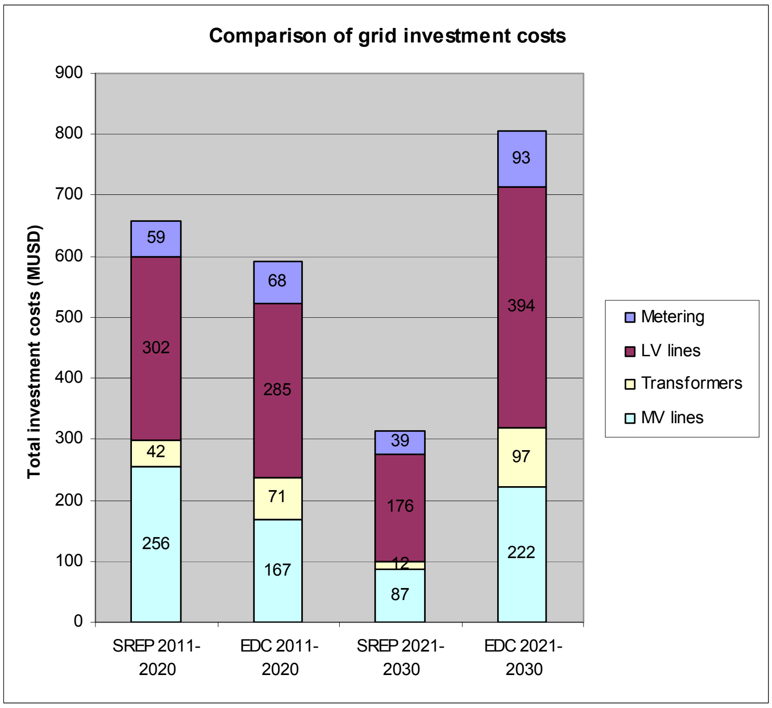
Table 35: Summary of results for grid extension in the baseline scenario

| Phase | Villages connected | HHs ('000) | MV line length (km) | MV line per village (km) | Invest. In MV (MUSUSD) | Invest. In distrib. (MUSUSD) | Total invest. (MUSUSD) | Cost per village (USD) | Cost per HH (USD) |
|---|---|---|---|---|---|---|---|---|---|
| 2011-2015 | 4 431 | 570 | 7 171 | 1,6 | 153,8 | 184,0 | 327,4 | 73 894 | 575 |
| 2016-2020 | 4 054 | 539 | 5 910 | 1,5 | 101,9 | 158,7 | 277 | 68 312 | 514 |
| 2021-2030 | 2 087 | 729 | 4 164 | 2,0 | 87,5 | 203,5 | 287 | 137 409 | 393 |
| **2011-2030** | 10 572 | 1 838 | 17 246 | 1,6 | 343,1 | 546,2 | 891 | 84 292 | 485 |

a) Analysis of investment costs

We highlight here once again that the cost of investment in distribution is in total nearly twice as much as in MV over the period – hence the cost of HH connection over and above village connectivity must be transparently addressed.

Figure 46: Total grid investment costs with detailed breakdown and comparison with EDC estimates (baseline scenario, in millions of USD)




The opposite figure shows investment costs in millions of USD, with breakdown by type of equipment. When compared with EDC figures (taken from their estimated budget for the grid extension programme, cf. 2.4.3), the amounts in the first phase (2011-2020) are rather similar, while there are significant differences in the second phase (2021-2030). This may be explained by several factors:

- EDC took into account a cost increase over the next 20 years, while figures provided by SREP are in constant price
- Population growth rate assumptions are very different: 3.8% on average for EDC, 1.2% for SREP
- In the SREP simulation, investment cost per households decreases significantly in the second period, because of grid densification[18].

[18] Villages next to existing backbone lines will be connected and villages already connected will increase their number of customers.

Nevertheless, planning 10 to 20 years ahead is obviously a very delicate exercise, and the results have much less importance than then ones of the first phase.

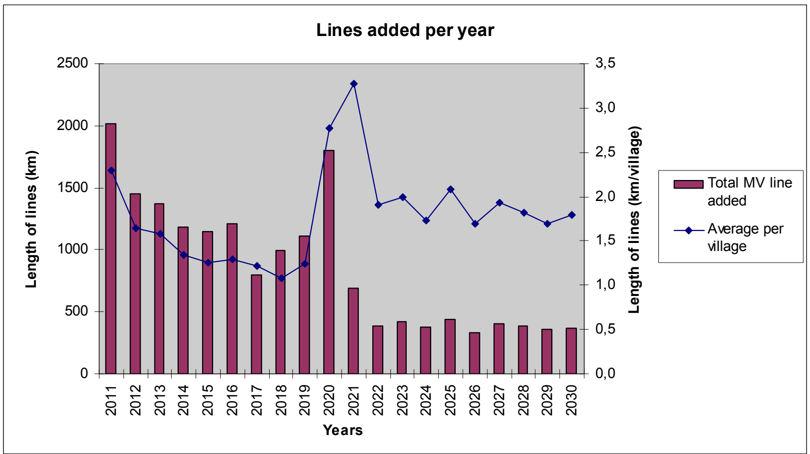
The difference in terms of investment costs per households is much lower as shown below:

Table 36 : Household investment cost with detailed breakdown and comparison with EDC estimates (baseline scenario, in millions of USD/connection)

| | 2011-2020 | | 2021-2030 | | |
|---|---|---|---|---|---|
| | SREP | EDC | SREP | EDC | SREP hypotheses |
| Metering | 50 | 65 | 50 | 60 | 50 USD/meter |
| LV lines | 150 | 271 | 200 | 252 | 15000 USD/km, 100 cust/km before 2020, 50 cust/km after |
| Transformers | 109 | 67 | 29 | 63 | 46 to 154 USD/kVA |
| MV lines | 236 | 163 | 114 | 142 | 20000 USD/km |
| **Total (MUSD)** | **545** | **566** | **393** | **517** | |

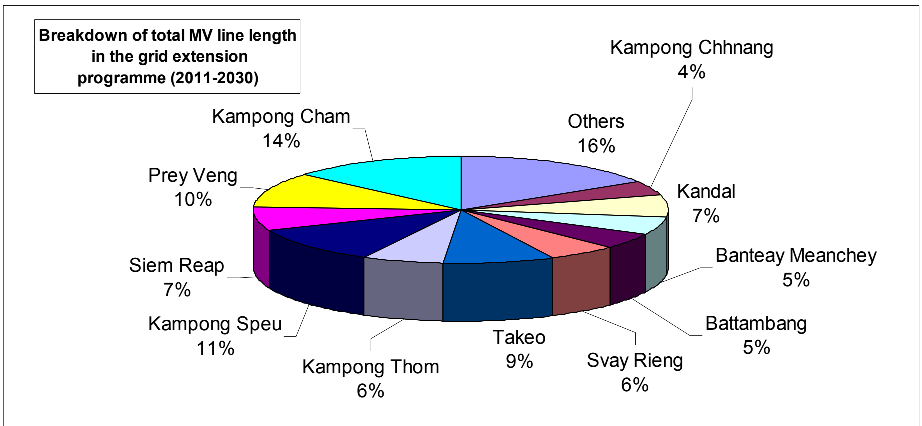
## b) Length of MV lines added and geographical location

Figure 47: Length of MV lines added (baseline scenario)




7200 km of MV lines are to be added during the first 5 years (8000 km according to EDC), then brought down to 5900 during the next five years, and remaining at 4200 during the last 10 years. It clearly appears that under this baseline scenario, the MV backbone extension effort in the first years is substantial, with almost 1,500 km of new lines to build every year until 2015.

Most remote villages targeted by EDC until 2020 are connected here at the end of the 2011-2020 period, because of the least-cost prioritisation done by GEOSIM, which explains why there is suddenly more MV lines added in 2020. However, the actual practice may be slightly different, with long MV backbone lines coming first, depending on political choices rather than techno-economic optimisation.




The breakdown of length of MV lines added per province is obviously consistent with the most populated provinces, except Kandal.

Figure 48: Breakdown of MV line length added per province (baseline scenario)

### 5.2.3 Detailed remarks for off grid areas

Given the optimistic grid extension assumptions, the share of mini-grid projects is very small, as most Development Poles are connected to the national grid by 2015. Moreover, this share decreases after 2015, as the grid extends further and thus interconnects with mini-grid projects. The baseline scenario is below the targets of the WB RE strategy for mini-grid projects, since their assumptions for grid extensions were significantly more conservative than EDC: the World Bank estimates 15 and 10% HH covered by mini grids in 2020 and 2030, while in the baseline scenario we reach only 3 and 1% !

This small market for mini-grid projects faces another issue: proximity with the national grid. For the few remaining projects, which can happen at the margin of national grid expansion efforts, most of them are located close to the grid.

Table 37 : Distance of proposed mini-grid projects to the national grid (baseline scenario)

| Technology | Distance to existing MV in 2010 (km) | Distance to forecasted MV in 2015 (km) |
|---|---|---|
| Diesel | 17.9 | 10.5 |
| Hydro | 26.5 | 16.9 |
| Biomass[19] | 14.9 | 7.2 |
| **All mini-grids** | **19.1** | **11.4** |

While this proximity is a challenge for isolated mini-grid projects, it actually represents an advantage for IPP projects, i.e. projects aiming at injecting power directly into the national grid and which can compete with its bulk generation cost. This is the case for some biomass and hydro projects (cf. chapter 4.3 for more details).

Nonetheless, it will definitely remain a challenge to achieve the required 208 mini grids by 2015 and to mobilise the related investments. After 2015, no mini-grid projects are proposed given the grid expansion, but some investment costs remain, mostly to expand the service in areas already electrified by one the mini-grid technologies (extending LV lines, upgrading transformers, adding new meters etc.). However, cost of replacement generation equipment (e.g. gensets) is not taken into account here. Overall, the investment figures are much higher in the WB strategy which totals 198MUSD to 2030, instead of 76MUSD for SREP.

Table 38 : Mini grid investments: number, capacity and investment cost. ( baseline scenario, in thousands of USD)

| Mini-grid projects in rural areas by 2015 | Number of projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 33 | 6 449 |
| Biomass mini-grid | 25 | 10 317 |
| New diesel mini-grid | 150 | 21 663 |
| **Total** | **208** | **38 429** |

| Investment costs in rural areas ('000 USD) | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Hydro mini-grid | 31 492 | 861 | 233 |
| Biomass mini-grid | 16 363 | 581 | 171 |
| New diesel mini-grid | 23 906 | 2 382 | 392 |
| **Total mini-grid projects** | **71 761** | **3 824** | **796** |

[19] Except cogeneration projects, which are by design interconnected with the national grid.

As seen above, the number of diesel projects largely exceeds the number of projects for other technologies. Investment costs for new diesel projects have been calculated assuming they would not be hybridised with PV. As a first estimate, existing diesel projects are not considered for hybridisation, because most of them are supposed to be connected to the national grid very soon. Following assumptions detailed in chapter 4.3.5, the additional PV capacity and related investment costs required to hybridise these new projects are detailed below:

Table 39: Installed capacity and investment costs for hybrid PV/diesel in the baseline scenario (investment costs include panels, electronics and batteries only, diesel gensets are excluded)

| Capacity range (kW) | Proposed solution | Baseline | | |
|---|---|---|---|---|
| | | Number of projects | PV installed capacity (kWp) | Investment cost ('000 USD) |
| <30 | 100% storage | 7 | 37 | 237 |
| 30-100 | 50% storage | 43 | 523 | 2 934 |
| >100 | 0% storage | 100 | 3 773 | 17 846 |
| | **Total** | **150** | **4 333** | **21 017** |

Finally, stand-alone systems consist essentially of PV-based technologies. Estimates given by WB RE strategy aim at 178,000 SHS to be installed, while the numbers provided by SREP are much lower at 37,000. An additional 2,000 community PV are to be installed, as well as solar battery charging stations in more than 1,100 villages.

Table 40: Stand alone systems : Village coverage rates, number of systems and investment costs

| Coverage for rural areas | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|
| Existing battery charging stations | 34,7% | 14,3% | 6,8% | 1,3% |
| Solar battery charging stations | 0,0% | 4,5% | 9,0% | 2,6% |
| **Total percentage of rural villages** | **57%** | **78%** | **100%** | **100%** |

| Stand-alone systems | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 16 744 | 20 679 | 0 |
| Community PV (new villages) | 997 | 997 | 0 |
| Solar battery charging stations (new villages) | 569 | 455 | 0 |

| Investment costs in rural areas ('000 USD) | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems | 6 698 | 8 272 | 0 |
| Community PV | 2 190 | 2 190 | 0 |
| Solar battery charging stations | 10 368 | 10 564 | 0 |
| **Total stand-alone systems** | **19 255** | **21 025** | **0** |

## 5.3 Sensitivity analysis: intermediate and conservative scenarios

### 5.3.1 Village and household coverage trends and by technology

Overall, the ultimate target of covering 100% of the villages are met in all three scenarios. However, the target of 70% households is met in the baseline scenario only, while the two others come slightly lower.

Reaching the 70% target in the conservative scenario is a difficult undertaking, because this would mean many more mini-grid projects would be needed in villages which are not Development Poles, i.e. with low socio-economic potential and thus very low expected profitabilities. Besides, as explained in the previous chapter, most of these projects would happen very close, or even under the planned national grid, which is usually a serious issue for any sensible project developer. Another solution to reach the 70% target in the intermediate and conservative scenarios, would be to increase the connection rate inside already electrified villages, but this would require direct subsidies as the remaining 30% of households in rural villages are usually located far from the village centre and/or have very low capability to pay (the average share of poor and very poor households according to NCDD data was around 30% in 2009).

As illustrated in the following graph, the contrast between the three scenarios also lies in the speed at which the targets are met, looking objectively into the difficulty of mobilising the funds as required in the baseline scenario.

In the baseline scenario, in 2030, only 1% of households have mini-grid connections, against 4% in the intermediate and 9% in the conservative scenario.

Regarding village coverage in 2030, 1% are mini-grid in the baseline scenario against 6% in the intermediate scenario and 15% in the conservative scenario.

The baseline and intermediate scenarios are coherent with the WB RE strategy targets of 45% grid equivalent HH connections in 2020, while the conservative scenario is slightly lower.

Figure 49: Trend of village and household coverage rates to 2030, 3 scenarios

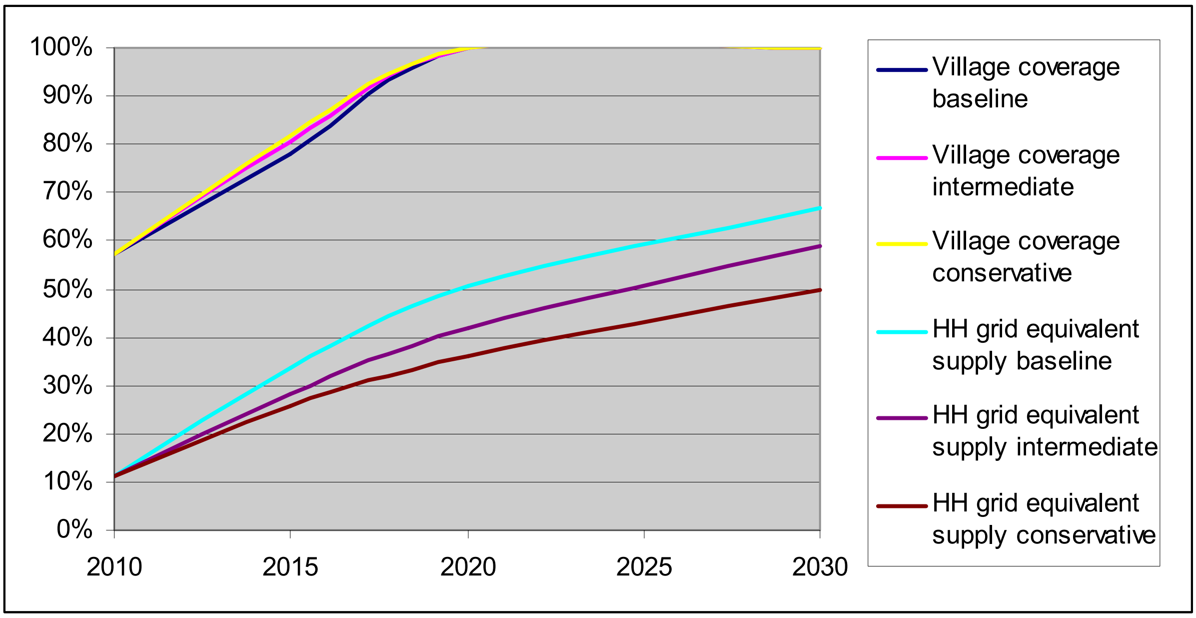


Table 41: Household Coverage rates achieved by all technologies in rural areas only

| BASELINE SCENARIO | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 6,9% | 29,1% | 47,4% | 66,2% |
| | Hydro mini-grid | 0,0% | 0,6% | 0,3% | 0,1% |
| | Biomass mini-grid | 0,0% | 0,4% | 0,3% | 0,0% |
| | Existing diesel mini-grid | 4,4% | 1,9% | 1,4% | 0,6% |
| | New diesel mini-grid | 0,0% | 1,9% | 1,2% | 0,1% |
| | Solar home systems | 0,0% | 0,7% | 1,4% | 0,2% |
| | **Total percentage of rural households** | **11%** | **34%** | **52%** | **67%** |
| Village coverage | National grid | 10,9% | 46,1% | 78,3% | 94,8% |
| | Hydro mini-grid | 0,0% | 1,5% | 0,6% | 0,2% |
| | Biomass mini-grid | 0,0% | 1,2% | 0,7% | 0,1% |
| | Existing diesel mini-grid | 11,9% | 5,4% | 2,7% | 0,9% |
| | New diesel mini-grid | 0,0% | 5,1% | 1,9% | 0,1% |
| | Existing battery charging stations | 34,7% | 14,3% | 6,8% | 1,3% |
| | Solar battery charging stations | 0,0% | 4,5% | 9,0% | 2,6% |
| | **Total percentage of rural villages** | **57%** | **78%** | **100%** | **100%** |

| INTERMEDIATE SCENARIO | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 6,9% | 21,4% | 35,5% | 55,1% |
| | Hydro mini-grid | 0,0% | 0,6% | 0,7% | 0,4% |
| | Biomass mini-grid | 0,0% | 0,5% | 0,5% | 0,3% |
| | Existing diesel mini-grid | 4,4% | 2,8% | 2,6% | 1,9% |
| | New diesel mini-grid | 0,0% | 2,9% | 2,8% | 1,3% |
| | Solar home systems | 0,0% | 1,4% | 3,0% | 1,6% |
| | **Total percentage of rural households** | **11%** | **30%** | **45%** | **61%** |
| Village coverage | National grid | 10,9% | 28,4% | 46,1% | 78,3% |
| | Hydro mini-grid | 0,0% | 1,8% | 1,5% | 0,6% |
| | Biomass mini-grid | 0,0% | 1,5% | 1,2% | 0,6% |
| | Existing diesel mini-grid | 11,9% | 7,3% | 5,4% | 2,7% |
| | New diesel mini-grid | 0,0% | 7,6% | 5,6% | 1,8% |
| | Existing battery charging stations | 34,7% | 20,8% | 14,4% | 7,0% |
| | Solar battery charging stations | 0,0% | 13,0% | 26,0% | 9,1% |
| | **Total percentage of rural villages** | **57%** | **80%** | **100%** | **100%** |

| CONSERVATIVE SCENARIO | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 6,9% | 16,3% | 25,8% | 41,0% |
| | Hydro mini-grid | 0,0% | 0,7% | 0,9% | 0,9% |
| | Biomass mini-grid | 0,0% | 0,6% | 0,7% | 0,5% |
| | Existing diesel mini-grid | 4,4% | 4,2% | 4,3% | 3,9% |
| | New diesel mini-grid | 0,0% | 3,9% | 4,6% | 3,5% |
| | Solar home systems | 0,0% | 2,0% | 4,3% | 3,3% |
| | **Total percentage of rural households** | **11%** | **28%** | **41%** | **53%** |
| Village coverage | National grid | 10,9% | 19,7% | 28,4% | 46,1% |
| | Hydro mini-grid | 0,0% | 1,8% | 1,8% | 1,6% |
| | Biomass mini-grid | 0,0% | 1,6% | 1,4% | 1,1% |
| | Existing diesel mini-grid | 11,9% | 9,8% | 8,4% | 6,4% |
| | New diesel mini-grid | 0,0% | 9,6% | 8,6% | 6,0% |
| | Existing battery charging stations | 34,7% | 23,6% | 20,0% | 13,8% |
| | Solar battery charging stations | 0,0% | 15,7% | 31,4% | 25,1% |
| | **Total percentage of rural villages** | **57%** | **82%** | **100%** | **100%** |

Figure 50: Share of national and off grid connections for HH to 2030, 3 scenarios

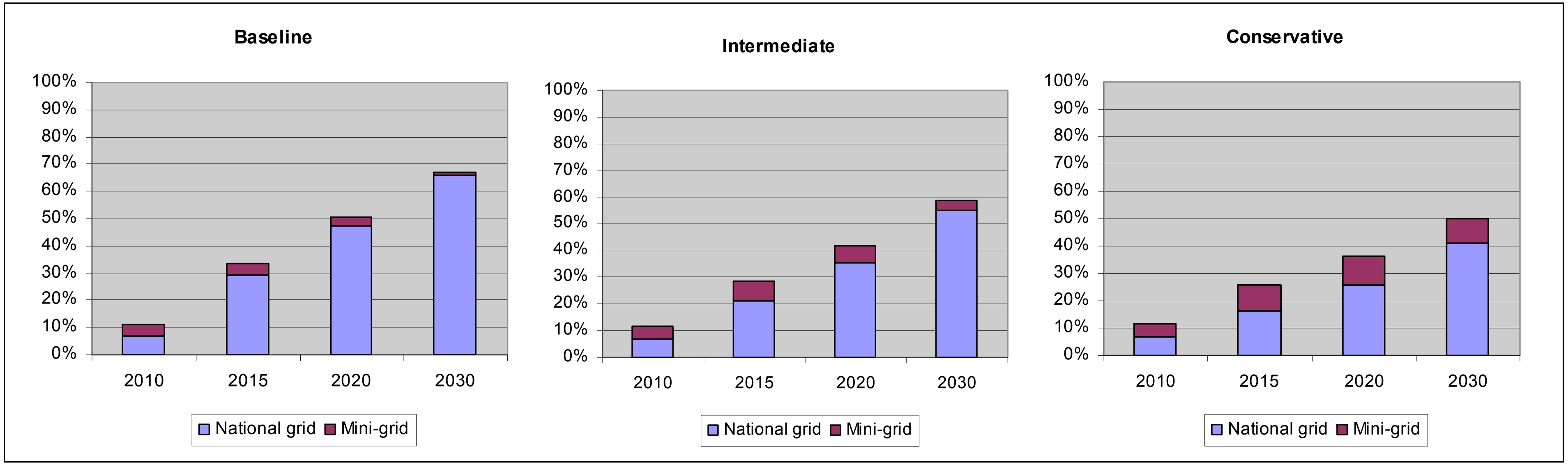
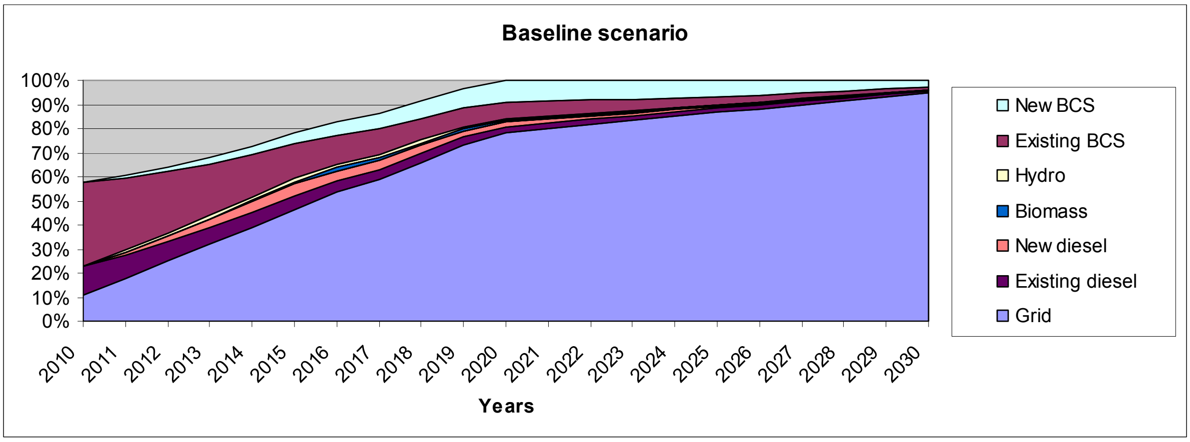
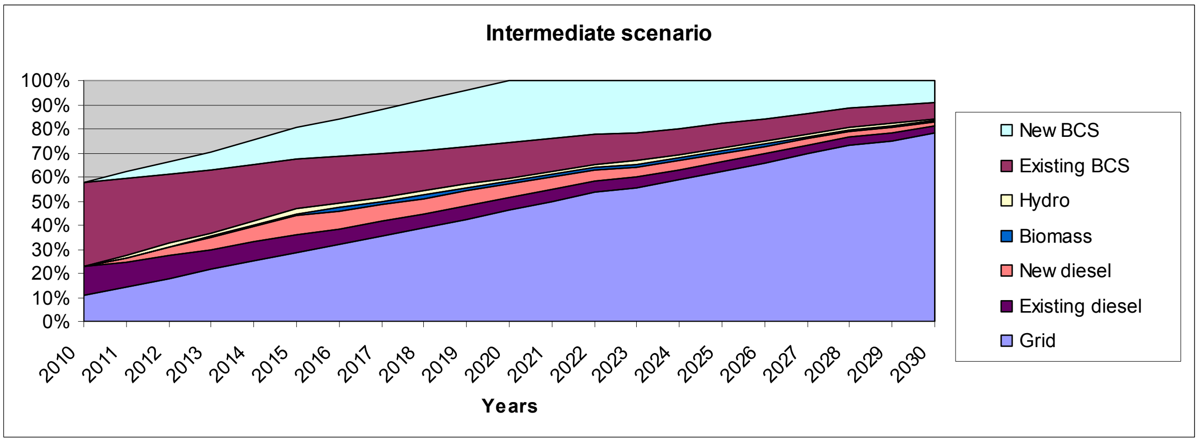
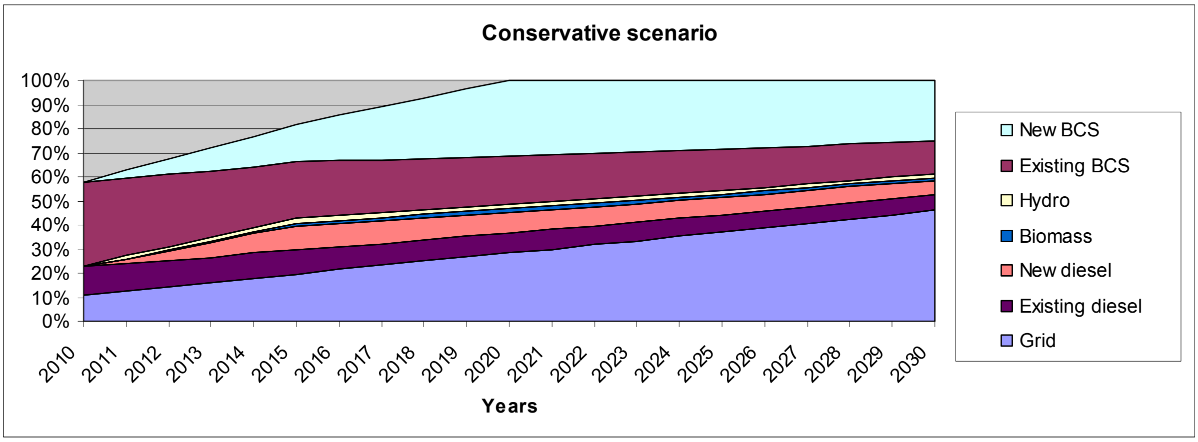


Figure 51: Evolution of village coverage for different technologies



### 5.3.2 Regarding investment costs:

- The global investment cost (including national grid, mini-grid and stand-alone systems) is 680 MUSD in the conservative scenario as compared to 880 and 1000 in the other two scenarios, which is an important difference. However, though all villages are covered in all three cases, only 50% instead of 70% HH are covered by grid equivalent supply in the conservative scenario.

- The requirements for grid investment reduce from 890MUSD to 420MUSD in which the requirement for MV investments reduces from 344MUSD to 143MUSD, thus bringing the responsibilities of EDC in terms of MV back bone financing and construction to very manageable levels.

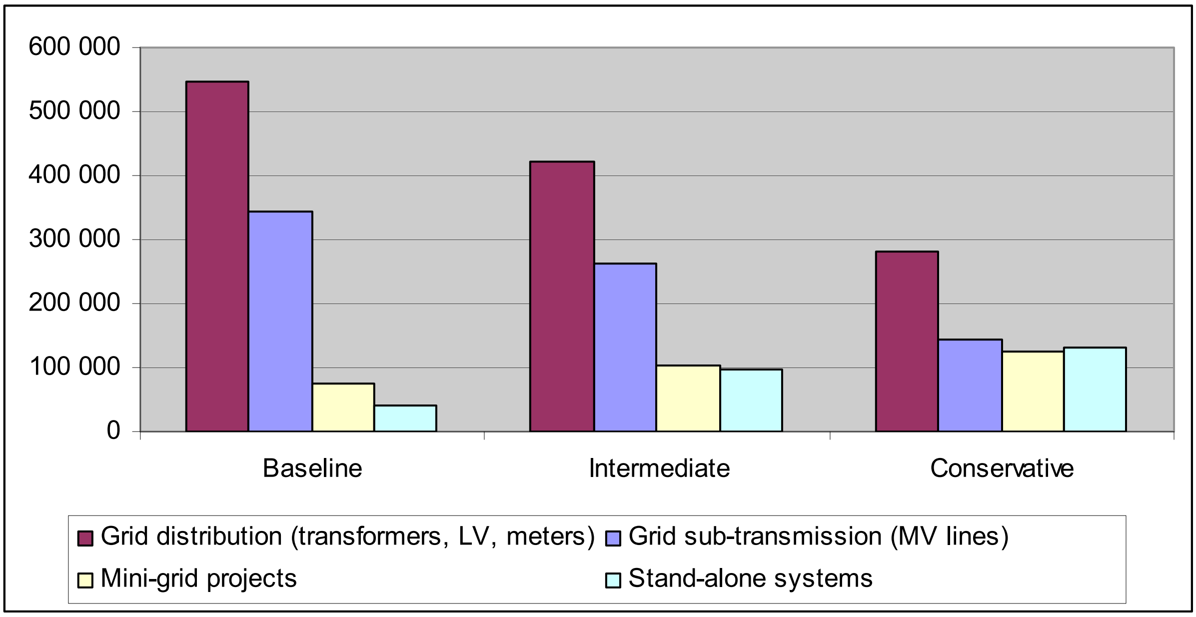
- For the first 5 years regarding the grid requirements,
  - The conservative scenario staggers grid investments to a very manageable 123MUSD (50MUSD for MV) ,
  - down from an ambitious 327 MUSD (143 for MV) in the baseline scenario and
  - from 200MUSD (84 for MV) in the intermediate scenario

- However, in order to still reach the village and household coverage targets, the consequence is that globally mini-grid and stand-alone investment requirements rise tremendously:
  - In the baseline scenario to 2030, 76MUSD are required for mini grids and 40MUSD for stand alone options;
  - In the intermediate scenario, these figures increase to 101MUSD and 96MUSD;
  - They reach 124MUSD and 131 MUSD for the conservative scenario.

- These figures show the depth of the potential off grid market and of private sector investment, as for the time being, there is no public financing of off grid options envisaged other than a bulk procurement of some 14 000 SHS by the REF. However, for the private sector to mobilise on this segment, a tremendous amount of work still is required by way of developing the legal framework, business and financing models. In order to meet targets for 2015, it is already doubtful in any of the three scenarios that the required financing for mini grid and stand alone options could be mobilised:
  - 72MUSD for mini grids and 19MUSD for stand alone systems are needed for the first 5 years in the baseline scenario
  - 91MUSD and 46MUSD in the intermediate scenario
  - Culminating to 109MUSD for mini-grids and 62MUSD for stand alone systems till 2015 for the conservative scenario....

  Hence, by no means is the conservative scenario “conservative” with regards to fund mobilisation from the private sector, or more broadly for off grid solutions bearing in mind the mobilisation to date is albeit marginal.

Figure 52: Breakdown of investments by technology – 3 scenarios




In case the proposed new diesel projects are hybridised with PV, the additional costs range between 21 to 45 MUSD as shown below:

Table 42: Installed capacity and investment costs for hybrid PV/diesel in three scenarios (investment costs include panels, electronics and batteries only, diesel gensets are excluded)

| Capacity range (kW) | Proposed solution | Baseline | | | Intermediate | | | Conservative | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of projects | PV installed capacity (kWp) | Investment cost ('000 USD) | Number of projects | PV installed capacity (kWp) | Investment cost ('000 USD) | Number of projects | PV installed capacity (kWp) | Investment cost ('000 USD) |
| <30 | 100% storage | 7 | 37 | 237 | 9 | 40 | 258 | 10 | 46 | 296 |
| 30-100 | 50% storage | 43 | 523 | 2 934 | 67 | 780 | 4 375 | 77 | 928 | 5 204 |
| >100 | 0% storage | 100 | 3 773 | 17 846 | 160 | 6 120 | 28 948 | 205 | 8 392 | 39 696 |
| | **Total** | **150** | **4 333** | **21 017** | **236** | **6 940** | **33 581** | **292** | **9 366** | **45 195** |

### 5.3.3 Length of MV lines added per year

The MV extension efforts are much smoother in the intermediate scenario than in the baseline scenario, but the first phase (2011-2020) remains more intensive than the second one. Most remote villages targeted by EDC until 2020 are connected here at the end of the 2011-2020 period, because of the least-cost prioritisation done by GEOSIM, which explains why there is suddenly more MV lines added in 2020. However, the actual practice may be slightly different, with long MV backbone lines coming first, depending on political choices rather than techno-economic optimisation.

In the conservative scenario, the chart illustrates that efforts are constant over the planning period.

| Km of MV lines added | 2011-2015 | 2016-2020 | 2021-2030 | TOTAL |
|---|---|---|---|---|
| Baseline scenario | 7 171 | 5 910 | 4 164 | 17 246 |
| Intermediate scenario | 4 214 | 2 957 | 5 910 | 13 082 |
| Conservative scenario | 2 489 | 1 725 | 2 957 | 7 171 |

Figure 53 : Breakdown of investments by technology – Details by scenario

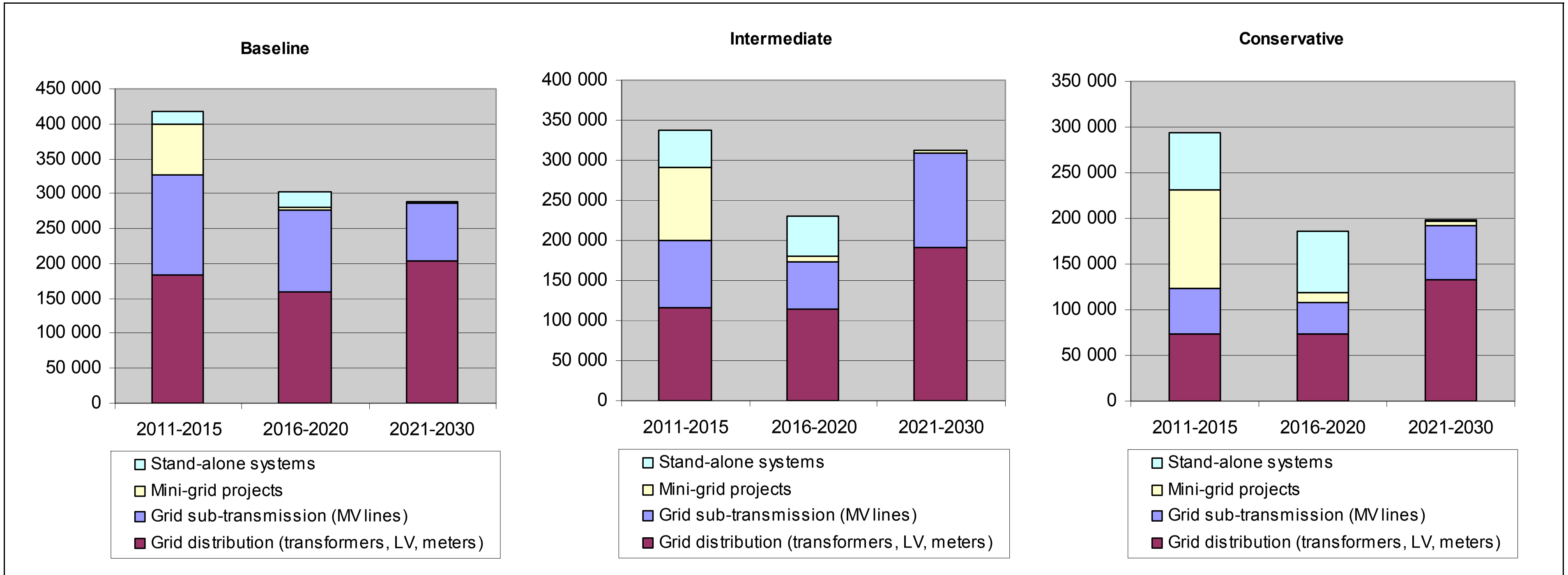


Table 43: Detailed grid & off grid investment costs, 3 periods & 3 scenarios (in '000 of USD)

## BASELINE SCENARIO

| Investment costs in rural areas ('000 USD) | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 143 429 | 118 203 | 83 282 |
| Distribution (transformers, LV, meters) | 183 994 | 158 735 | 203 490 |
| **Subtotal grid extension** | **327 423** | **276 938** | **286 772** |
| Hydro mini-grid | 31 492 | 861 | 233 |
| Biomass mini-grid | 16 363 | 581 | 171 |
| New diesel mini-grid | 23 906 | 2 382 | 392 |
| **Subtotal mini-grid projects** | **71 761** | **3 824** | **796** |
| Solar home systems | 6 698 | 8 272 | 0 |
| Community PV | 2 190 | 2 190 | 0 |
| Solar battery charging stations | 10 368 | 10 564 | 0 |
| **Subtotal stand-alone systems** | **19 255** | **21 025** | **0** |
| **Total** | **418 440** | **301 787** | **287 568** |

## INTERMEDIATE SCENARIO

| Investment costs in rural areas ('000 USD) | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 84 286 | 59 143 | 118 203 |
| Distribution (transformers, LV, meters) | 116 008 | 113 812 | 191 409 |
| **Subtotal grid extension** | **200 294** | **172 955** | **309 612** |
| Hydro mini-grid | 34 204 | 1 194 | 813 |
| Biomass mini-grid | 19 810 | 870 | 482 |
| New diesel mini-grid | 37 302 | 5 134 | 1 779 |
| **Subtotal mini-grid projects** | **91 317** | **7 199** | **3 074** |
| Solar home systems | 14 438 | 17 937 | 0 |
| Community PV | 4 779 | 4 779 | 0 |
| Solar battery charging stations | 26 792 | 27 293 | 0 |
| **Subtotal stand-alone systems** | **46 009** | **50 009** | **0** |
| **Total** | **337 620** | **230 163** | **312 685** |

## CONSERVATIVE SCENARIO

| Investment costs in rural areas ('000 USD) | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 49 785 | 34 501 | 59 143 |
| Distribution (transformers, LV, meters) | 73 163 | 73 722 | 133 119 |
| **Subtotal grid extension** | **122 948** | **108 223** | **192 261** |
| Hydro mini-grid | 37 604 | 1 327 | 1 067 |
| Biomass mini-grid | 22 679 | 1 115 | 718 |
| New diesel mini-grid | 48 429 | 7 558 | 3 398 |
| **Subtotal mini-grid projects** | **108 713** | **10 000** | **5 184** |
| Solar home systems | 20 442 | 25 323 | 1 143 |
| Community PV | 6 295 | 6 295 | 0 |
| Solar battery charging stations | 35 546 | 36 207 | 0 |
| **Subtotal stand-alone systems** | **62 283** | **67 825** | **1 143** |
| **Total** | **293 944** | **186 048** | **198 588** |

### 5.3.4 Investment costs per household and per village

As shown below, investment costs per village are relatively similar in the three scenarii. They are slightly higher in the conservative scenario, because this scenario follows only the beginning of the EDC extension plan, with a large share of backbone extension and little densification.

Table 44: Investment costs for grid extension per household and village, 3 periods & 3 scenarios

| | Baseline scenario | | Intermediate scenario | | Conservative scenario | |
|---|---|---|---|---|---|---|
| Phase | Cost per village (USD) | Cost per HH (USD) | Cost per village (USD) | Cost per HH (USD) | Cost per village (USD) | Cost per HH (USD) |
| 2011-2015 | 73 894 | 575 | 90 836 | 533 | 110 664 | 500 |
| 2016-2020 | 68 312 | 514 | 77 698 | 419 | 98 924 | 383 |
| 2021-2030 | 137 409 | 393 | 76 372 | 435 | 86 371 | 351 |
| **2011-2030** | **84 292** | **485** | **80 479** | **455** | **95 561** | **394** |

In the conservative scenario, the cost per household is overall cheaper than in the baseline scenario: 394USD / HH against 485. This is because the coverage rate is much lower in the conservative scenario, and hence the focus is on the more populated settlements.

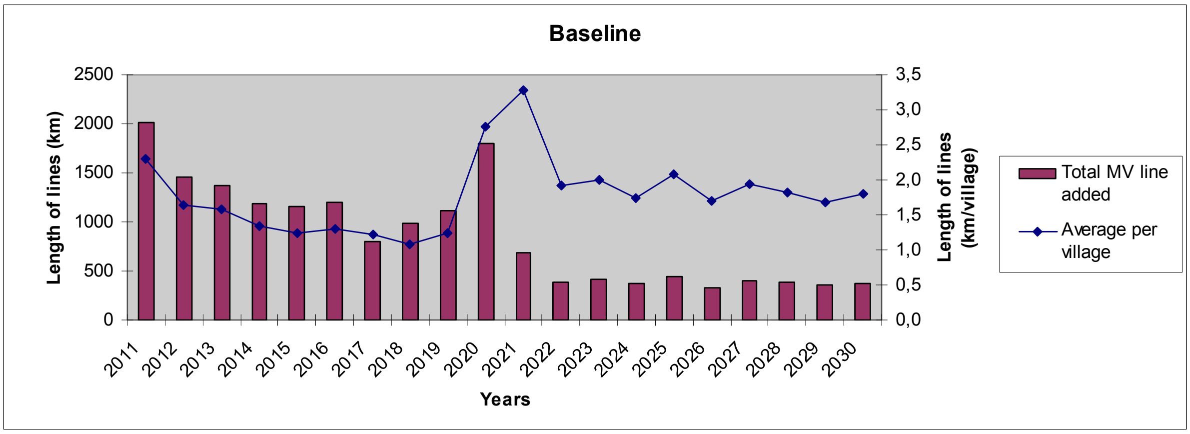
More generally, investment costs for all technologies (not only national grid but also mini-grids and stand-alones) are also slightly lower in the conservative scenario for the same reasons:

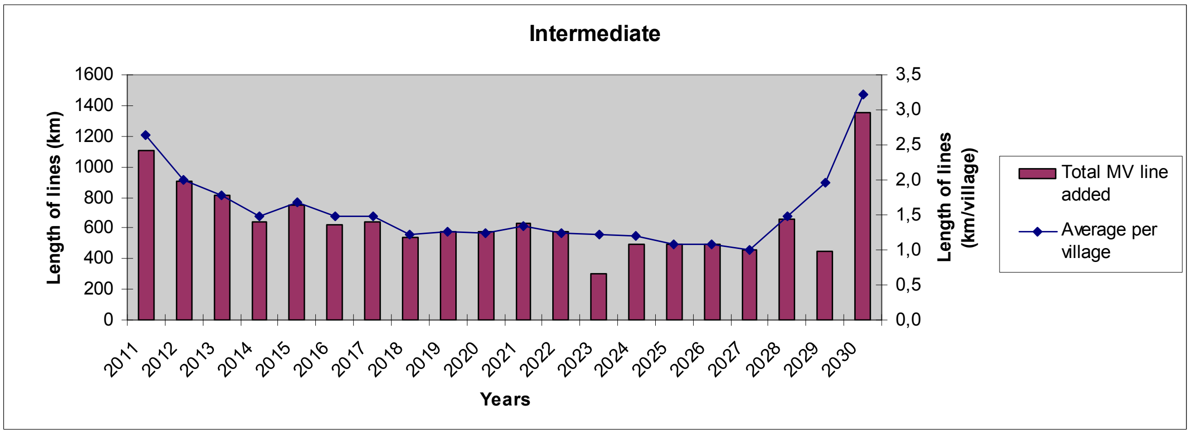
Table 45: Investment costs for all technologies per household, 3 periods & 3 scenarios (in USD per household)

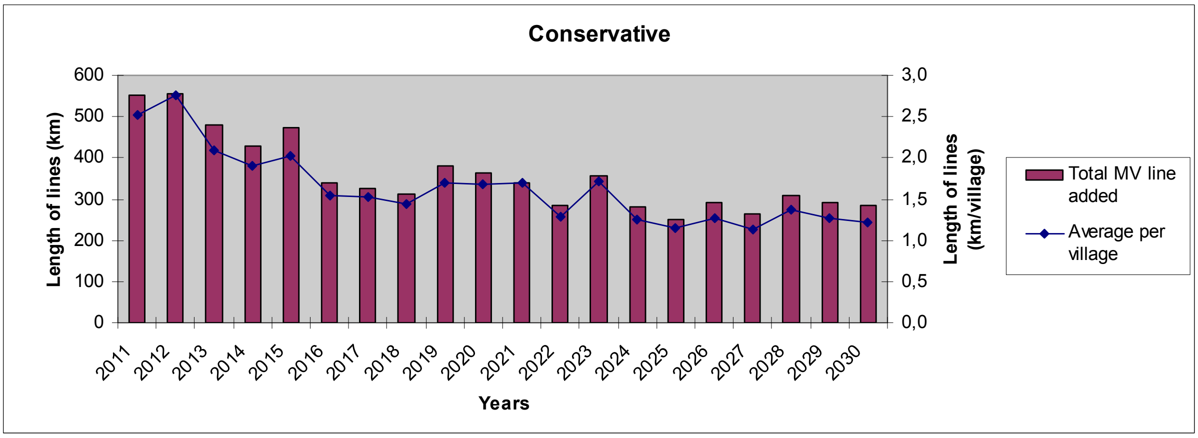
| Phase | Baseline | Intermediate | Conservative |
|---|---|---|---|
| 2011-2015 | 697 | 701 | 687 |
| 2016-2020 | 573 | 503 | 477 |
| 2021-2030 | 453 | 504 | 382 |
| **2011-2030** | **572** | **565** | **508** |

The below show the length of MV lines which are to be added every year, with the corresponding average length per new village connected.

Figure 54: Length of MV lines added



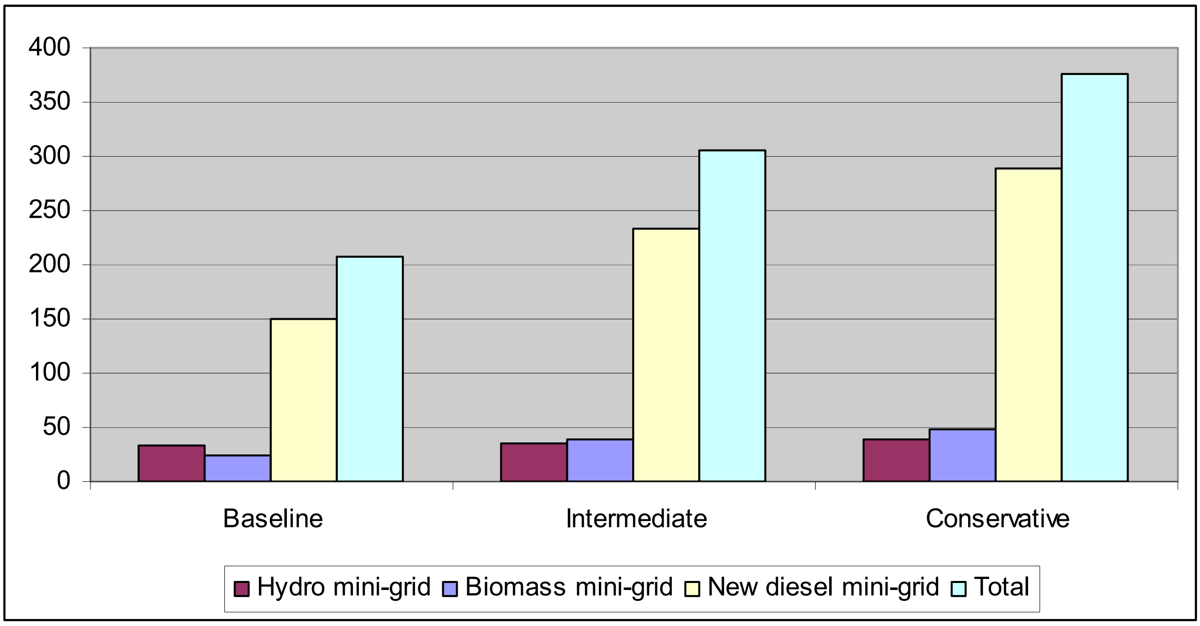
### 5.3.5 Twice as many mini grid projects in the conservative scenario

In line with the investment analysis above, the following tables show that being conservative regarding grid extension during the first years because of financial constraints, while still aiming at achieving the same village connection rates implies that we reach 376 projects mini grid projects required over the 20 years instead of 208; total capacity installed increases from 38 MW to 70MW. It must also be noted here that diesel based mini grids, in all three scenarios account for about 3/4 of all the mini grids. This is due to the site specific nature of hydro power production and biomass based power generation. It also calls upon the planner to seriously consider all options for reducing the cost of diesel based mini grids power generation, through all forms of possible hybrids including solar PV.

Table 46: Number of mini-grids and capacity by technology for the 3 scenarios

| | Baseline | | Intermediate | | Conservative | |
|---|---|---|---|---|---|---|
| Mini-grid projects in rural areas by 2015 | Number of projects | Total Installed capacity (kW) | Number of projects | Total Installed capacity (kW) | Number of projects | Total Installed capacity (kW) |
| Hydro mini-grid | 33 | 6 449 | 35 | 6 639 | 38 | 7 309 |
| Biomass mini-grid | 25 | 10 317 | 38 | 13 832 | 49 | 16 207 |
| New diesel mini-grid | 150 | 21 663 | 233 | 34 701 | 289 | 46 833 |
| **Total** | **208** | **38 429** | **306** | **55 171** | **376** | **70 348** |

Figure 55: Number of mini grids projects, all scenarios



Logically, investment costs also follow the same trend in terms of total numbers, with a very high effort during the first period in order to meet the 2015 target. Again, as already discussed, this does not seem to be realistic in terms of private sector mobilisation, and one should probably develop yet another scenario staggering this off grid investment requirement.

Table 47: Investment costs for mini-grid technologies (in '000 of USD)

| BASELINE | 2011-2015 | 2016-2020 | 2021-2030 | 2011-2030 |
|---|---|---|---|---|
| Hydro mini-grid | 31 492 | 861 | 233 | 32 586 |
| Biomass mini-grid | 16 363 | 581 | 171 | 17 115 |
| New diesel mini-grid | 23 906 | 2 382 | 392 | 26 681 |
| **Total mini-grid projects** | **71 761** | **3 824** | **796** | **76 382** |

| INTERMEDIATE | 2011-2015 | 2016-2020 | 2021-2030 | 2011-2030 |
|---|---|---|---|---|
| Hydro mini-grid | 34 204 | 1 194 | 813 | 36 212 |
| Biomass mini-grid | 19 810 | 870 | 482 | 21 162 |
| New diesel mini-grid | 37 302 | 5 134 | 1 779 | 44 216 |
| **Total mini-grid projects** | **91 317** | **7 199** | **3 074** | **101 589** |

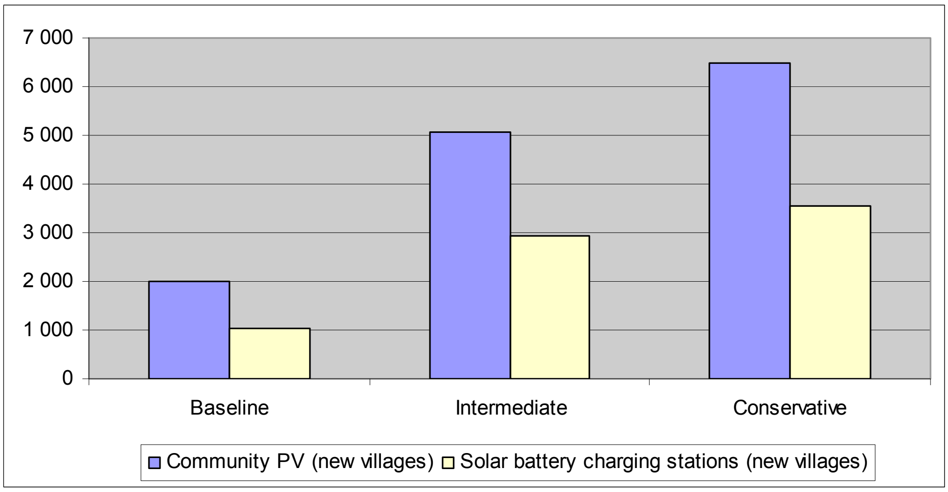
| CONSERVATIVE | 2011-2015 | 2016-2020 | 2021-2030 | 2011-2030 |
|---|---|---|---|---|
| Hydro mini-grid | 37 604 | 1 327 | 1 067 | 39 998 |
| Biomass mini-grid | 22 679 | 1 115 | 718 | 24 513 |
| New diesel mini-grid | 48 429 | 7 558 | 3 398 | 59 385 |
| **Total mini-grid projects** | **108 713** | **10 000** | **5 184** | **123 896** |

### 5.3.6 Stand alone systems

Stand alone systems include battery charging stations (BCS), community PV and Solar Home Systems (SHS). Existing battery charging stations account for 35% of village coverage to date and then reduces over time to reach 4% in the baseline scenario, 16% in the intermediate scenario and 39% in the conservative scenario.

Given the intermediate targets fixed by the RGC, all these stand alone systems are modelled to be installed before 2020, and the investment amount over the coming 10 years is far from negligible for SHS, PV BCS and Community PV combined: 40 MUSD in the baseline scenario, 96 MUSD in the intermediate scenario and 130 MUSD in the conservative scenario. How realistic this is remains an open question. It must also be born in mind that SREP figures for potential SHS is just a potential figure covering all the rich, non served households.

Figure 56: Number of standalone systems, all scenarios



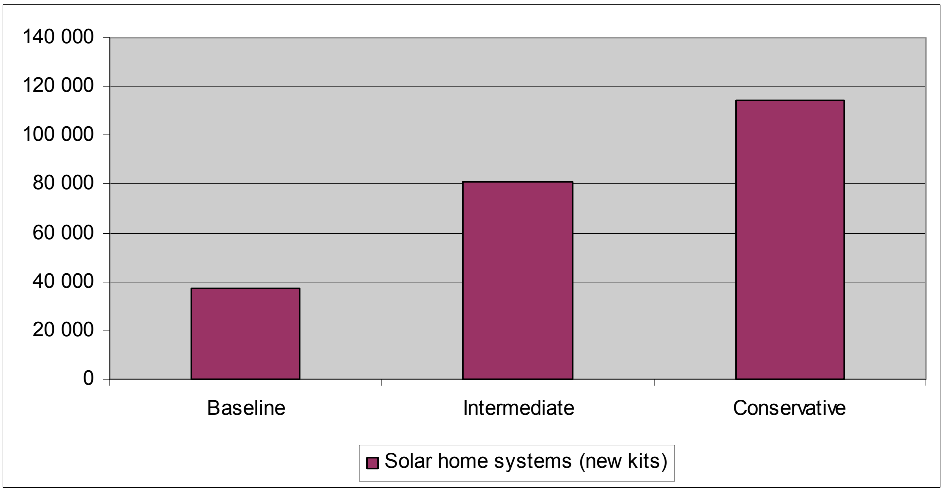




Figure 57: Number of standalone systems, all scenarios

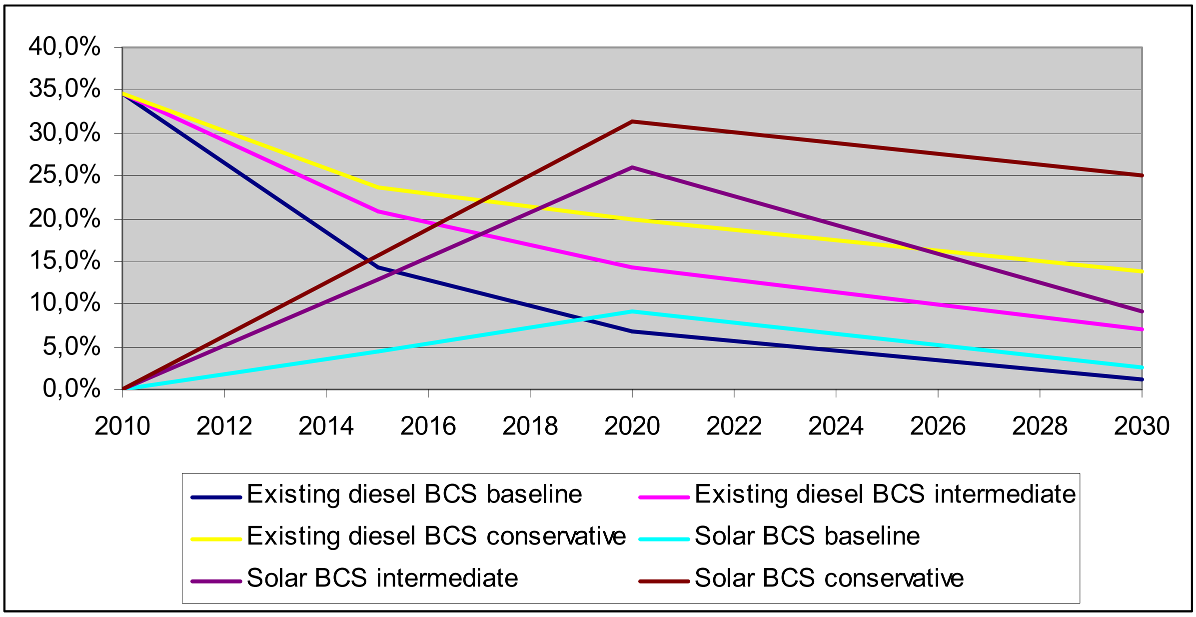


Table 48: Number of standalone systems to install, all scenarios

| BASELINE SCENARIO | 2011-2015 | 2016-2020 |
|---|---|---|
| Solar home systems (new kits) | 16 744 | 20 679 |
| Community PV (new villages) | 997 | 997 |
| Solar battery charging stations (new villages) | 569 | 455 |

| INTERMEDIATE SCENARIO | 2011-2015 | 2016-2020 |
|---|---|---|
| Solar home systems (new kits) | 36 094 | 44 842 |
| Community PV (new villages) | 2 539 | 2 539 |
| Solar battery charging stations (new villages) | 1635 | 1308 |

| CONSERVATIVE SCENARIO | 2011-2015 | 2016-2020 |
|---|---|---|
| Solar home systems (new kits) | 51 105 | 63 308 |
| Community PV (new villages) | 3 238 | 3 237 |
| Solar battery charging stations (new villages) | 1980 | 1584 |

Table 49: Breakdown of investments in standalone systems, all scenarios (in '000 USD)

| BASELINE SCENARIO | 2011-2015 | 2016-2020 |
|---|---|---|
| Solar home systems (new kits) | 6 698 | 8 272 |
| Community PV (new villages) | 2 190 | 2 190 |
| Solar battery charging stations (new villages) | 10368 | 10564 |

| INTERMEDIATE SCENARIO | 2011-2015 | 2016-2020 |
|---|---|---|
| Solar home systems (new kits) | 14 438 | 17 937 |
| Community PV (new villages) | 4 779 | 4 779 |
| Solar battery charging stations (new villages) | 26792 | 27293 |

| CONSERVATIVE SCENARIO | 2011-2015 | 2016-2020 |
|---|---|---|
| Solar home systems (new kits) | 20 442 | 25 323 |
| Community PV (new villages) | 6 295 | 6 295 |
| Solar battery charging stations (new villages) | 35546 | 36207 |

## 5.4 COMPARATIVE NATIONAL MAPS FOR ALL THREE SCENARIOS

Figure 58: Map of grid extension (intermediate scenario)

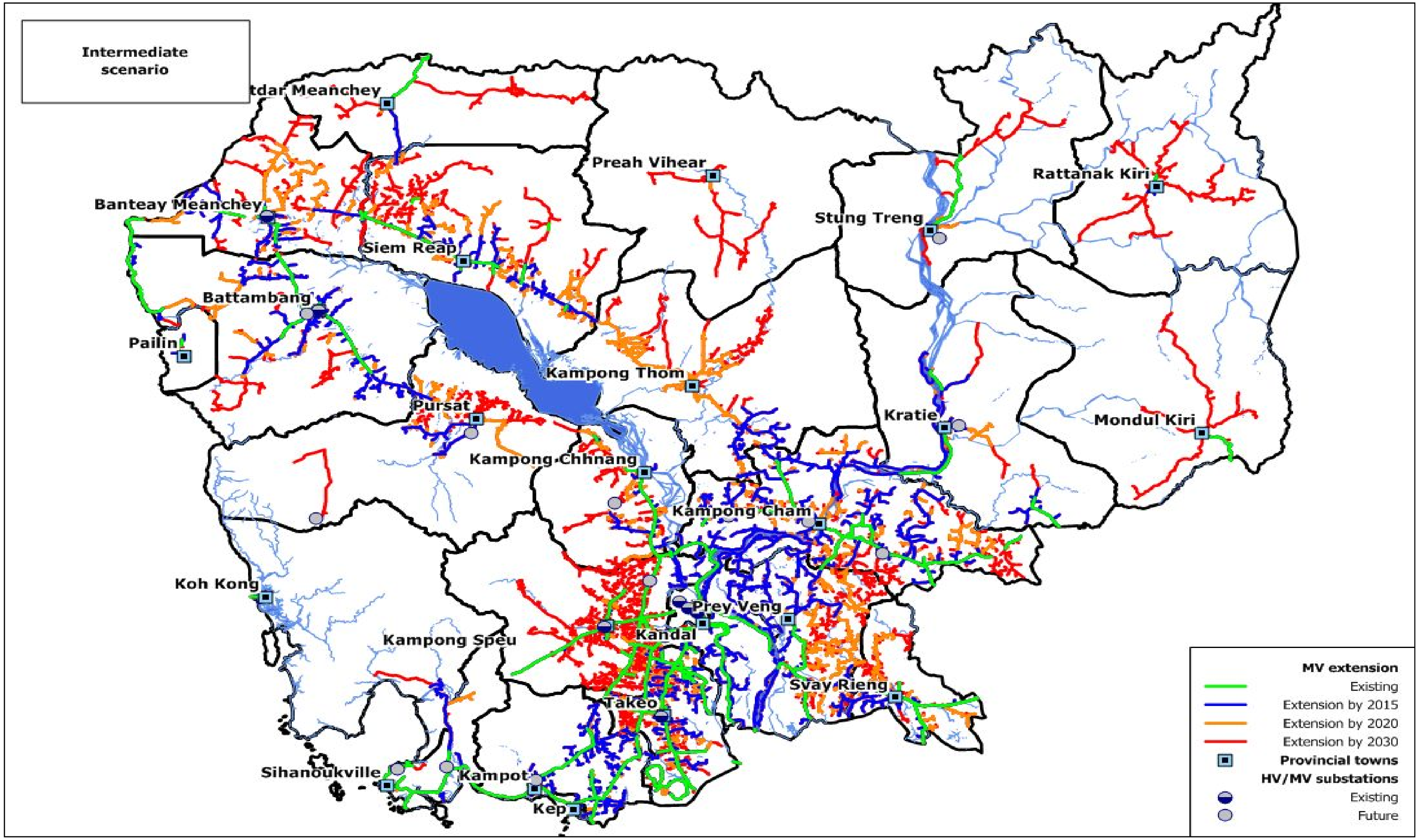


Figure 59: Map of grid extension (conservative scenario)

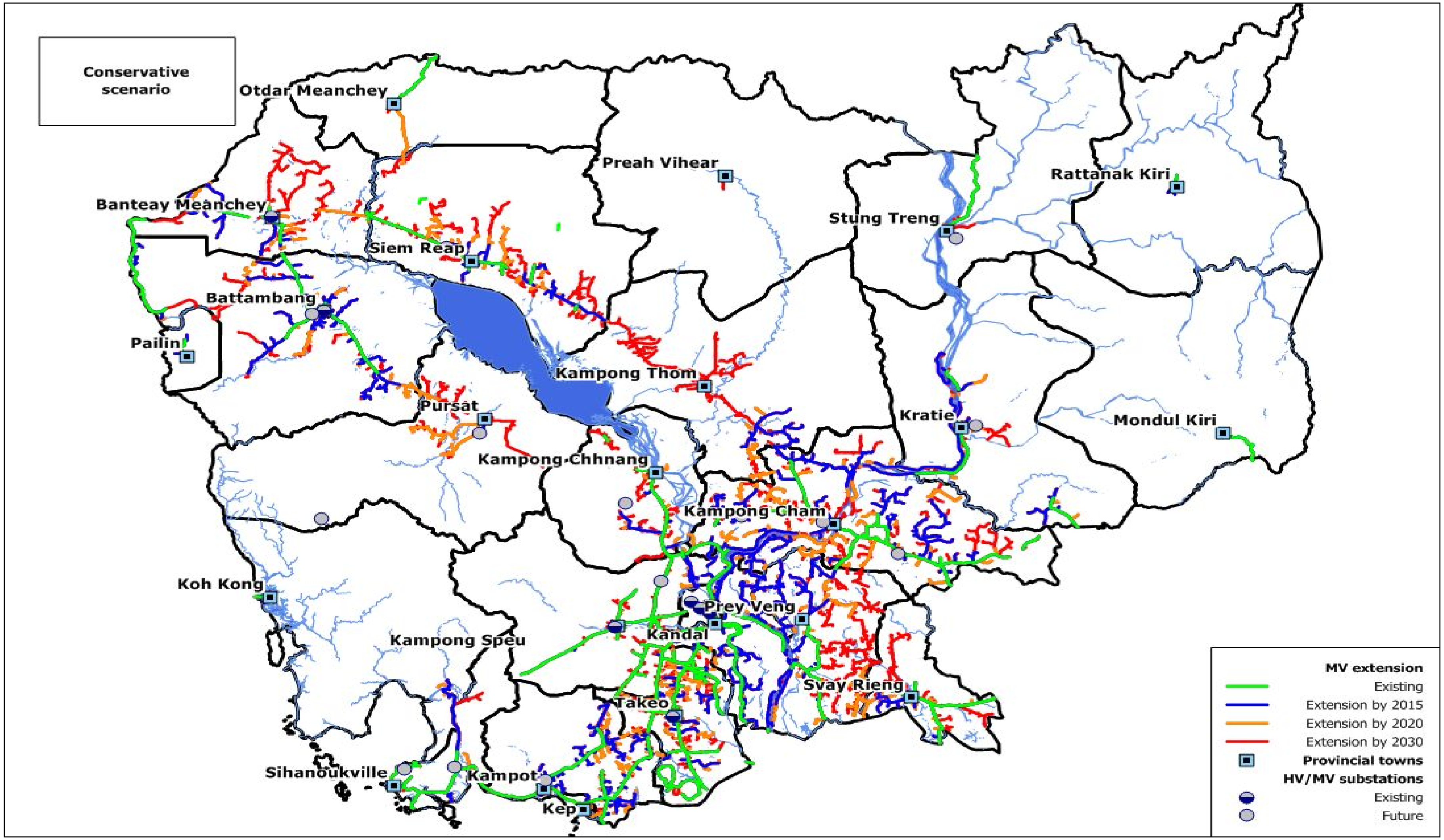


Figure 60: 2030 Map of mini-grid projects (baseline scenario)

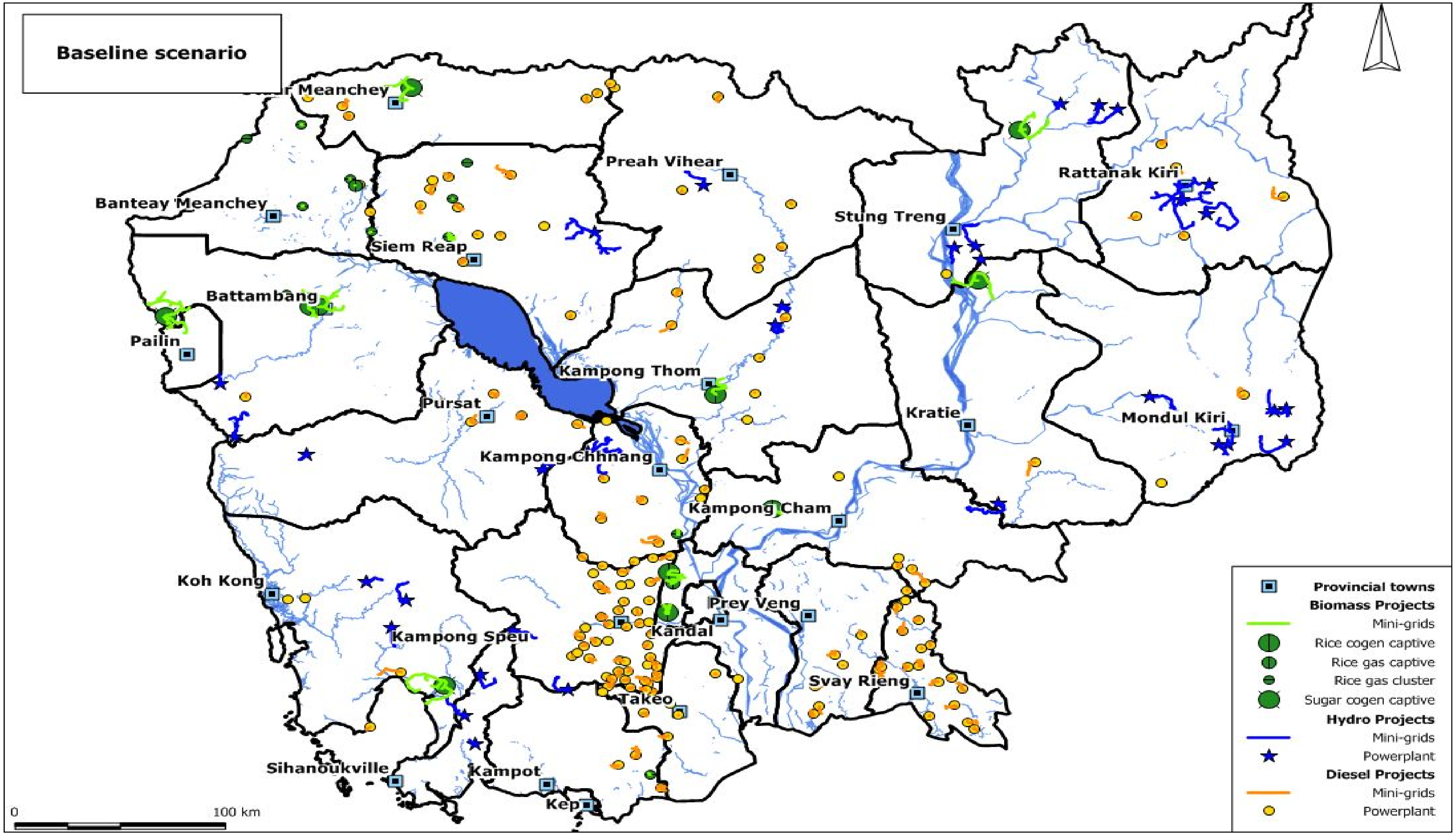


Figure 61 : 2030 Map of mini-grid projects (intermediate scenario)

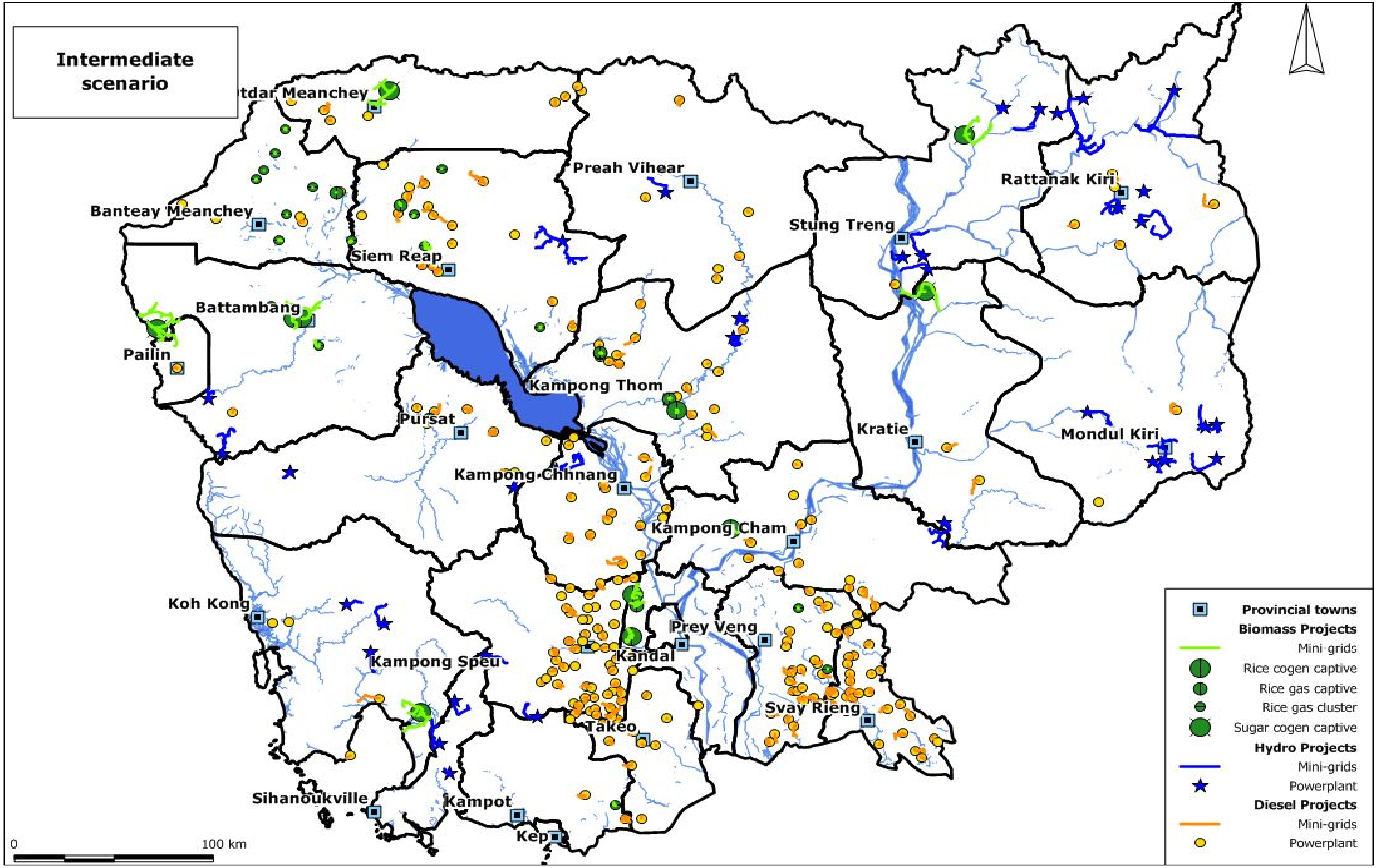


Figure 62 : 2030 Map of mini-grid projects (conservative scenario)

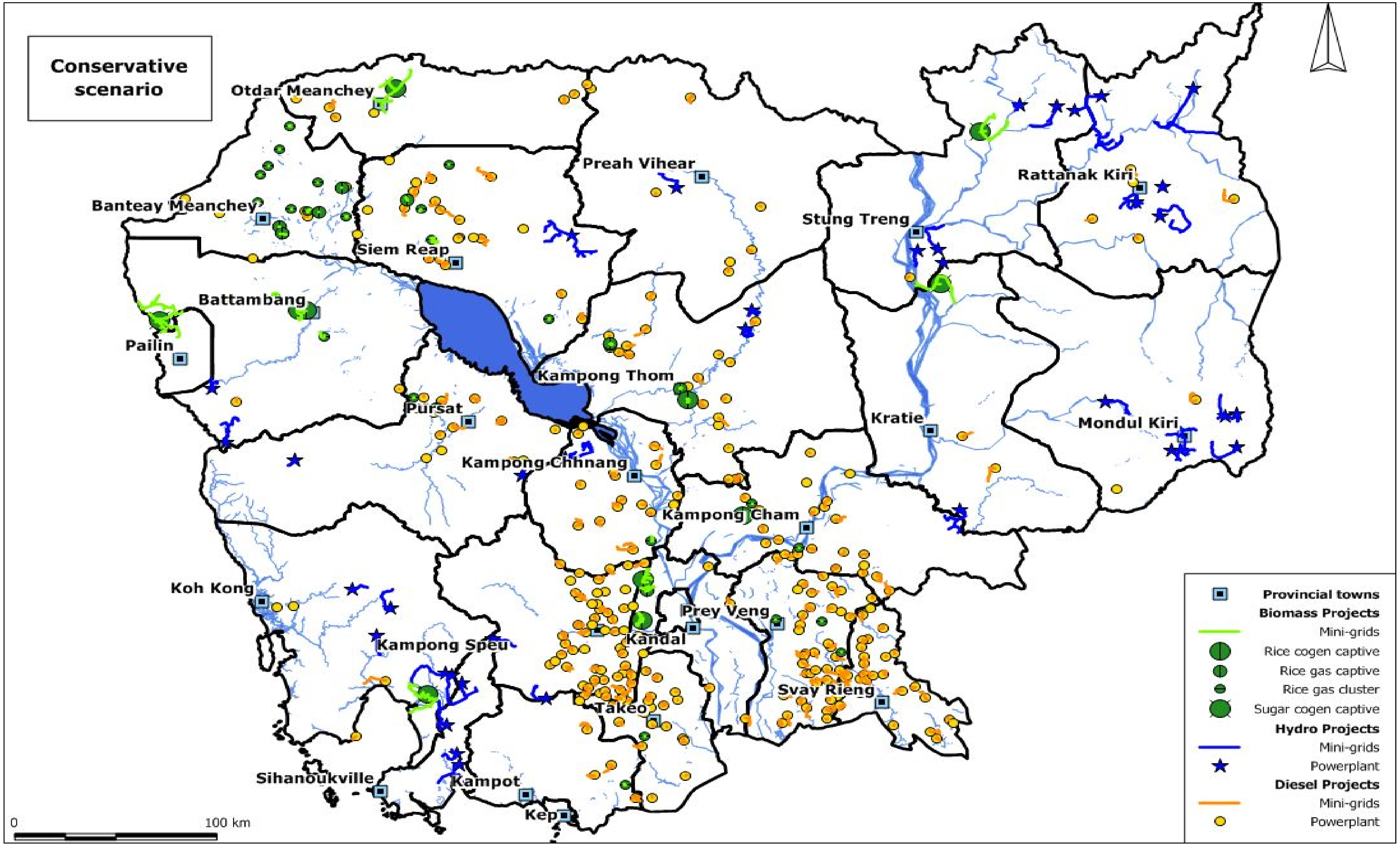


Figure 63: 2030 Map of candidates for stand-alone systems (baseline scenario)

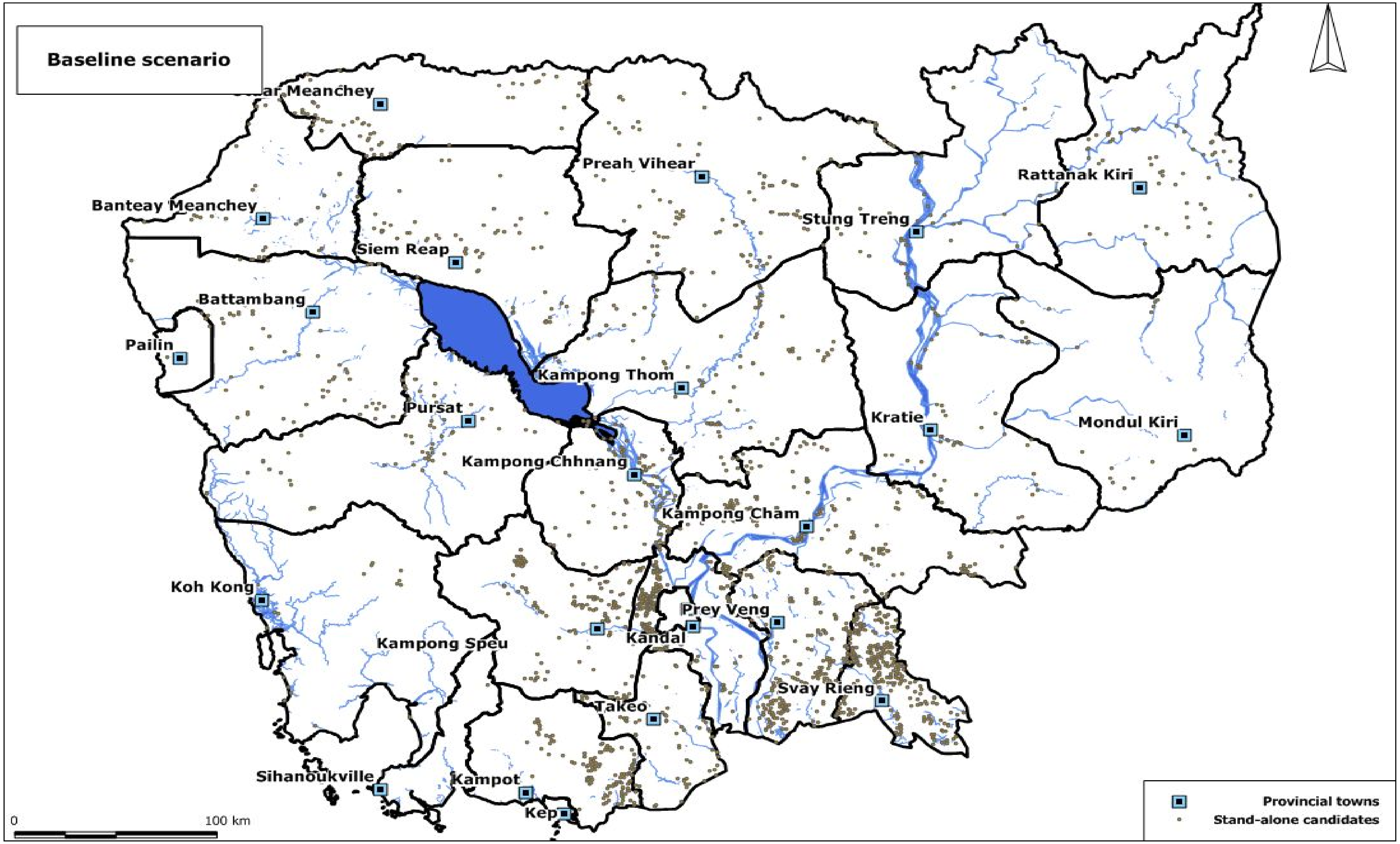


Figure 64: 2030 Map of candidates for stand-alone systems (intermediate scenario)

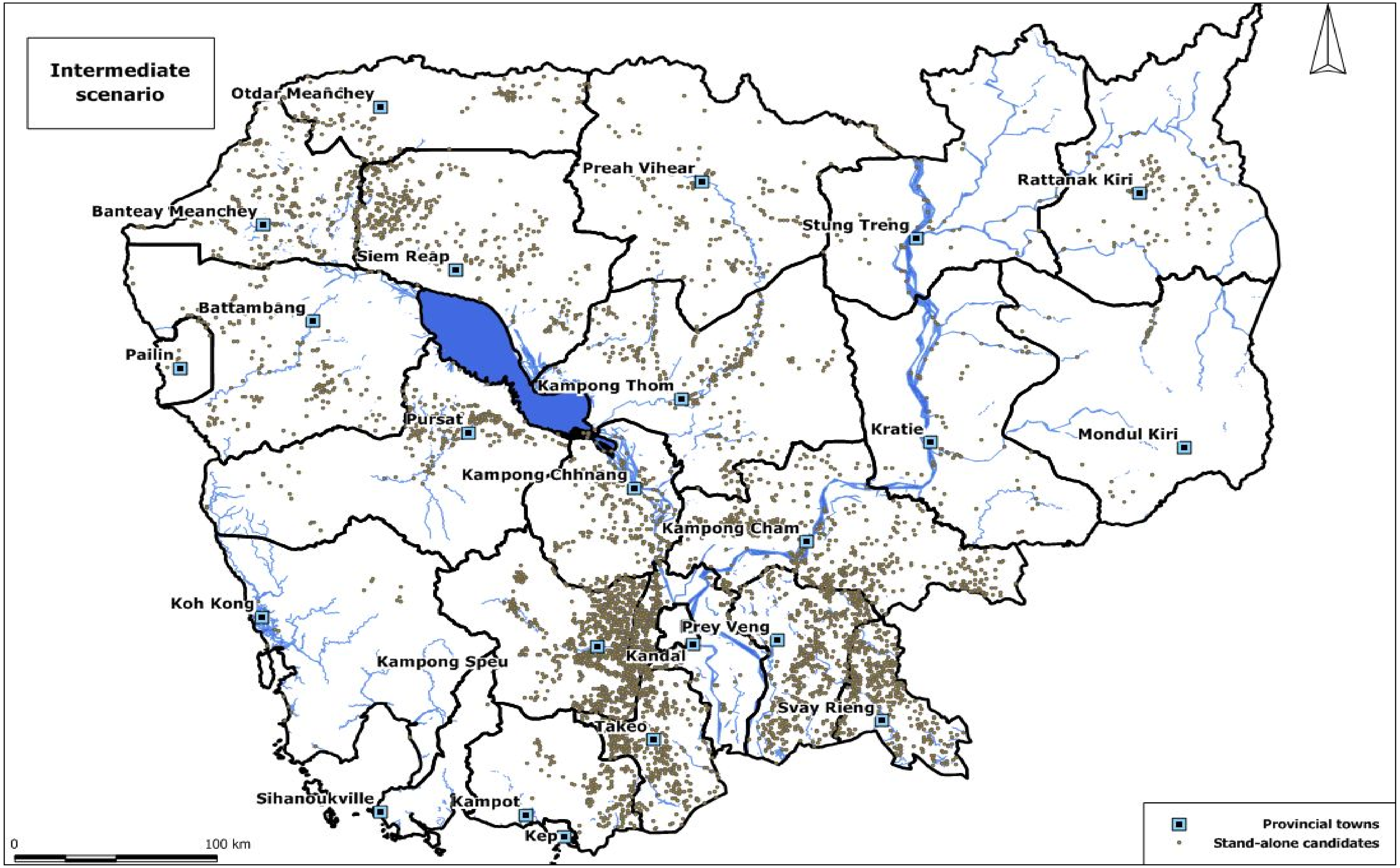
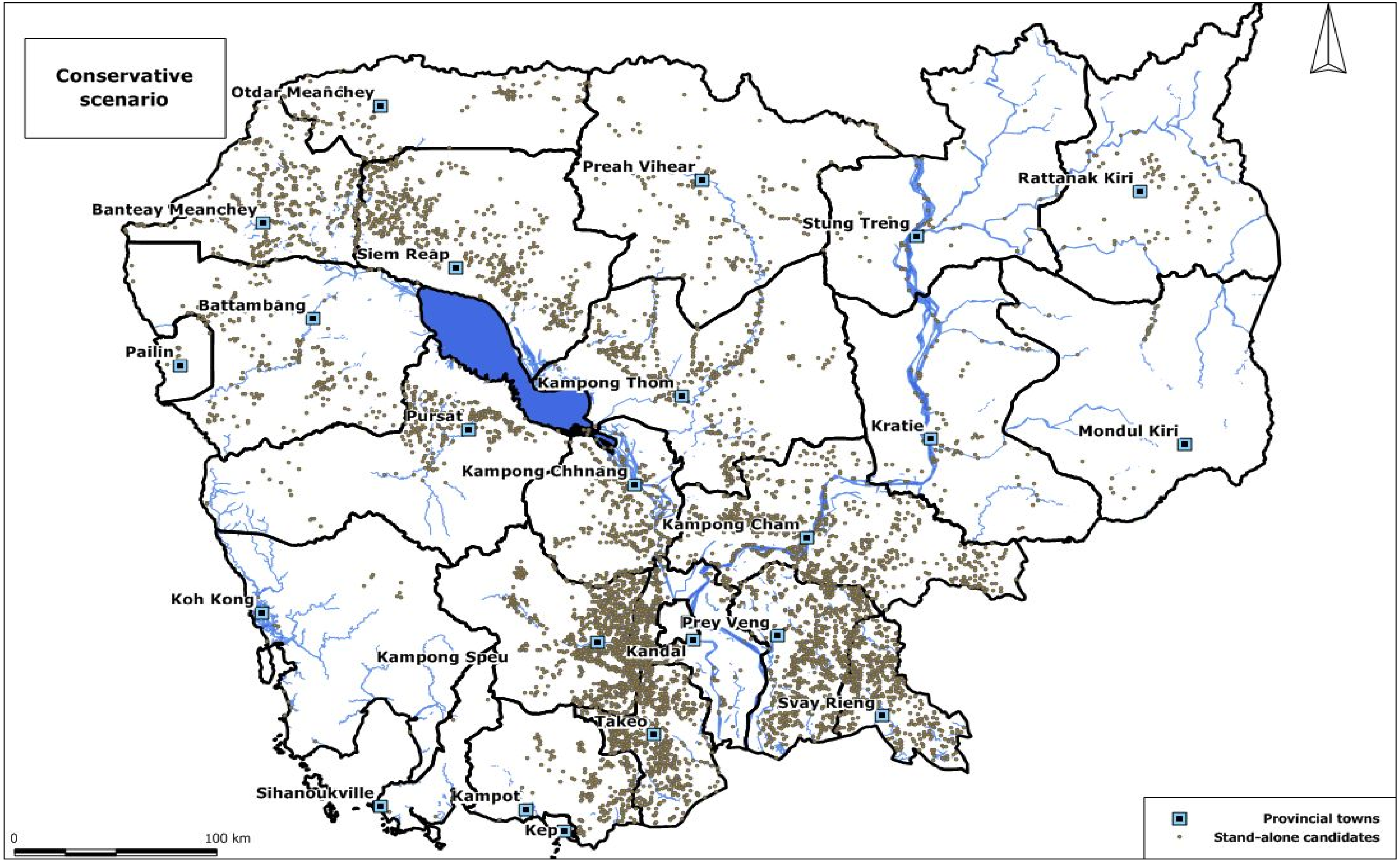


Figure 65: 2030 Map of candidates for stand-alone systems (conservative scenario)



# 6 SUMMARY PROVINCIAL RESULTS FOR THE BASELINE SCENARIO

## 6.1 INTRODUCTION

In this chapter, detailed results province by province will be presented for the baseline scenario only. Please note that separate provincial brochures give further details on each province and for the three scenarios.

Results for each province are presented in separate sections, containing:

- A map showing the planned EDC lines for 2020[20], as well as current REE and EDC license zones, and the proposed mini-grid projects (hydro, biomass, diesel). Candidate villages for stand-alone systems are represented as well.
- Various tables, providing indications on:
  - Household and village coverage rate for different time horizons (2010, 2015, 2020 and 2030), with the breakdown per technology
  - Additional length of MV lines and demand for grid extension
  - Number of mini-grid projects and cumulated installed capacity. Please note that only mini-grid projects, with the powerhouse inside the province are included in this table. However, some villages and households of the province may be electrified by a cross-border project, with the powerhouse located in another province.
  - Number of stand-alone systems to be installed for different phases
  - Total investment costs per phase and per technology. NB: in this table, investment costs for mini-grid projects have been split by village. Therefore, cross-border projects may still result in investment costs in this province. For example, with a project costing 300,000 USD and supplying 2 villages in province A and 1 village in province B, 200,000 USD of investment will be affected to province A, and 100,000 USD will be affected to province B.

## 6.2 PROVINCIAL DISTRIBUTION OF INVESTMENTS UNTIL 2015

Investment costs per province for the 2011-2015 phase are summarized in the following table:

Table 50: Investment cost for the 2011-2015 phase by province and technology in the baseline scenario ('000 USD)

| Province | National grid | Hydro mini-grid | Biomass mini-grid | New diesel mini-grid | Solar home systems | Community PV | Solar BCS | Total |
|---|---|---|---|---|---|---|---|---|
| Banteay Meanchey | 8 845 | 0 | 899 | 113 | 111 | 47 | 133 | **10 148** |
| Battambang | 10 479 | 1 381 | 2 761 | 113 | 198 | 72 | 242 | **15 247** |
| Kampong Cham | 27 533 | 1 031 | 998 | 661 | 705 | 186 | 1 119 | **32 231** |
| Kampong Chhnang | 4 610 | 3 054 | 262 | 2 344 | 349 | 134 | 377 | **11 130** |
| Kampong Speu | 1 889 | 1 570 | 59 | 6 336 | 297 | 109 | 699 | **10 959** |
| Kampong Thom | 11 299 | 2 074 | 1 107 | 851 | 325 | 129 | 635 | **16 420** |
| Kampot | 8 053 | 0 | 237 | 947 | 633 | 124 | 854 | **10 848** |
| Kandal | 9 906 | 0 | 2 142 | 0 | 561 | 154 | 933 | **13 696** |
| Kep | 392 | 0 | 0 | 0 | 0 | 0 | 0 | **392** |
| Koh Kong | 594 | 1 925 | 2 147 | 291 | 33 | 19 | 76 | **5 084** |

[20] Although we have done some simulation until and before 2020 using the GEOSIM® grid extension module, this was only necessary to determine the potential for mini-grid projects, and therefore maps show only the official grid extension lines in order to be consistent with the plans made by EDC.

| Province | National grid | Hydro mini-grid | Biomass mini-grid | New diesel mini-grid | Solar home systems | Community PV | Solar BCS | Total |
|---|---|---|---|---|---|---|---|---|
| Kracheh | 5 237 | 172 | 199 | 345 | 172 | 84 | 270 | **6 478** |
| Mondul Kiri | 0 | 4 931 | 0 | 220 | 26 | 25 | 45 | **5 247** |
| Otdar Meanchey | 740 | 0 | 1 837 | 1 192 | 174 | 80 | 307 | **4 330** |
| Pailin | 581 | 455 | 312 | 0 | 12 | 6 | 23 | **1 388** |
| Preah Sihanouk | 988 | 1 152 | 0 | 0 | 12 | 2 | 0 | **2 154** |
| Preah Vihear | 220 | 543 | 0 | 699 | 286 | 182 | 390 | **2 320** |
| Prey Veng | 17 963 | 0 | 0 | 1 208 | 946 | 237 | 1 308 | **21 663** |
| Pursat | 5 902 | 1 860 | 0 | 1 245 | 218 | 89 | 301 | **9 614** |
| Ratanak Kiri | 105 | 5 677 | 0 | 746 | 102 | 51 | 382 | **7 062** |
| Siem Reap | 11 657 | 2 933 | 969 | 1 931 | 212 | 68 | 264 | **18 034** |
| Stung Treng | 404 | 2 736 | 2 434 | 57 | 94 | 70 | 235 | **6 029** |
| Svay Rieng | 5 243 | 0 | 0 | 3 763 | 983 | 249 | 1 341 | **11 579** |
| Takeo | 10 789 | 0 | 0 | 846 | 249 | 74 | 434 | **12 392** |
| **Total** | **132 640** | **31 492** | **16 363** | **23 060** | **6 449** | **2 116** | **9 934** | **222 054** |

The following table splits the 23 provinces into 4 groups for each technology and for the total investment, using the k-means statistical method.

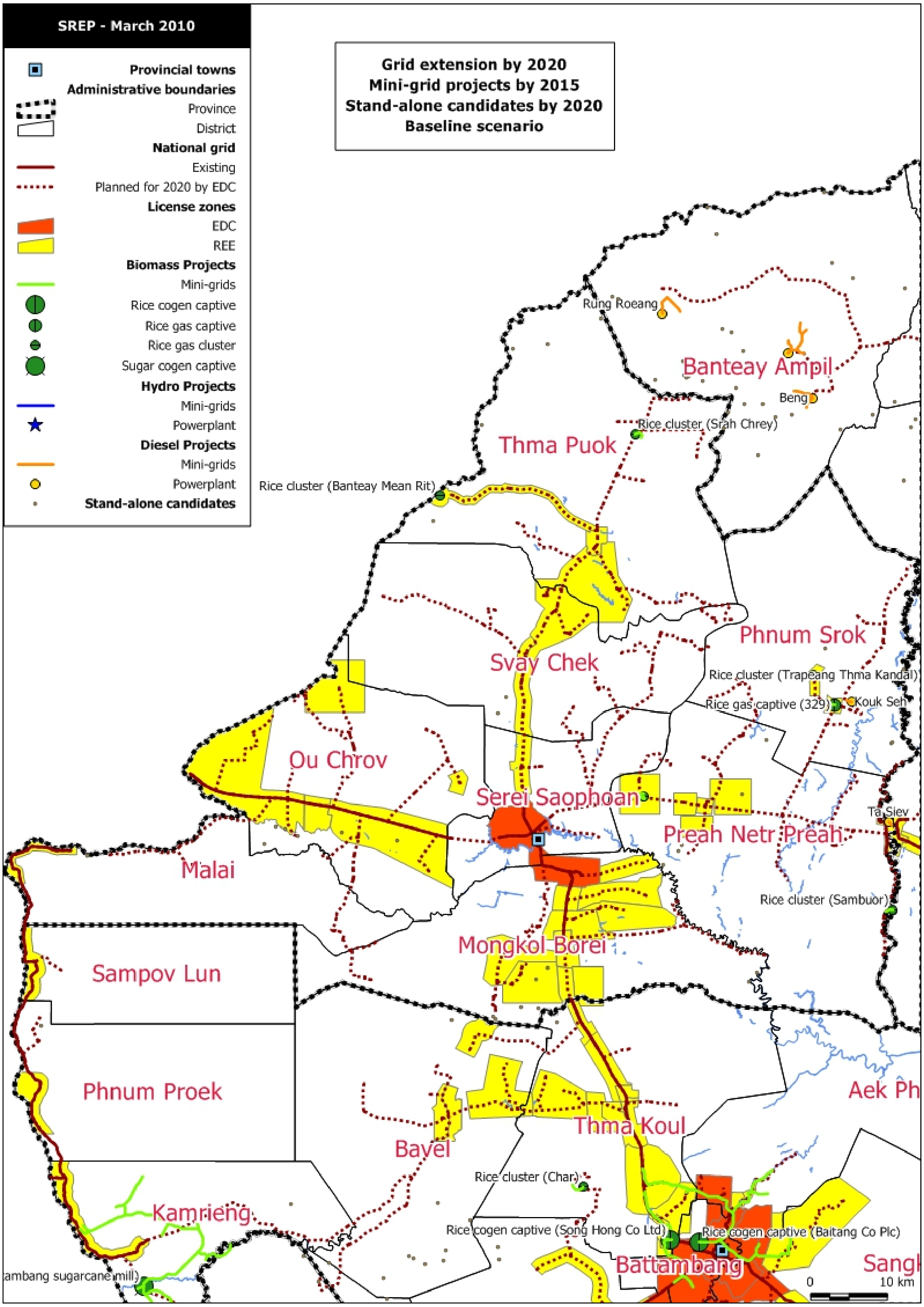
**Table 51Classification of provinces into 4 groups by investment costs in each technology (1-green means highest investment, 4-red means lowest)**

| Province | National grid | Hydro mini-grid | Biomass mini-grid | New diesel mini-grid | Stand-alone systems | Total |
|---|---|---|---|---|---|---|
| Banteay Meanchey | 3 | 4 | 3 | 4 | 4 | 3 |
| Battambang | 3 | 3 | 1 | 4 | 3 | 2 |
| Kampong Cham | 1 | 3 | 3 | 3 | 2 | 1 |
| Kampong Chhnang | 4 | 2 | 4 | 3 | 3 | 3 |
| Kampong Speu | 4 | 3 | 4 | 1 | 3 | 3 |
| Kampong Thom | 3 | 3 | 3 | 3 | 3 | 2 |
| Kampot | 3 | 4 | 4 | 3 | 2 | 3 |
| Kandal | 3 | 4 | 2 | 4 | 2 | 3 |
| Kep | 4 | 4 | 4 | 4 | 4 | 4 |
| Koh Kong | 4 | 3 | 2 | 4 | 4 | 4 |
| Kracheh | 4 | 4 | 4 | 4 | 3 | 4 |
| Mondul Kiri | 4 | 1 | 4 | 4 | 4 | 4 |
| Otdar Meanchey | 4 | 4 | 2 | 3 | 3 | 4 |
| Pailin | 4 | 4 | 4 | 4 | 4 | 4 |
| Preah Sihanouk | 4 | 3 | 4 | 4 | 4 | 4 |
| Preah Vihear | 4 | 4 | 4 | 3 | 3 | 4 |
| Prey Veng | 2 | 4 | 4 | 3 | 1 | 2 |
| Pursat | 3 | 3 | 4 | 3 | 3 | 3 |
| Ratanak Kiri | 4 | 1 | 4 | 3 | 3 | 4 |
| Siem Reap | 3 | 2 | 3 | 3 | 3 | 2 |
| Stung Treng | 4 | 2 | 1 | 4 | 3 | 4 |
| Svay Rieng | 4 | 4 | 4 | 2 | 1 | 3 |
| Takeo | 3 | 4 | 4 | 3 | 3 | 3 |

The above table leads to the following remarks:

- Highly populated provinces such as Kampong Cham, Battambang, Prey Veng and Siem Reap naturally require the highest total investment costs. Kampong Thom is an exception to this rule, with relatively high investment costs for all technologies and a low population
- Grid expansion efforts are highest in the provinces around the existing main systems, i.e. Phnom Penh system (Kandal, Takeo, Prey Veng, Kampot) and the Western System (Banteay Meanchey, Battambang, Siem Reap). Pursat and Kampong Thom also enjoy significant investments in backbone infrastructure, being located between these two large systems due to be interconnected. Some remote provinces such as Mondul Kiri, Rattanak Kiri and Preah Vihear are also supposed to build very long MV lines, but due to the least-cost optimisation algorithm used to prioritise the lines until 2020, most of them have been assumed for the 2016-2020 period, which is not included in the above table. This may not happen this way in reality, as there may be a political will to extend the grid much sooner in these provinces, even if not profitable (but of course provided transmission lines do reach them).
- Hydro potential investments focus on the North-Eastern province (Rattanak Kiri, Mondul Kiri, Stung Treng), while the theoretical technical potential in the West and South-Western part (Battambang, Pursat, Kampot, Koh Kong), is kept in check by the quick development of the national grid
- Biomass investments are naturally higher where large cogeneration projects have been identified, e.g. Battambang, Otdar Meanchey, Stung Treng, Kandal and Koh Kong. These large projects tend to distort the actual representation in terms of number of projects, which should give the preference to North-Western provinces around the Tonle Sap lake (Battambang, Banteay Meanchey, Siem Reap).
- Most proposed diesel projects are in provinces where grid investment are relatively modest, which seems sensible. But a closer look at maps reveals that they are never really far from the planned MV lines (cf. comments in 5.2.3), therefore attention will need to be paid to this risk factor for potential investors.
- Finally, investments in stand-alone systems is unexpectedly higher in provinces with high population and decent national grid coverage (existing and planned). On the other hand, remote provinces such as Mondul Kiri, Rattanak Kiri or Koh Kong are not in the top provinces in terms of stand-alone systems. This may be explained by the plain population factor, and the fact that even in province with very high levels of national grid coverage, many villages, although located “under the lines”, may still remain unelectrified until 2020.

## 6.3 Banteay Meanchey



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 4.4% | 26.2% | 52.3% | 68.6% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 1.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 6.6% | 3.0% | 0.5% | 0.3% |
| | New diesel mini-grid | 0.0% | 0.2% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.2% | 0.5% | 0.1% |
| | **Total rural connections** | **11%** | **31%** | **53%** | **69%** |
| Village coverage | National grid | 6.1% | 44.5% | 93.8% | 98.8% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 1.9% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 16.5% | 7.5% | 0.9% | 0.3% |
| | New diesel mini-grid | 0.0% | 0.7% | 0.0% | 0.0% |
| | Existing battery charging stations | 37.4% | 18.7% | 3.1% | 0.7% |
| | Solar battery charging stations | 0.0% | 1.1% | 2.3% | 0.2% |
| | **Total rural villages** | **60%** | **74%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 442 | 386 | 68 |
| Grid demand of newly connected villages (GWh/year) | 22 | 17 | 3 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 5 | 606 |
| New diesel mini-grid | 2 | 96 |
| **Total** | **7** | **702** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

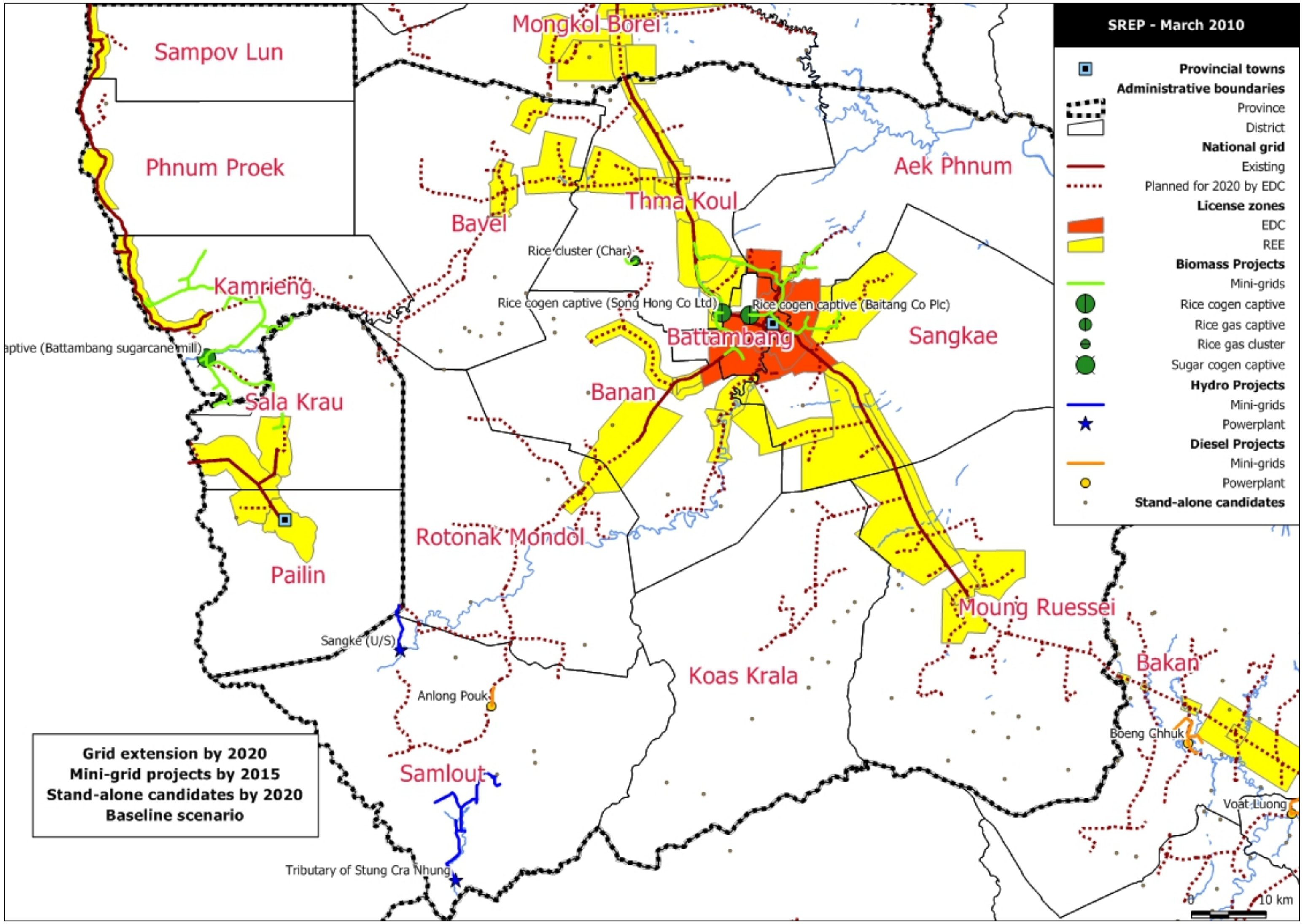
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 278 | 346 | 0 |
| Community PV (new villages) | 16 | 15 | 0 |
| Solar battery charging stations (new villages) | 7 | 5 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 8,845 | 7,729 | 1,355 |
| Distribution (transformers, LV, meters) | 8,886 | 9,961 | 5,799 |
| **Subtotal grid extension** | **17,732** | **17,690** | **7,154** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 899 | 24 | 0 |
| New diesel mini-grid | 113 | 2 | 0 |
| **Subtotal mini-grid projects** | **1,012** | **27** | **0** |
| Solar home systems | 111 | 138 | 4 |
| Community PV | 47 | 47 | 0 |
| Solar battery charging stations | 133 | 136 | 0 |
| **Subtotal stand-alone systems** | **291** | **321** | **4** |
| **Total** | **19,035** | **18,038** | **7,158** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.4 BATTAMBANG



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 9.4% | 37.6% | 53.7% | 67.9% |
| | Hydro mini-grid | 0.0% | 0.2% | 0.3% | 0.3% |
| | Biomass mini-grid | 0.0% | 0.8% | 0.7% | 0.0% |
| | Existing diesel mini-grid | 7.1% | 2.4% | 1.8% | 0.5% |
| | New diesel mini-grid | 0.0% | 0.2% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.3% | 0.6% | 0.2% |
| | **Total rural connections** | **17%** | **41%** | **57%** | **69%** |
| Village coverage | National grid | 18.9% | 65.1% | 86.5% | 94.4% |
| | Hydro mini-grid | 0.0% | 1.7% | 1.7% | 1.4% |
| | Biomass mini-grid | 0.0% | 3.0% | 1.7% | 0.0% |
| | Existing diesel mini-grid | 20.2% | 6.1% | 2.6% | 0.8% |
| | New diesel mini-grid | 0.0% | 0.3% | 0.0% | 0.0% |
| | Existing battery charging stations | 33.0% | 10.0% | 4.1% | 1.5% |
| | Solar battery charging stations | 0.0% | 1.8% | 3.5% | 2.0% |
| | **Total rural villages** | **72%** | **88%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 524 | 217 | 225 |
| Grid demand of newly connected villages (GWh/year) | 47 | 8 | 11 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 2 | 420 |
| Biomass mini-grid | 4 | 2,878 |
| New diesel mini-grid | 1 | 101 |
| **Total** | **7** | **3,399** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

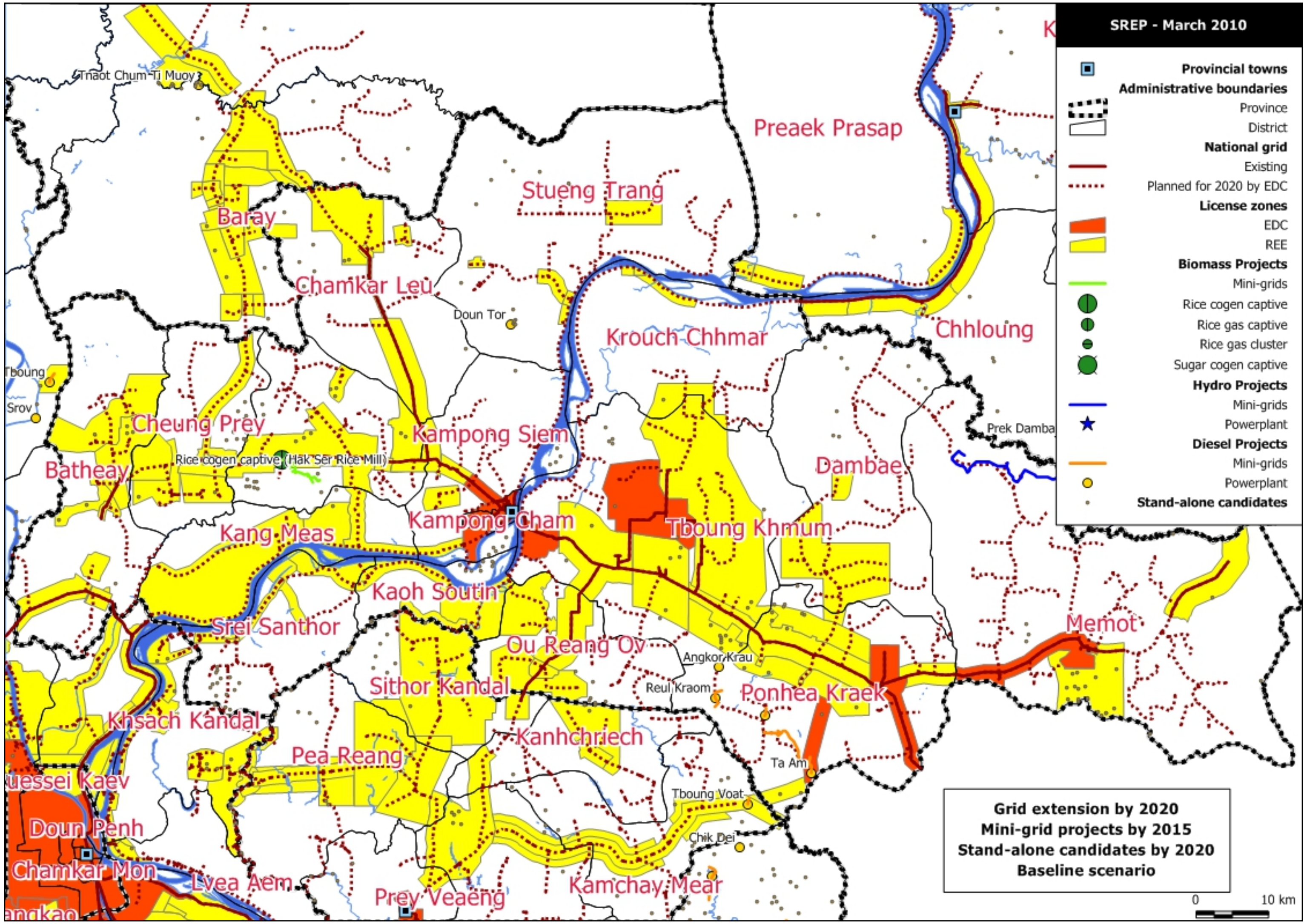
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 496 | 638 | 0 |
| Community PV (new villages) | 25 | 25 | 0 |
| Solar battery charging stations (new villages) | 12 | 9 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 10,479 | 4,348 | 4,493 |
| Distribution (transformers, LV, meters) | 15,767 | 9,220 | 11,172 |
| **Subtotal grid extension** | **26,247** | **13,567** | **15,665** |
| Hydro mini-grid | 1,381 | 34 | 31 |
| Biomass mini-grid | 2,761 | 107 | 33 |
| New diesel mini-grid | 113 | 19 | 0 |
| **Subtotal mini-grid projects** | **4,255** | **160** | **63** |
| Solar home systems | 198 | 255 | 0 |
| Community PV | 72 | 72 | 0 |
| Solar battery charging stations | 242 | 248 | 0 |
| **Subtotal stand-alone systems** | **513** | **575** | **0** |
| **Total** | **31,014** | **14,302** | **15,729** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.5 KAMPONG CHAM



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 7.4% | 36.3% | 53.0% | 68.4% |
| | Hydro mini-grid | 0.0% | 0.1% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.2% | 0.2% | 0.0% |
| | Existing diesel mini-grid | 5.1% | 1.1% | 0.9% | 0.1% |
| | New diesel mini-grid | 0.0% | 0.4% | 0.1% | 0.0% |
| | Solar home systems | 0.0% | 0.5% | 1.0% | 0.1% |
| | **Total rural connections** | **12%** | **39%** | **55%** | **69%** |
| Village coverage | National grid | 12.5% | 62.9% | 85.7% | 98.0% |
| | Hydro mini-grid | 0.0% | 0.4% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.7% | 0.6% | 0.1% |
| | Existing diesel mini-grid | 15.1% | 4.2% | 2.1% | 0.3% |
| | New diesel mini-grid | 0.0% | 1.0% | 0.1% | 0.0% |
| | Existing battery charging stations | 31.9% | 8.3% | 4.2% | 0.2% |
| | Solar battery charging stations | 0.0% | 3.7% | 7.3% | 1.4% |
| | **Total rural villages** | **59%** | **81%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 1,377 | 476 | 328 |
| Grid demand of newly connected villages (GWh/year) | 103 | 17 | 21 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 1 | 800 |
| New diesel mini-grid | 5 | 617 |
| **Total** | **6** | **1,417** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

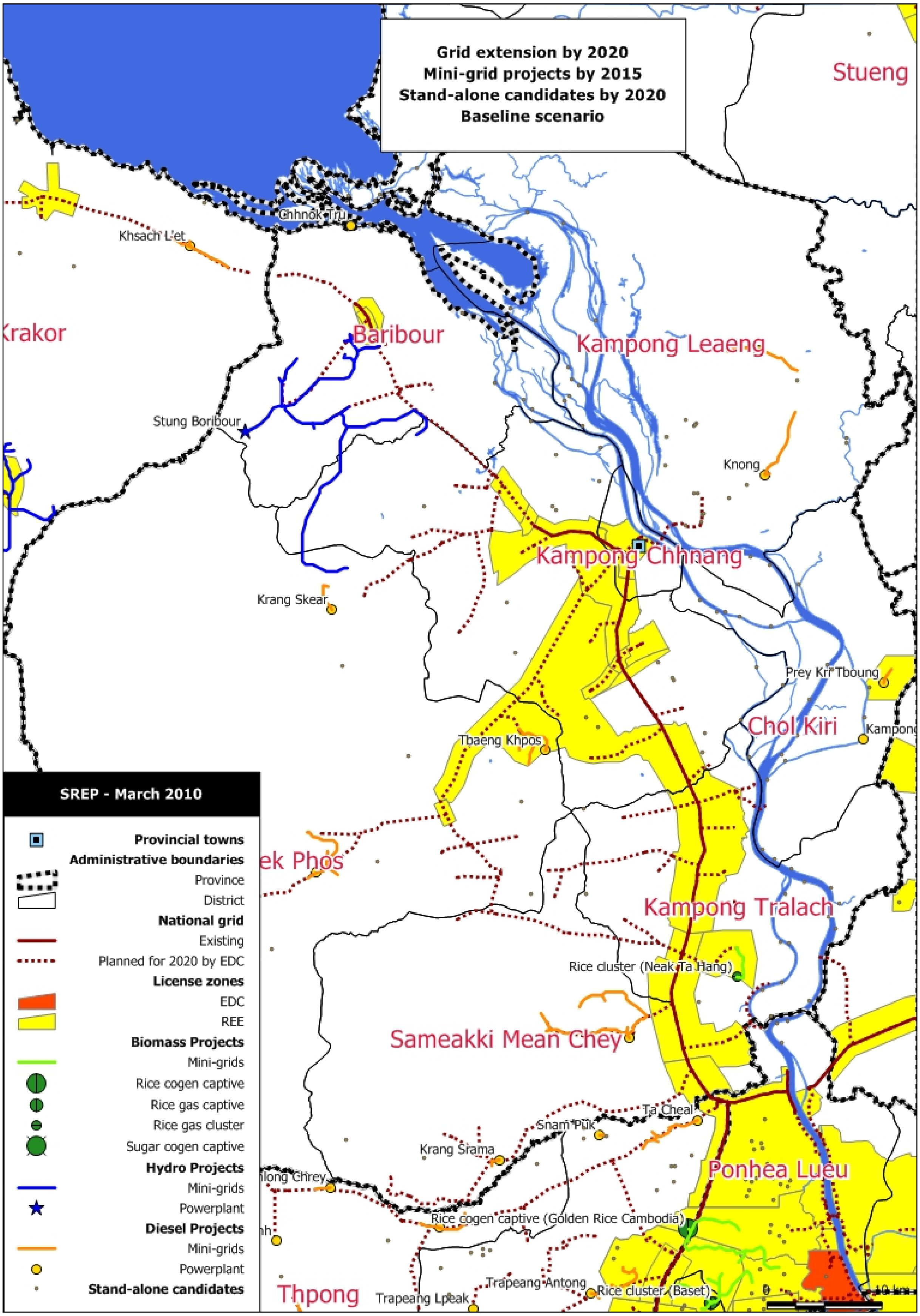
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 1,762 | 2,129 | 0 |
| Community PV (new villages) | 96 | 97 | 0 |
| Solar battery charging stations (new villages) | 62 | 49 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 27,533 | 9,519 | 6,560 |
| Distribution (transformers, LV, meters) | 35,840 | 18,700 | 21,770 |
| **Subtotal grid extension** | **63,373** | **28,219** | **28,330** |
| Hydro mini-grid | 1,031 | 0 | 0 |
| Biomass mini-grid | 998 | 49 | 14 |
| New diesel mini-grid | 661 | 19 | 5 |
| **Subtotal mini-grid projects** | **2,689** | **69** | **19** |
| Solar home systems | 705 | 852 | 0 |
| Community PV | 186 | 186 | 0 |
| Solar battery charging stations | 1,119 | 1,136 | 0 |
| **Subtotal stand-alone systems** | **2,009** | **2,173** | **0** |
| **Total** | **68,071** | **30,461** | **28,349** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.6 KAMPONG CHHNANG



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 3.4% | 18.8% | 39.1% | 66.0% |
| | Hydro mini-grid | 0.0% | 1.6% | 0.6% | 0.1% |
| | Biomass mini-grid | 0.0% | 0.3% | 0.2% | 0.0% |
| | Existing diesel mini-grid | 2.5% | 1.4% | 0.8% | 0.0% |
| | New diesel mini-grid | 0.0% | 5.1% | 5.0% | 0.0% |
| | Solar home systems | 0.0% | 0.9% | 1.9% | 0.1% |
| | **Total rural connections** | **6%** | **28%** | **48%** | **66%** |
| Village coverage | National grid | 8.7% | 37.5% | 74.3% | 98.1% |
| | Hydro mini-grid | 0.0% | 4.3% | 0.9% | 0.2% |
| | Biomass mini-grid | 0.0% | 0.8% | 0.2% | 0.0% |
| | Existing diesel mini-grid | 8.5% | 4.5% | 1.7% | 0.0% |
| | New diesel mini-grid | 0.0% | 8.1% | 4.2% | 0.0% |
| | Existing battery charging stations | 43.8% | 21.1% | 11.3% | 1.3% |
| | Solar battery charging stations | 0.0% | 3.7% | 7.4% | 0.4% |
| | **Total rural villages** | **61%** | **80%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 230 | 273 | 324 |
| Grid demand of newly connected villages (GWh/year) | 12 | 12 | 17 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 1 | 815 |
| Biomass mini-grid | 1 | 191 |
| New diesel mini-grid | 10 | 2,342 |
| **Total** | **12** | **3,348** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

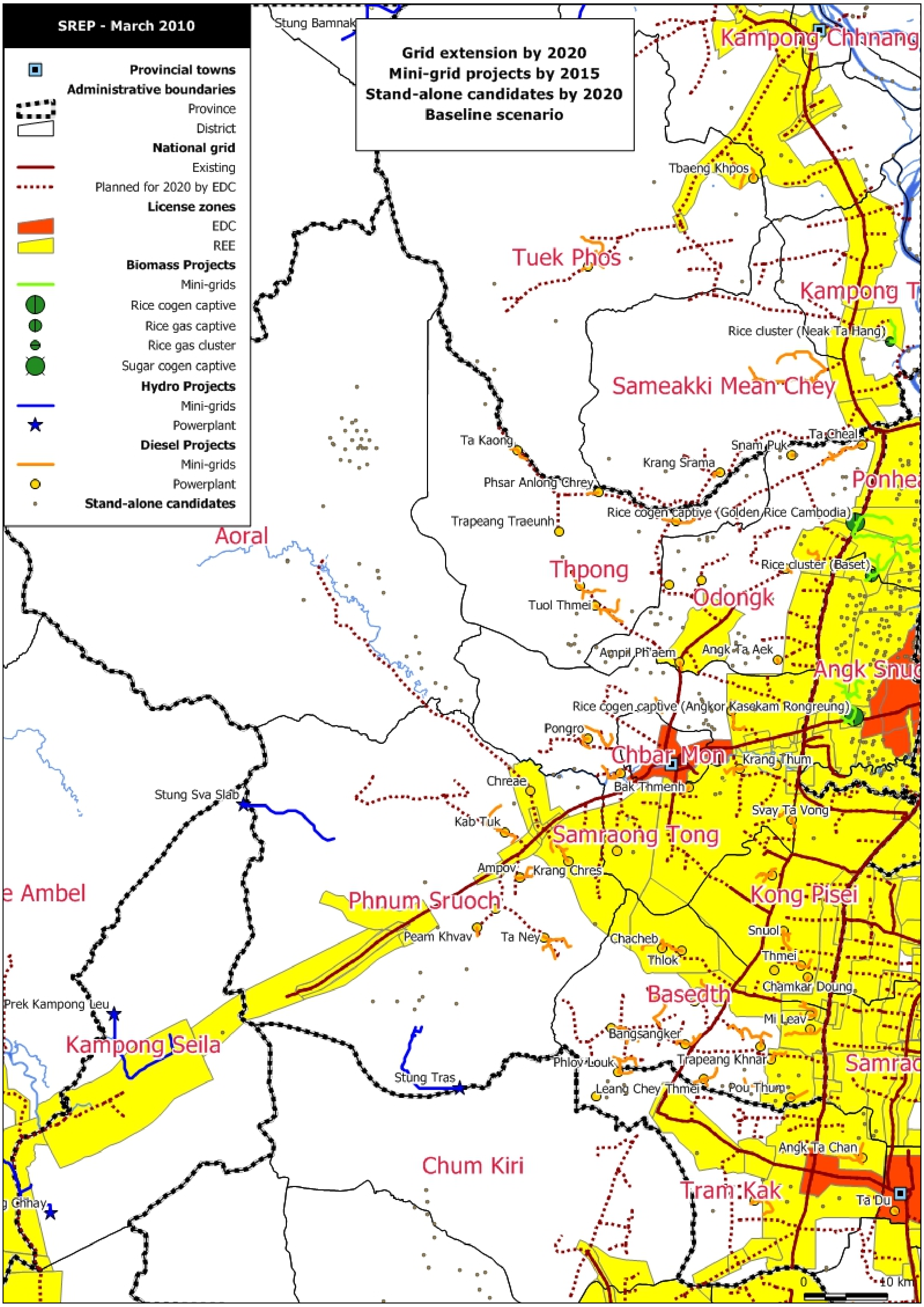
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 872 | 1,080 | 0 |
| Community PV (new villages) | 50 | 49 | 0 |
| Solar battery charging stations (new villages) | 20 | 16 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 4,610 | 5,468 | 6,478 |
| Distribution (transformers, LV, meters) | 5,414 | 6,709 | 12,191 |
| **Subtotal grid extension** | **10,024** | **12,177** | **18,669** |
| Hydro mini-grid | 3,054 | 52 | 13 |
| Biomass mini-grid | 262 | 14 | 1 |
| New diesel mini-grid | 2,344 | 297 | 17 |
| **Subtotal mini-grid projects** | **5,660** | **363** | **30** |
| Solar home systems | 349 | 432 | 0 |
| Community PV | 134 | 134 | 0 |
| Solar battery charging stations | 377 | 384 | 0 |
| **Subtotal stand-alone systems** | **860** | **950** | **0** |
| **Total** | **16,543** | **13,489** | **18,700** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.7 KAMPONG SPEU



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 3.2% | 9.0% | 41.8% | 66.1% |
| | Hydro mini-grid | 0.0% | 0.7% | 1.1% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 0.3% | 0.7% | 0.3% | 0.1% |
| | New diesel mini-grid | 0.0% | 7.6% | 1.5% | 0.0% |
| | Solar home systems | 0.0% | 0.5% | 1.1% | 0.4% |
| | **Total rural connections** | **4%** | **19%** | **46%** | **67%** |
| Village coverage | National grid | 6.0% | 13.9% | 85.7% | 95.7% |
| | Hydro mini-grid | 0.0% | 0.7% | 0.7% | 0.1% |
| | Biomass mini-grid | 0.0% | 0.1% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 2.4% | 2.3% | 0.5% | 0.1% |
| | New diesel mini-grid | 0.0% | 17.2% | 2.1% | 0.0% |
| | Existing battery charging stations | 28.6% | 17.6% | 3.1% | 1.1% |
| | Solar battery charging stations | 0.0% | 3.9% | 7.8% | 3.1% |
| | **Total rural villages** | **37%** | **56%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 94 | 1,043 | 186 |
| Grid demand of newly connected villages (GWh/year) | 6 | 37 | 10 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 1 | 241 |
| Biomass mini-grid | 1 | 650 |
| New diesel mini-grid | 48 | 5,369 |
| **Total** | **50** | **6,261** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

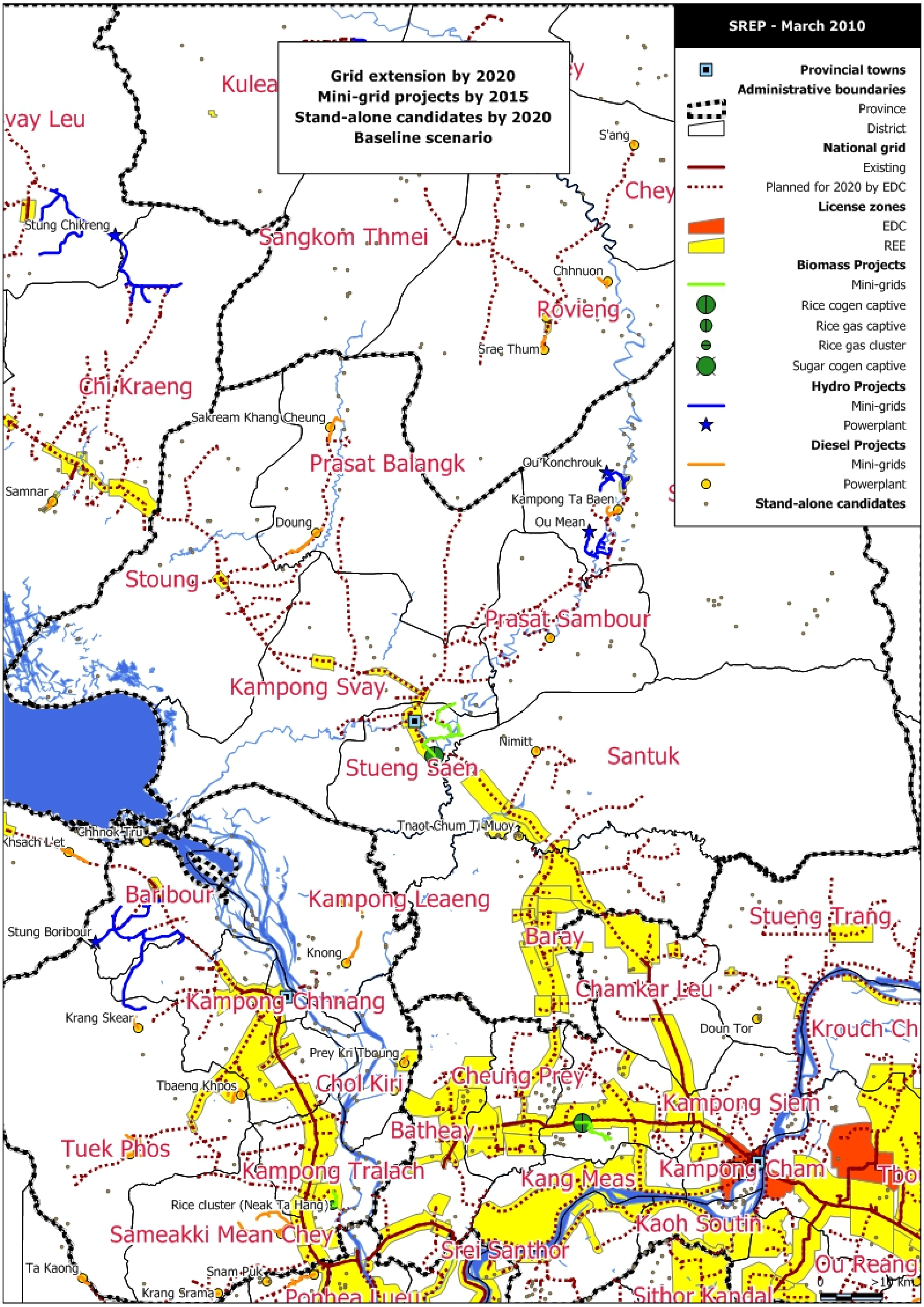
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 742 | 937 | 0 |
| Community PV (new villages) | 70 | 71 | 0 |
| Solar battery charging stations (new villages) | 51 | 40 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 1,889 | 20,862 | 3,725 |
| Distribution (transformers, LV, meters) | 3,279 | 20,874 | 12,390 |
| **Subtotal grid extension** | **5,168** | **41,736** | **16,116** |
| Hydro mini-grid | 1,570 | 97 | 24 |
| Biomass mini-grid | 59 | 0 | 0 |
| New diesel mini-grid | 6,336 | 325 | 43 |
| **Subtotal mini-grid projects** | **7,966** | **422** | **67** |
| Solar home systems | 297 | 375 | 45 |
| Community PV | 109 | 109 | 0 |
| Solar battery charging stations | 699 | 712 | 0 |
| **Subtotal stand-alone systems** | **1,105** | **1,196** | **45** |
| **Total** | **14,238** | **43,354** | **16,227** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.8 Kampong Thom



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 0.0% | 26.0% | 46.6% | 66.1% |
| | Hydro mini-grid | 0.0% | 1.2% | 0.5% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.4% | 0.4% | 0.0% |
| | Existing diesel mini-grid | 6.6% | 1.1% | 0.7% | 0.7% |
| | New diesel mini-grid | 0.0% | 1.3% | 0.2% | 0.0% |
| | Solar home systems | 0.0% | 0.6% | 1.2% | 0.4% |
| | **Total rural connections** | **7%** | **31%** | **50%** | **67%** |
| Village coverage | National grid | 0.0% | 50.5% | 82.4% | 94.0% |
| | Hydro mini-grid | 0.0% | 3.2% | 1.1% | 0.0% |
| | Biomass mini-grid | 0.0% | 1.4% | 0.6% | 0.0% |
| | Existing diesel mini-grid | 17.3% | 3.9% | 1.5% | 1.0% |
| | New diesel mini-grid | 0.0% | 3.4% | 0.4% | 0.0% |
| | Existing battery charging stations | 30.5% | 10.6% | 4.9% | 1.7% |
| | Solar battery charging stations | 0.0% | 4.5% | 9.1% | 3.4% |
| | **Total rural villages** | **48%** | **78%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 565 | 314 | 199 |
| Grid demand of newly connected villages (GWh/year) | 36 | 13 | 9 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 2 | 400 |
| Biomass mini-grid | 1 | 700 |
| New diesel mini-grid | 6 | 810 |
| **Total** | **9** | **1,910** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

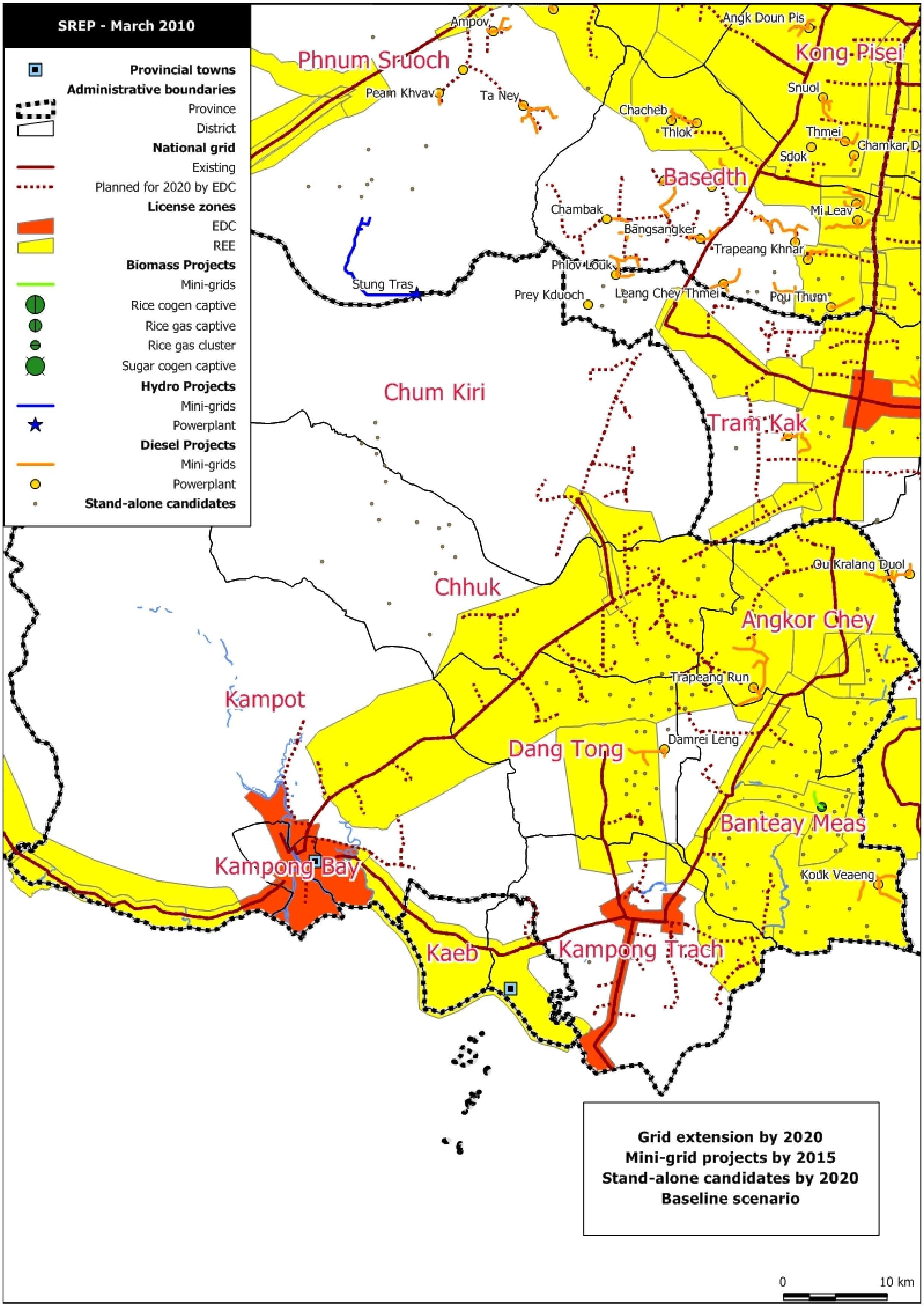
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 813 | 1,006 | 0 |
| Community PV (new villages) | 50 | 50 | 0 |
| Solar battery charging stations (new villages) | 33 | 26 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 11,299 | 6,279 | 3,987 |
| Distribution (transformers, LV, meters) | 13,395 | 9,058 | 9,669 |
| **Subtotal grid extension** | **24,694** | **15,337** | **13,656** |
| Hydro mini-grid | 2,074 | 100 | 11 |
| Biomass mini-grid | 1,107 | 34 | 5 |
| New diesel mini-grid | 851 | 47 | 2 |
| **Subtotal mini-grid projects** | **4,031** | **181** | **17** |
| Solar home systems | 325 | 402 | 3 |
| Community PV | 129 | 129 | 0 |
| Solar battery charging stations | 635 | 646 | 0 |
| **Subtotal stand-alone systems** | **1,089** | **1,177** | **3** |
| **Total** | **29,815** | **16,695** | **13,676** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.9 Kampot



SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
Phnum Sruoch
Kong Pisei
Basedth
Chum Kiri
Tram Kak
Chhuk
Angkor Chey
Kampot
Dang Tong
Banteay Meas
Kampong Bay
Kaeb
Kampong Trach
Stung Tras
Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
0
10 km

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 6.2% | 33.9% | 46.0% | 67.7% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.2% | 0.3% | 0.0% |
| | Existing diesel mini-grid | 0.9% | 0.3% | 0.4% | 0.0% |
| | New diesel mini-grid | 0.0% | 1.7% | 2.3% | 0.0% |
| | Solar home systems | 0.0% | 1.3% | 2.6% | 0.0% |
| | **Total rural connections** | **7%** | **37%** | **52%** | **68%** |
| Village coverage | National grid | 15.3% | 66.0% | 68.6% | 99.8% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.7% | 0.7% | 0.0% |
| | Existing diesel mini-grid | 3.7% | 1.3% | 1.1% | 0.0% |
| | New diesel mini-grid | 0.0% | 4.4% | 4.4% | 0.0% |
| | Existing battery charging stations | 42.3% | 14.2% | 13.3% | 0.0% |
| | Solar battery charging stations | 0.0% | 6.0% | 12.0% | 0.2% |
| | **Total rural villages** | **61%** | **92%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 403 | 7 | 281 |
| Grid demand of newly connected villages (GWh/year) | 31 | 0 | 19 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 1 | 158 |
| New diesel mini-grid | 3 | 829 |
| **Total** | **4** | **987** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

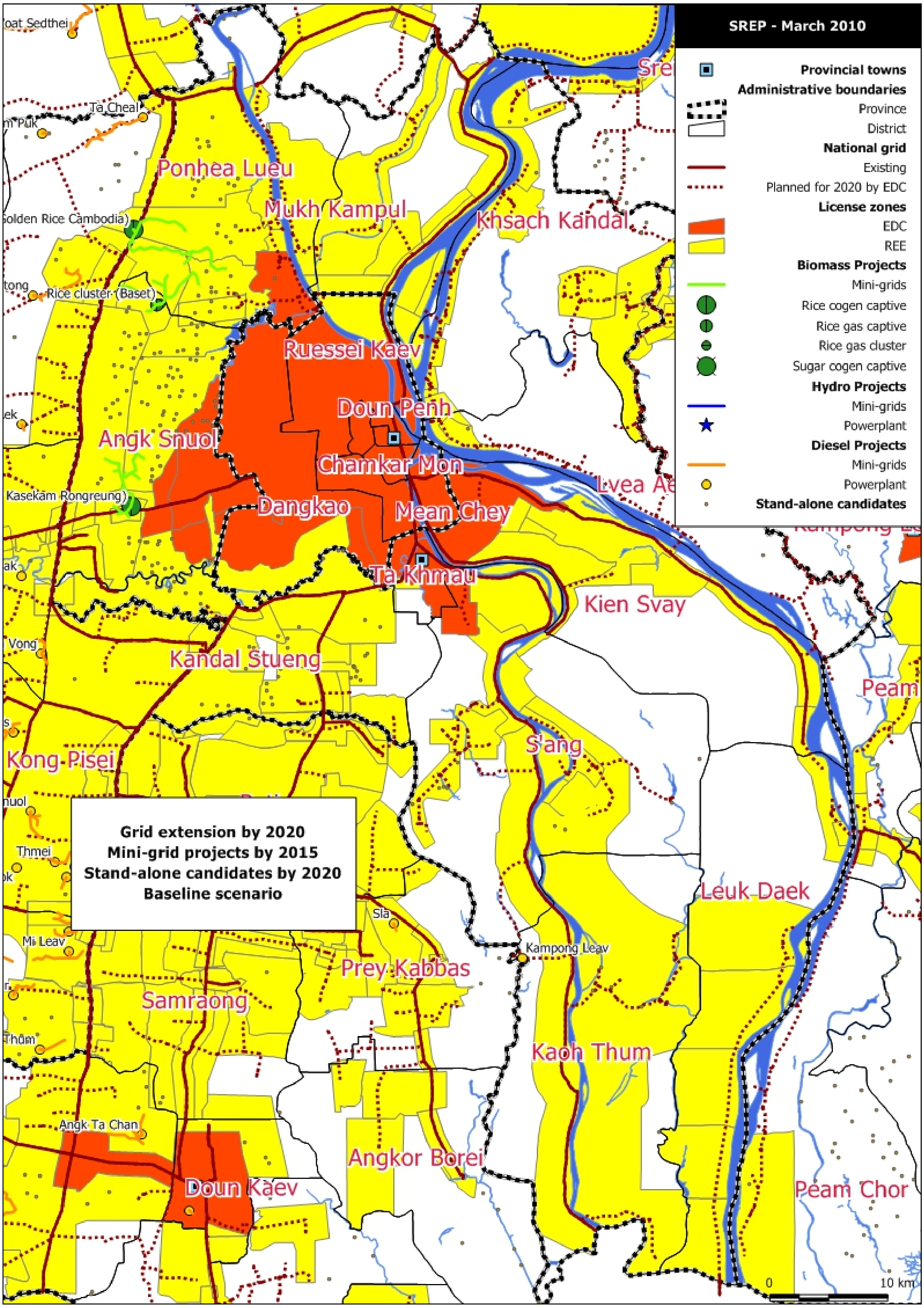
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 1,582 | 1,908 | 0 |
| Community PV (new villages) | 58 | 58 | 0 |
| Solar battery charging stations (new villages) | 28 | 22 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 8,053 | 143 | 5,629 |
| Distribution (transformers, LV, meters) | 10,778 | 3,850 | 12,884 |
| **Subtotal grid extension** | **18,831** | **3,992** | **18,513** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 237 | 22 | 3 |
| New diesel mini-grid | 947 | 152 | 26 |
| **Subtotal mini-grid projects** | **1,184** | **173** | **29** |
| Solar home systems | 633 | 763 | 0 |
| Community PV | 124 | 124 | 0 |
| Solar battery charging stations | 854 | 870 | 0 |
| **Subtotal stand-alone systems** | **1,611** | **1,757** | **0** |
| **Total** | **21,626** | **5,923** | **18,542** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.10 Kandal


SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
Ponhea Lueu
Mukh Kampul
Khsach Kandal
Ruessei Kaev
Doun Penh
Angk Snuol
Chamkar Mon
Dangkao
Mean Chey
Lvea Ae
Ta Khmau
Kien Svay
Kandal Stueng
Peam
S'ang
Kong Pisei
Leuk Daek
Prey Kabbas
Samraong
Kaoh Thum
Angkor Borei
Doun Kaev
Peam Chor
Ta Cheal
Golden Rice Cambodia)
Rice cluster (Baset)
Kasekam Rongreung)
Thmei
Sla
Mi Leav
Kampong Leav
Angk Ta Chan
0
10 km

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 19.6% | 45.5% | 55.6% | 68.1% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.5% | 0.6% | 0.0% |
| | Existing diesel mini-grid | 7.0% | 1.2% | 1.5% | 0.0% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.6% | 1.2% | 0.0% |
| | **Total rural connections** | **27%** | **48%** | **59%** | **68%** |
| Village coverage | National grid | 24.5% | 59.2% | 68.9% | 97.5% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 4.4% | 3.2% | 0.3% |
| | Existing diesel mini-grid | 15.8% | 5.6% | 5.6% | 0.1% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing battery charging stations | 27.4% | 9.4% | 7.6% | 0.0% |
| | Solar battery charging stations | 0.0% | 7.3% | 14.7% | 2.1% |
| | **Total rural villages** | **68%** | **86%** | **100%** | **100%** |

Coverage rates achieved in rural areas under the baseline scenario (percentage)

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 495 | 65 | 278 |
| Grid demand of newly connected villages (GWh/year) | 61 | 2 | 21 |

Grid extension figures in rural areas under the baseline scenario

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 3 | 1,045 |
| New diesel mini-grid | 0 | 0 |
| **Total** | **3** | **1,045** |

Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)

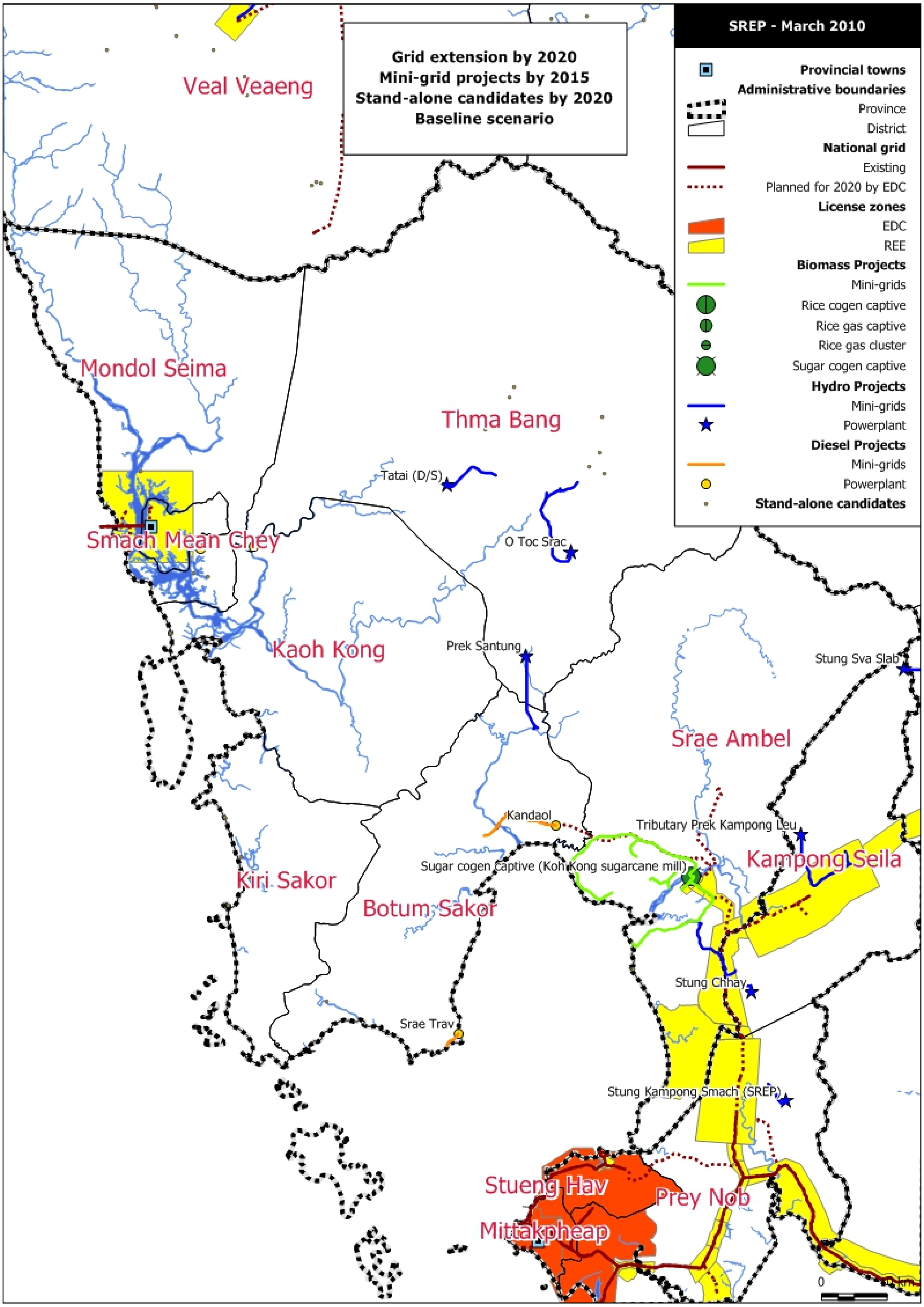
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 1,402 | 1,701 | 0 |
| Community PV (new villages) | 110 | 109 | 0 |
| Solar battery charging stations (new villages) | 72 | 58 | 0 |

Stand-alone systems in rural areas under the baseline scenario

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 9,906 | 1,295 | 5,556 |
| Distribution (transformers, LV, meters) | 17,885 | 7,156 | 16,514 |
| **Subtotal grid extension** | **27,791** | **8,450** | **22,070** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 2,142 | 97 | 39 |
| New diesel mini-grid | 0 | 0 | 0 |
| **Subtotal mini-grid projects** | **2,142** | **97** | **39** |
| Solar home systems | 561 | 680 | 0 |
| Community PV | 154 | 154 | 0 |
| Solar battery charging stations | 933 | 950 | 0 |
| **Subtotal stand-alone systems** | **1,648** | **1,785** | **0** |
| **Total** | **31,581** | **10,332** | **22,109** |

Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)

## 6.11 Koh Kong


Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
Veal Veaeng
Mondol Seima
Thma Bang
Tatai (D/S)
O Toc Srac
Smach Mean Chey
Kaoh Kong
Prek Santung
Stung Sva Slab
Srae Ambel
Kandaol
Tributary Prek Kampong Leu
Kampong Seila
Sugar cogen captive (Koh Kong sugarcane mill)
Kiri Sakor
Botum Sakor
Stung Chhay
Srae Trav
Stung Kampong Smach (SREP)
Stueng Hav
Prey Nob
Mittakpheap
0

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 4.4% | 22.5% | 30.6% | 49.6% |
| | Hydro mini-grid | 0.0% | 2.7% | 3.9% | 3.3% |
| | Biomass mini-grid | 0.0% | 4.2% | 3.6% | 0.6% |
| | Existing diesel mini-grid | 27.4% | 15.4% | 17.1% | 10.9% |
| | New diesel mini-grid | 0.0% | 2.0% | 1.5% | 0.9% |
| | Solar home systems | 0.0% | 0.4% | 0.9% | 0.9% |
| | **Total rural connections** | **32%** | **47%** | **58%** | **66%** |
| Village coverage | National grid | 0.9% | 17.8% | 28.0% | 50.5% |
| | Hydro mini-grid | 0.0% | 12.1% | 12.1% | 9.3% |
| | Biomass mini-grid | 0.0% | 14.0% | 9.3% | 1.9% |
| | Existing diesel mini-grid | 57.9% | 33.6% | 30.8% | 21.5% |
| | New diesel mini-grid | 0.0% | 6.5% | 3.7% | 1.9% |
| | Existing battery charging stations | 12.1% | 2.8% | 2.8% | 2.8% |
| | Solar battery charging stations | 0.0% | 6.5% | 13.1% | 12.1% |
| | **Total rural villages** | **71%** | **93%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 30 | 37 | 95 |
| Grid demand of newly connected villages (GWh/year) | 4 | 2 | 5 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 3 | 203 |
| Biomass mini-grid | 1 | 750 |
| New diesel mini-grid | 4 | 316 |
| **Total** | **8** | **1,269** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

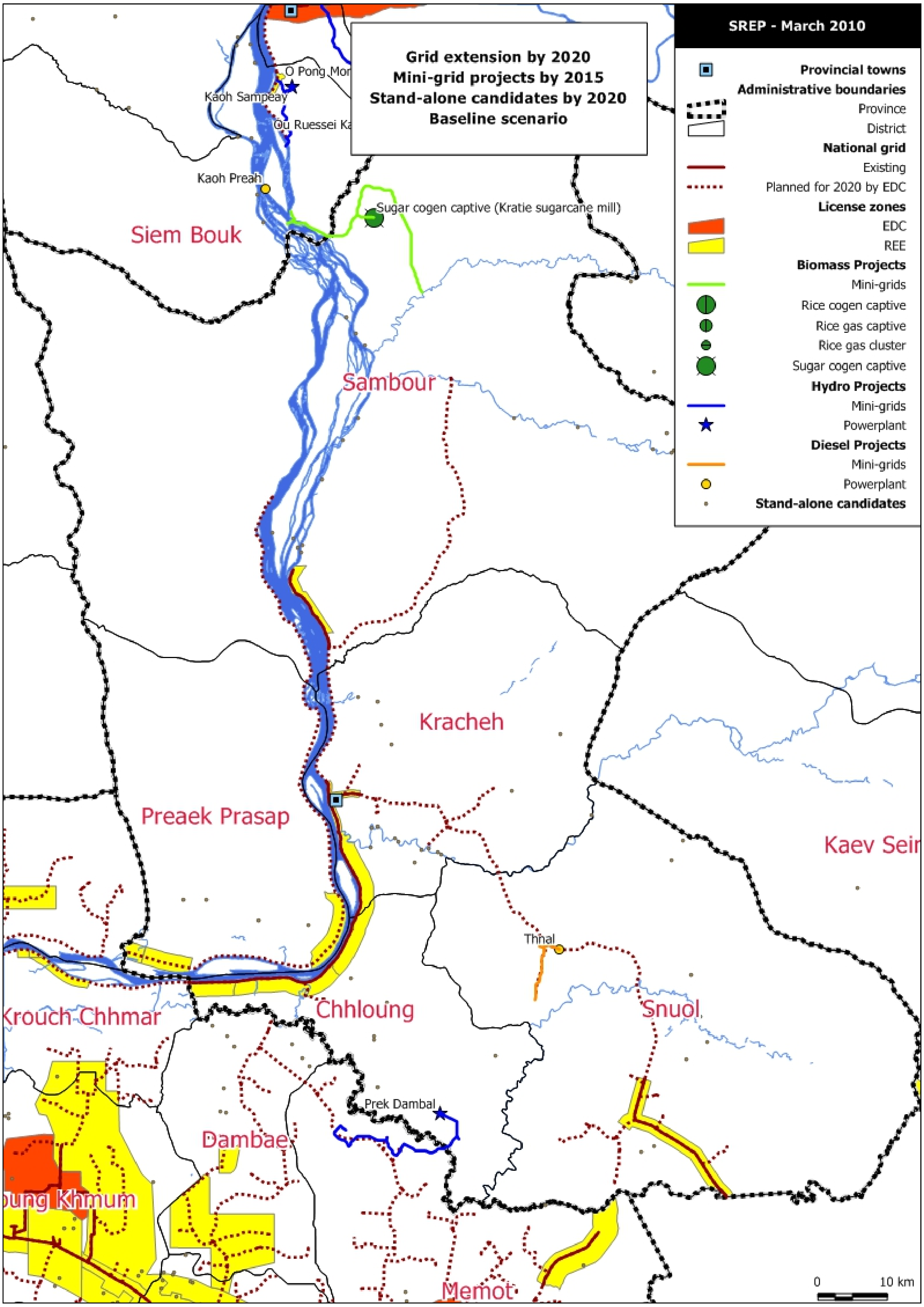
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 82 | 101 | 29 |
| Community PV (new villages) | 8 | 9 | 0 |
| Solar battery charging stations (new villages) | 7 | 6 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 594 | 744 | 1,905 |
| Distribution (transformers, LV, meters) | 905 | 554 | 1,903 |
| **Subtotal grid extension** | **1,499** | **1,298** | **3,809** |
| Hydro mini-grid | 1,925 | 47 | 31 |
| Biomass mini-grid | 2,147 | 45 | 26 |
| New diesel mini-grid | 291 | 25 | 7 |
| **Subtotal mini-grid projects** | **4,362** | **117** | **64** |
| Solar home systems | 33 | 40 | 18 |
| Community PV | 19 | 19 | 0 |
| Solar battery charging stations | 76 | 77 | 0 |
| **Subtotal stand-alone systems** | **128** | **136** | **18** |
| **Total** | **5,989** | **1,552** | **3,890** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.12 KRACHEH


Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
O Pong Mor
Kaoh Sampeay
Ou Ruessei Ka
Kaoh Preah
Sugar cogen captive (Kratie sugarcane mill)
Siem Bouk
Sambour
Kracheh
Preaek Prasap
Kaev Seir
Thnal
Krouch Chhmar
Chhloung
Snuol
Prek Dambal
Dambae
Memot
0
10 km

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 4.8% | 34.2% | 49.2% | 64.9% |
| | Hydro mini-grid | 0.0% | 0.1% | 0.2% | 0.2% |
| | Biomass mini-grid | 0.0% | 0.3% | 0.5% | 0.0% |
| | Existing diesel mini-grid | 2.9% | 1.3% | 1.8% | 0.7% |
| | New diesel mini-grid | 0.0% | 1.0% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.7% | 1.5% | 0.5% |
| | **Total rural connections** | **8%** | **38%** | **53%** | **66%** |
| Village coverage | National grid | 9.5% | 63.6% | 72.3% | 90.5% |
| | Hydro mini-grid | 0.0% | 0.4% | 0.4% | 0.4% |
| | Biomass mini-grid | 0.0% | 0.4% | 0.4% | 0.0% |
| | Existing diesel mini-grid | 12.6% | 5.2% | 3.9% | 0.9% |
| | New diesel mini-grid | 0.0% | 2.6% | 0.0% | 0.0% |
| | Existing battery charging stations | 43.7% | 13.0% | 10.4% | 3.0% |
| | Solar battery charging stations | 0.0% | 6.3% | 12.6% | 5.2% |
| | **Total rural villages** | **66%** | **92%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 262 | 79 | 192 |
| Grid demand of newly connected villages (GWh/year) | 20 | 3 | 7 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 1 | 200 |
| Biomass mini-grid | 1 | 300 |
| New diesel mini-grid | 1 | 307 |
| **Total** | **3** | **807** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

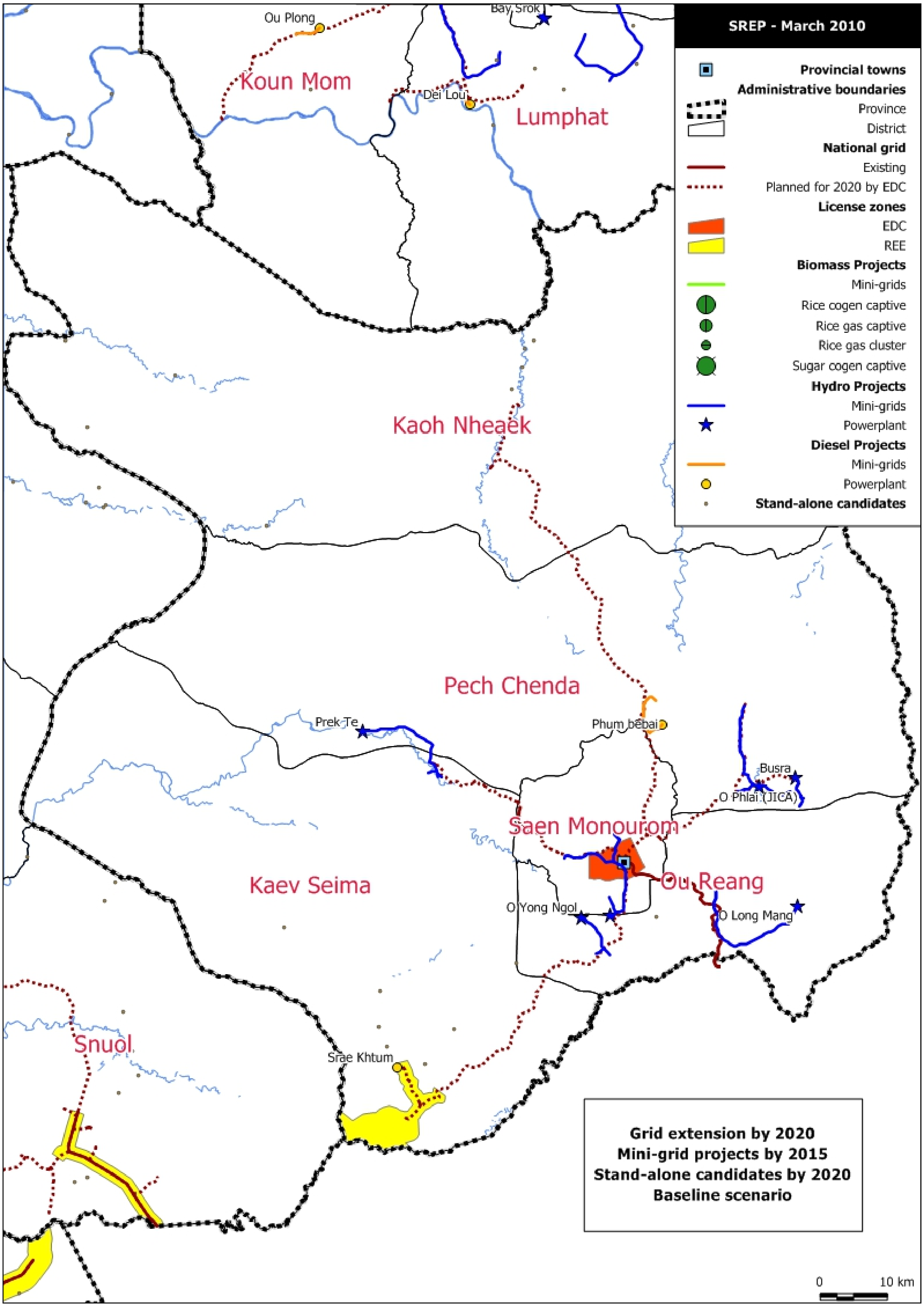
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 430 | 548 | 0 |
| Community PV (new villages) | 26 | 27 | 0 |
| Solar battery charging stations (new villages) | 15 | 12 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 5,237 | 1,574 | 3,846 |
| Distribution (transformers, LV, meters) | 5,855 | 2,802 | 5,330 |
| **Subtotal grid extension** | **11,092** | **4,376** | **9,176** |
| Hydro mini-grid | 172 | 7 | 4 |
| Biomass mini-grid | 199 | 20 | 4 |
| New diesel mini-grid | 345 | 53 | 0 |
| **Subtotal mini-grid projects** | **715** | **79** | **8** |
| Solar home systems | 172 | 219 | 3 |
| Community PV | 84 | 84 | 0 |
| Solar battery charging stations | 270 | 276 | 0 |
| **Subtotal stand-alone systems** | **526** | **579** | **3** |
| **Total** | **12,333** | **5,034** | **9,187** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.13 MONDUL KIRI



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 6.6% | 7.1% | 38.3% | 57.4% |
| | Hydro mini-grid | 0.0% | 12.9% | 2.5% | 0.5% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 16.9% | 15.3% | 9.5% | 5.2% |
| | New diesel mini-grid | 0.0% | 1.8% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.5% | 1.0% | 1.2% |
| | **Total rural connections** | **23%** | **38%** | **51%** | **64%** |
| Village coverage | National grid | 10.1% | 10.1% | 65.2% | 71.9% |
| | Hydro mini-grid | 0.0% | 32.6% | 4.5% | 1.1% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 43.8% | 23.6% | 13.5% | 10.1% |
| | New diesel mini-grid | 0.0% | 3.4% | 0.0% | 0.0% |
| | Existing battery charging stations | 25.8% | 16.9% | 9.0% | 9.0% |
| | Solar battery charging stations | 0.0% | 3.9% | 7.9% | 7.9% |
| | **Total rural villages** | **80%** | **90%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 0 | 253 | 26 |
| Grid demand of newly connected villages (GWh/year) | 0 | 4 | 2 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 6 | 981 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 2 | 134 |
| **Total** | **8** | **1,115** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

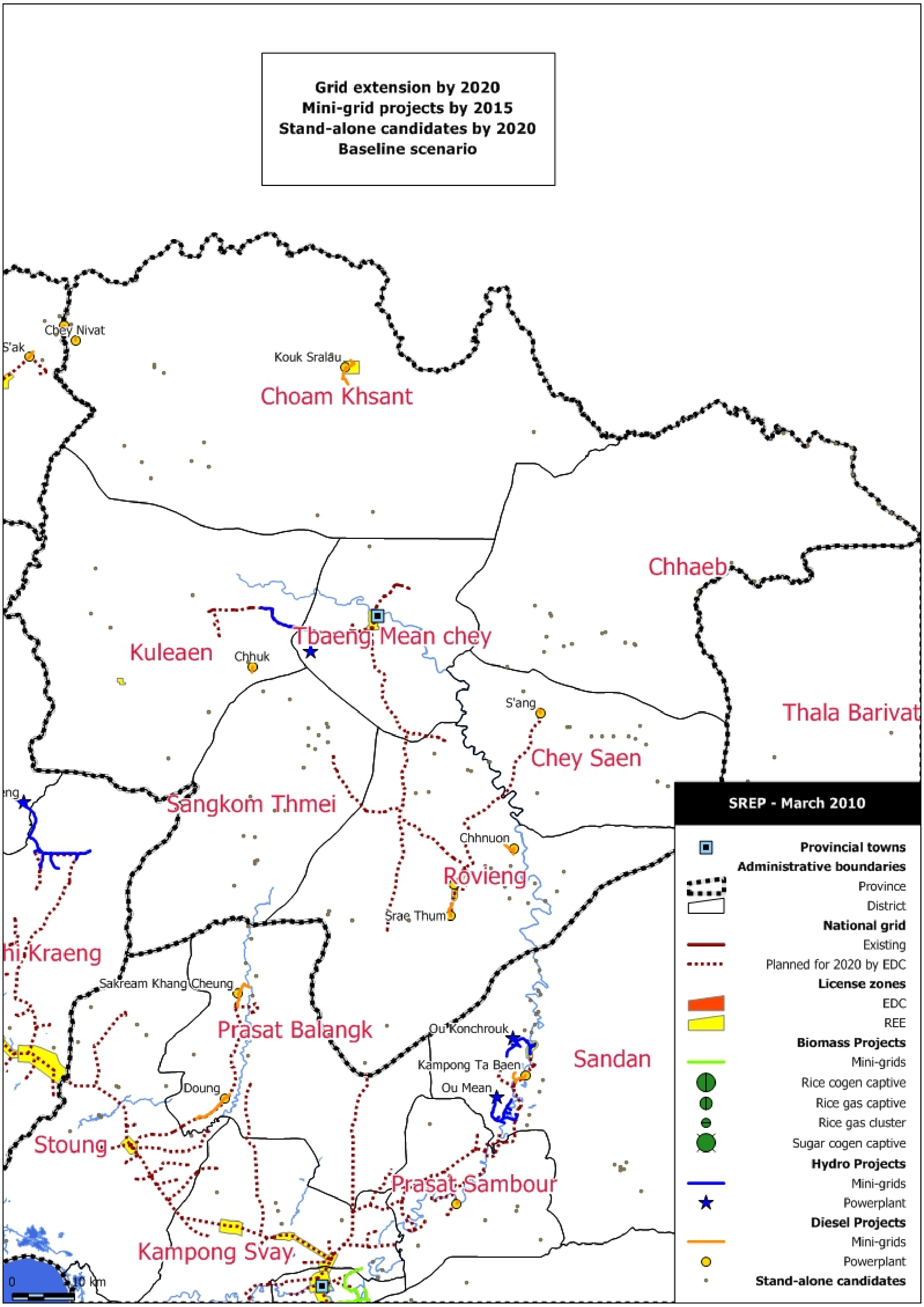
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 66 | 92 | 79 |
| Community PV (new villages) | 8 | 7 | 0 |
| Solar battery charging stations (new villages) | 4 | 3 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 0 | 5,052 | 519 |
| Distribution (transformers, LV, meters) | 30 | 2,633 | 1,244 |
| **Subtotal grid extension** | **30** | **7,685** | **1,763** |
| Hydro mini-grid | 4,931 | 118 | 11 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 220 | 7 | 0 |
| **Subtotal mini-grid projects** | **5,150** | **125** | **11** |
| Solar home systems | 26 | 37 | 32 |
| Community PV | 25 | 25 | 0 |
| Solar battery charging stations | 45 | 46 | 0 |
| **Subtotal stand-alone systems** | **96** | **108** | **32** |
| **Total** | **5,276** | **7,918** | **1,806** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.14 Preah Vihear



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 0.0% | 1.6% | 17.9% | 35.8% |
| | Hydro mini-grid | 0.0% | 0.8% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 4.5% | 6.7% | 5.4% | 6.9% |
| | New diesel mini-grid | 0.0% | 3.5% | 3.2% | 3.0% |
| | Solar home systems | 0.0% | 1.9% | 4.2% | 3.5% |
| | **Total rural connections** | **4%** | **14%** | **31%** | **49%** |
| Village coverage | National grid | 0.0% | 2.5% | 37.9% | 51.5% |
| | Hydro mini-grid | 0.0% | 1.5% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 8.6% | 7.6% | 3.5% | 3.5% |
| | New diesel mini-grid | 0.0% | 8.6% | 6.1% | 4.0% |
| | Existing battery charging stations | 42.9% | 38.4% | 29.3% | 21.2% |
| | Solar battery charging stations | 0.0% | 11.6% | 23.2% | 19.7% |
| | **Total rural villages** | **52%** | **70%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 11 | 223 | 90 |
| Grid demand of newly connected villages (GWh/year) | 0 | 6 | 3 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 1 | 73 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 8 | 807 |
| **Total** | **9** | **880** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

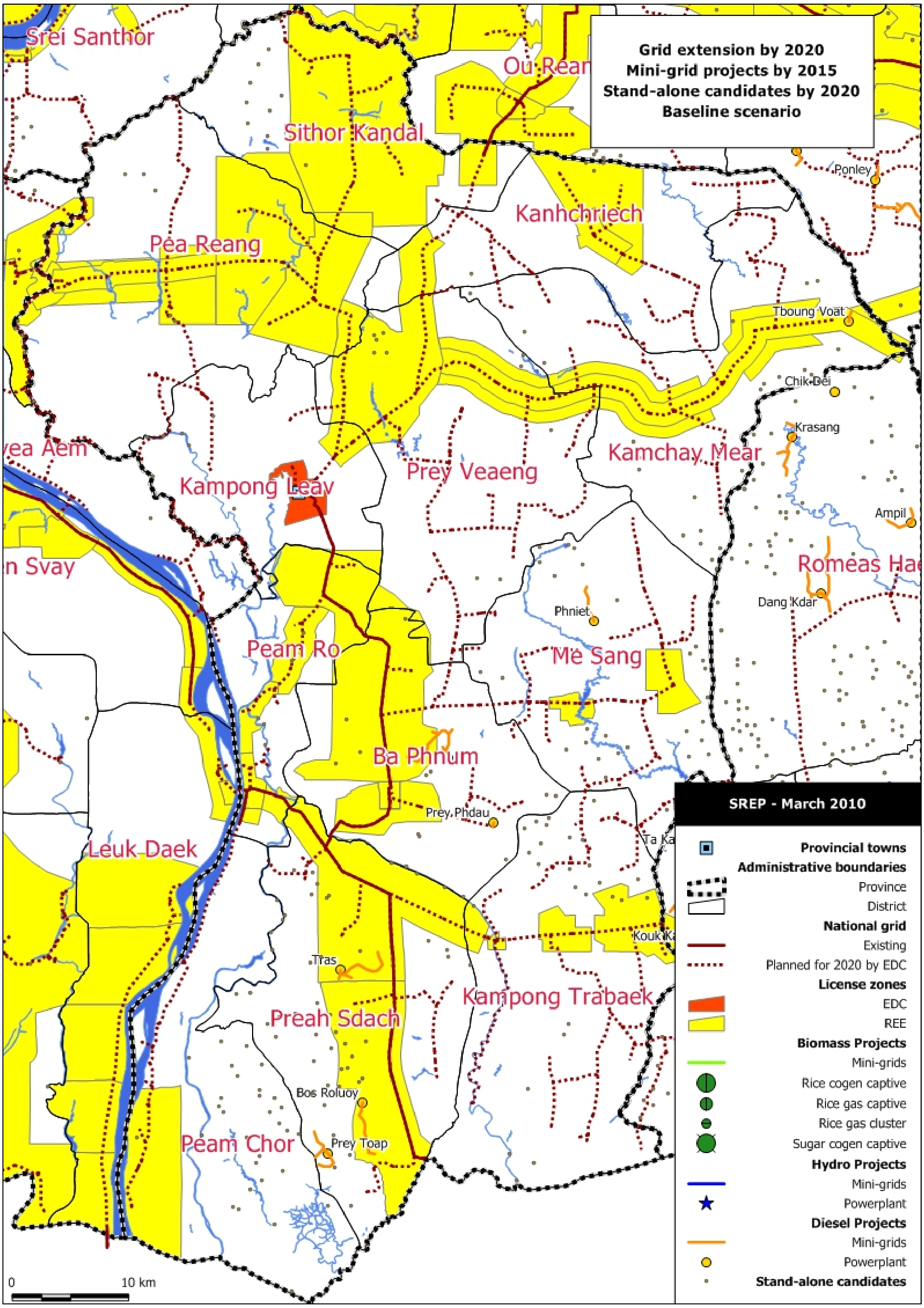
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 716 | 961 | 0 |
| Community PV (new villages) | 52 | 52 | 0 |
| Solar battery charging stations (new villages) | 23 | 18 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 220 | 4,467 | 1,801 |
| Distribution (transformers, LV, meters) | 221 | 2,905 | 3,386 |
| **Subtotal grid extension** | **441** | **7,372** | **5,188** |
| Hydro mini-grid | 543 | 22 | 0 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 699 | 114 | 66 |
| **Subtotal mini-grid projects** | **1,242** | **135** | **66** |
| Solar home systems | 286 | 384 | 44 |
| Community PV | 182 | 182 | 0 |
| Solar battery charging stations | 390 | 400 | 0 |
| **Subtotal stand-alone systems** | **858** | **966** | **44** |
| **Total** | **2,541** | **8,474** | **5,298** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.15 Prey Veng



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 0.9% | 27.6% | 45.7% | 67.8% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 2.8% | 0.7% | 0.6% | 0.0% |
| | New diesel mini-grid | 0.0% | 1.2% | 1.2% | 0.0% |
| | Solar home systems | 0.0% | 0.9% | 2.0% | 0.0% |
| | **Total rural connections** | **4%** | **30%** | **50%** | **68%** |
| Village coverage | National grid | 1.7% | 49.1% | 77.4% | 99.5% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 6.5% | 2.1% | 1.0% | 0.0% |
| | New diesel mini-grid | 0.0% | 2.7% | 2.1% | 0.0% |
| | Existing battery charging stations | 49.8% | 18.4% | 9.2% | 0.2% |
| | Solar battery charging stations | 0.0% | 5.2% | 10.3% | 0.4% |
| | **Total rural villages** | **58%** | **77%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 898 | 333 | 407 |
| Grid demand of newly connected villages (GWh/year) | 55 | 15 | 27 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 7 | 1,141 |
| **Total** | **7** | **1,141** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

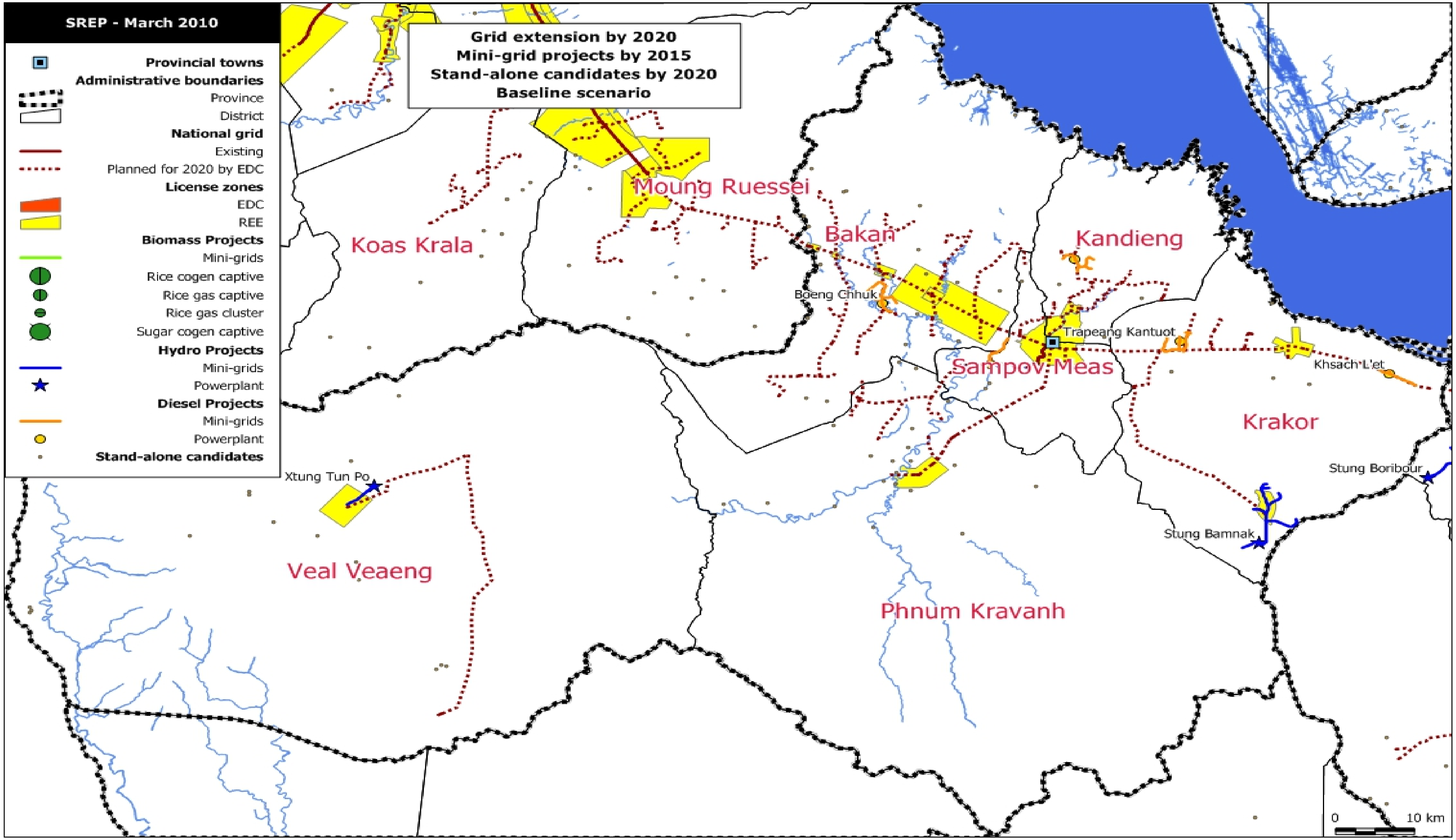
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 2,364 | 2,802 | 0 |
| Community PV (new villages) | 110 | 109 | 0 |
| Solar battery charging stations (new villages) | 58 | 46 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 17,963 | 6,658 | 8,142 |
| Distribution (transformers, LV, meters) | 21,859 | 13,458 | 21,801 |
| **Subtotal grid extension** | **39,822** | **20,116** | **29,943** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 1,208 | 180 | 29 |
| **Subtotal mini-grid projects** | **1,208** | **180** | **29** |
| Solar home systems | 946 | 1,121 | 0 |
| Community PV | 237 | 237 | 0 |
| Solar battery charging stations | 1,308 | 1,327 | 0 |
| **Subtotal stand-alone systems** | **2,491** | **2,685** | **0** |
| **Total** | **43,521** | **22,981** | **29,972** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.16 PURSAT


SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
Moung Ruessei
Koas Krala
Bakan
Kandieng
Boeng Chhuk
Trapeang Kantuot
Sampov Meas
Khsach L'et
Krakor
Stung Boribour
Stung Bamnak
Xtung Tun Po
Veal Veaeng
Phnum Kravanh
0
10 km

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 1.7% | 20.0% | 46.7% | 64.4% |
| | Hydro mini-grid | 0.0% | 1.2% | 1.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 8.2% | 4.9% | 0.3% | 0.4% |
| | New diesel mini-grid | 0.0% | 2.9% | 0.3% | 0.0% |
| | Solar home systems | 0.0% | 0.7% | 1.4% | 0.6% |
| | **Total rural connections** | **10%** | **30%** | **50%** | **65%** |
| Village coverage | National grid | 3.0% | 32.3% | 82.5% | 92.2% |
| | Hydro mini-grid | 0.0% | 1.5% | 1.1% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 21.2% | 13.9% | 0.6% | 0.6% |
| | New diesel mini-grid | 0.0% | 7.6% | 0.6% | 0.0% |
| | Existing battery charging stations | 37.2% | 20.6% | 8.7% | 4.1% |
| | Solar battery charging stations | 0.0% | 3.2% | 6.5% | 3.0% |
| | **Total rural villages** | **61%** | **79%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 295 | 330 | 124 |
| Grid demand of newly connected villages (GWh/year) | 13 | 14 | 4 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 2 | 449 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 5 | 971 |
| **Total** | **7** | **1,420** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

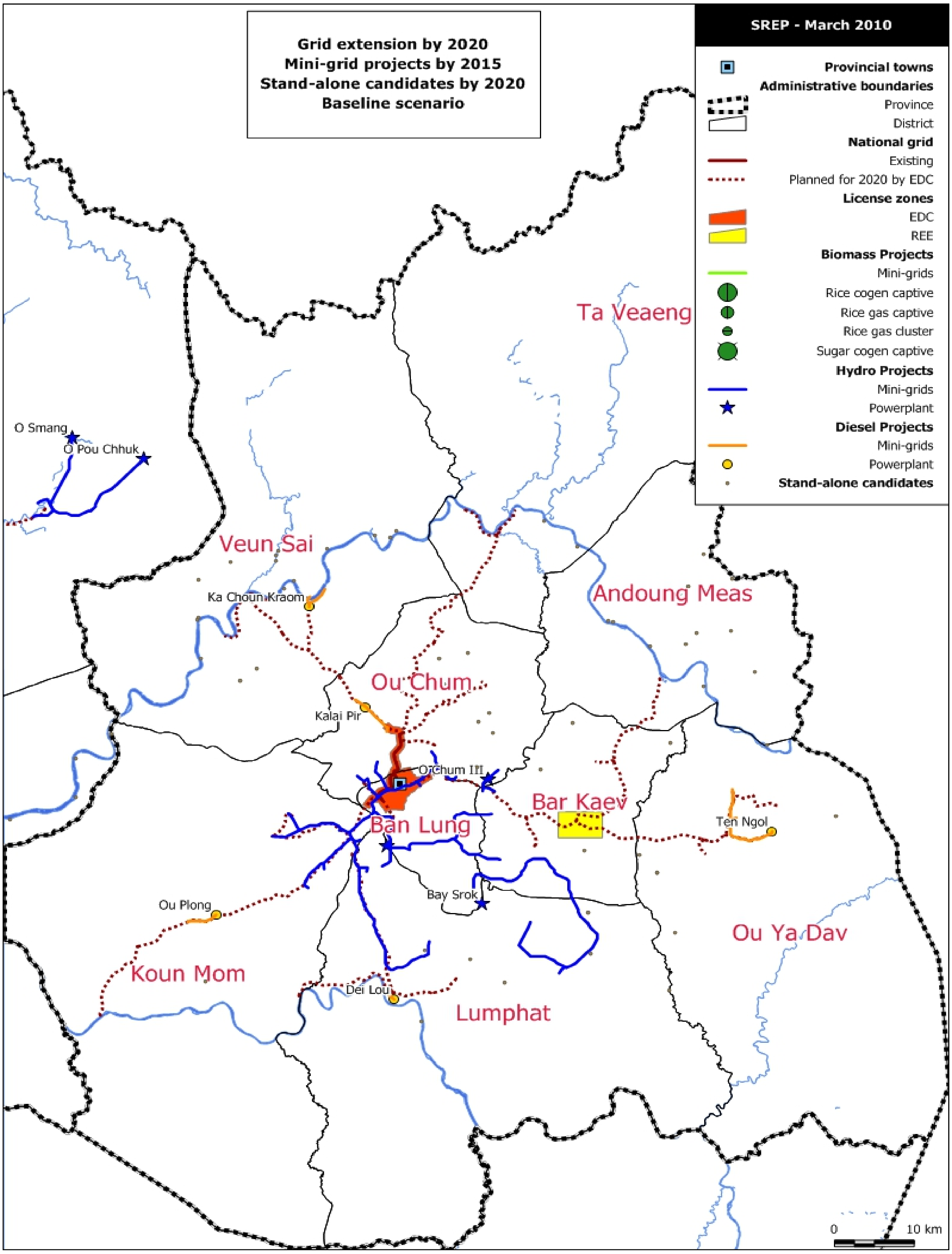
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 544 | 671 | 0 |
| Community PV (new villages) | 35 | 35 | 0 |
| Solar battery charging stations (new villages) | 15 | 12 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 5,902 | 6,606 | 2,490 |
| Distribution (transformers, LV, meters) | 5,220 | 7,026 | 5,262 |
| **Subtotal grid extension** | **11,122** | **13,632** | **7,751** |
| Hydro mini-grid | 1,860 | 49 | 8 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 1,245 | 52 | 5 |
| **Subtotal mini-grid projects** | **3,105** | **101** | **13** |
| Solar home systems | 218 | 268 | 1 |
| Community PV | 89 | 89 | 0 |
| Solar battery charging stations | 301 | 306 | 0 |
| **Subtotal stand-alone systems** | **608** | **664** | **1** |
| **Total** | **14,834** | **14,396** | **7,766** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.17 RATTANAK KIRI



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 1.8% | 3.9% | 29.8% | 50.5% |
| | Hydro mini-grid | 0.0% | 7.0% | 3.9% | 1.8% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 7.1% | 10.4% | 6.7% | 7.0% |
| | New diesel mini-grid | 0.0% | 3.2% | 0.3% | 0.0% |
| | Solar home systems | 0.0% | 0.8% | 1.8% | 1.6% |
| | **Total rural connections** | **9%** | **25%** | **42%** | **61%** |
| Village coverage | National grid | 3.0% | 3.9% | 56.2% | 66.5% |
| | Hydro mini-grid | 0.0% | 15.9% | 5.6% | 2.1% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 35.6% | 29.2% | 13.7% | 10.7% |
| | New diesel mini-grid | 0.0% | 6.4% | 0.4% | 0.0% |
| | Existing battery charging stations | 8.6% | 3.4% | 2.1% | 1.7% |
| | Solar battery charging stations | 0.0% | 10.9% | 21.9% | 18.9% |
| | **Total rural villages** | **47%** | **70%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 5 | 368 | 90 |
| Grid demand of newly connected villages (GWh/year) | 0 | 8 | 3 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 3 | 1,216 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 5 | 520 |
| **Total** | **8** | **1,737** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

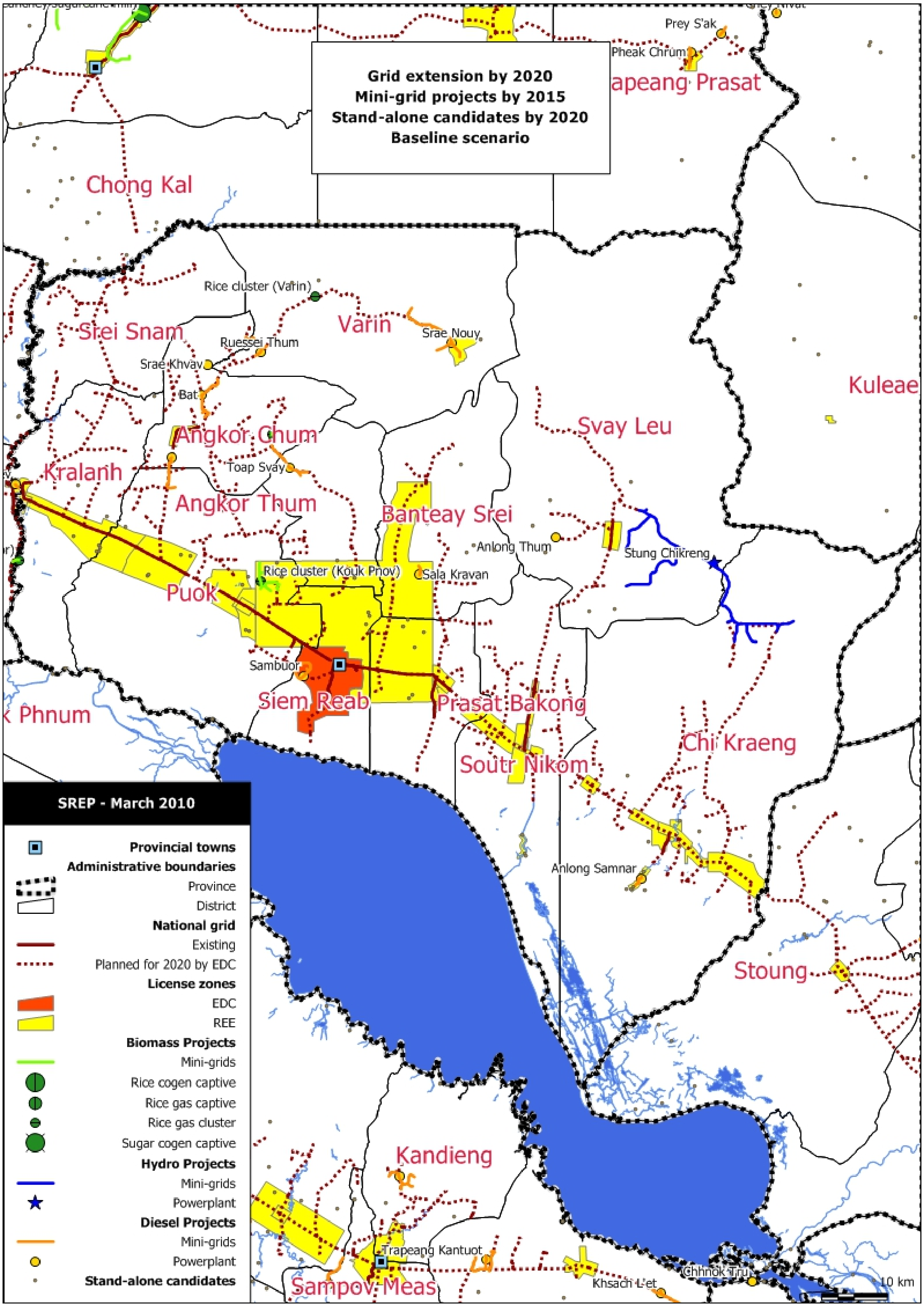
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 254 | 347 | 53 |
| Community PV (new villages) | 28 | 28 | 0 |
| Solar battery charging stations (new villages) | 26 | 20 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 105 | 7,357 | 1,793 |
| Distribution (transformers, LV, meters) | 152 | 4,397 | 3,045 |
| **Subtotal grid extension** | **256** | **11,755** | **4,838** |
| Hydro mini-grid | 5,677 | 194 | 78 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 746 | 39 | 3 |
| **Subtotal mini-grid projects** | **6,423** | **234** | **81** |
| Solar home systems | 102 | 139 | 62 |
| Community PV | 51 | 51 | 0 |
| Solar battery charging stations | 382 | 393 | 0 |
| **Subtotal stand-alone systems** | **535** | **584** | **62** |
| **Total** | **7,214** | **12,572** | **4,981** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.18 Siem Reap



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 5.1% | 24.9% | 47.5% | 68.4% |
| | Hydro mini-grid | 0.0% | 0.8% | 0.3% | 0.1% |
| | Biomass mini-grid | 0.0% | 0.7% | 0.6% | 0.0% |
| | Existing diesel mini-grid | 2.3% | 2.0% | 2.3% | 0.1% |
| | New diesel mini-grid | 0.0% | 2.6% | 1.4% | 0.0% |
| | Solar home systems | 0.0% | 0.3% | 0.7% | 0.1% |
| | **Total rural connections** | **7%** | **31%** | **53%** | **69%** |
| Village coverage | National grid | 9.4% | 46.6% | 85.7% | 98.6% |
| | Hydro mini-grid | 0.0% | 1.3% | 0.5% | 0.1% |
| | Biomass mini-grid | 0.0% | 1.3% | 0.8% | 0.0% |
| | Existing diesel mini-grid | 5.7% | 3.6% | 3.2% | 0.1% |
| | New diesel mini-grid | 0.0% | 6.2% | 2.3% | 0.0% |
| | Existing battery charging stations | 47.2% | 17.7% | 4.3% | 0.5% |
| | Solar battery charging stations | 0.0% | 1.6% | 3.2% | 0.7% |
| | **Total rural villages** | **62%** | **78%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 583 | 589 | 164 |
| Grid demand of newly connected villages (GWh/year) | 27 | 19 | 16 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 1 | 800 |
| Biomass mini-grid | 4 | 789 |
| New diesel mini-grid | 11 | 1 673 |
| **Total** | **16** | **3 262** |

**Grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

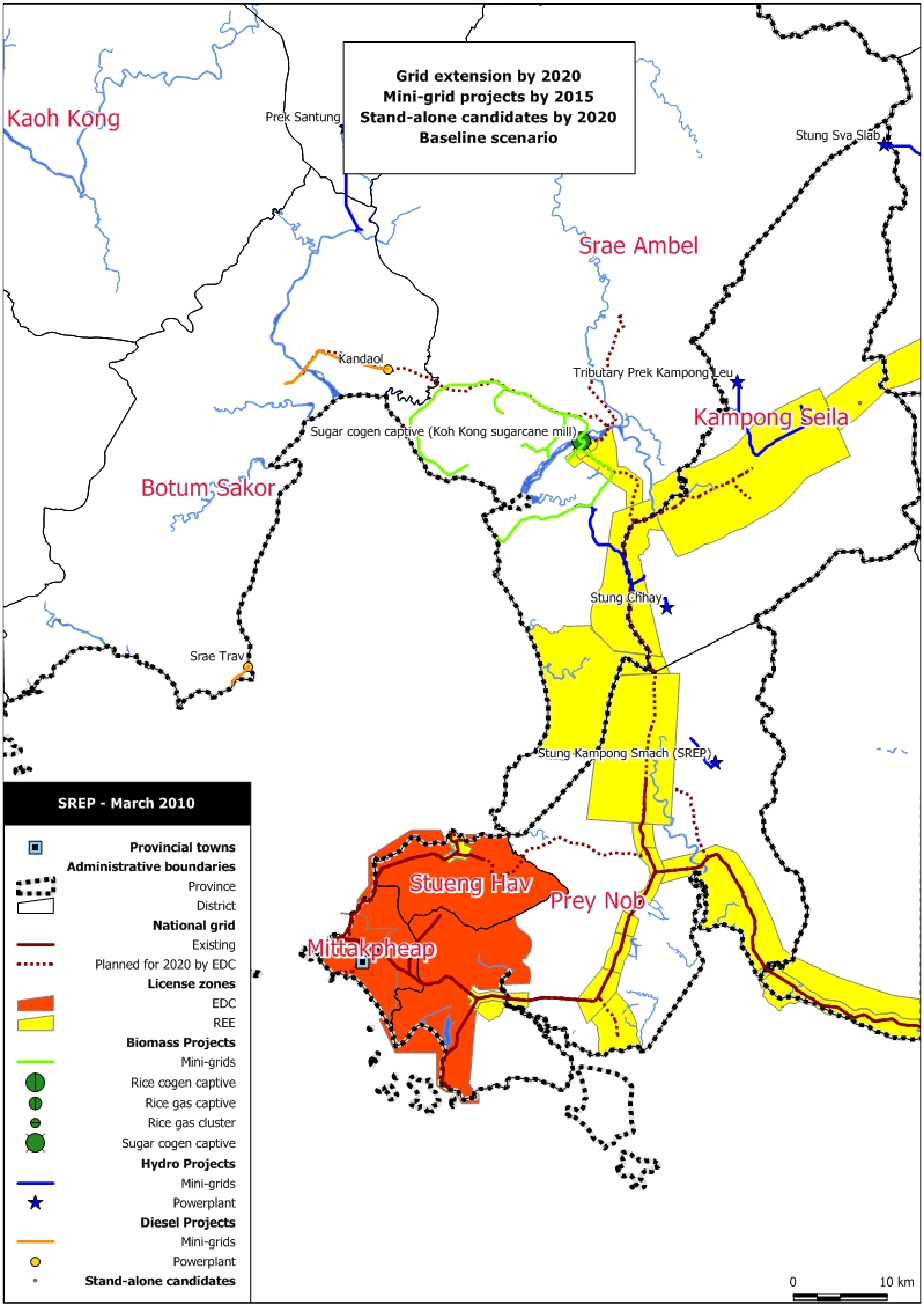
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 530 | 677 | 0 |
| Community PV (new villages) | 32 | 32 | 0 |
| Solar battery charging stations (new villages) | 14 | 11 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 11,657 | 11,772 | 3,282 |
| Distribution (transformers, LV, meters) | 11,269 | 12,413 | 11,740 |
| **Subtotal grid extension** | **22,926** | **24,185** | **15,023** |
| Hydro mini-grid | 2,933 | 44 | 6 |
| Biomass mini-grid | 969 | 52 | 11 |
| New diesel mini-grid | 1,931 | 166 | 27 |
| **Subtotal mini-grid projects** | **5,833** | **263** | **45** |
| Solar home systems | 212 | 271 | 5 |
| Community PV | 68 | 68 | 0 |
| Solar battery charging stations | 264 | 269 | 0 |
| **Subtotal stand-alone systems** | **544** | **608** | **5** |
| **Total** | **29,303** | **25,056** | **15,073** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.19 PREAH SIHANOUK



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 22.1% | 44.1% | 55.2% | 67.9% |
| | Hydro mini-grid | 0.0% | 1.9% | 1.9% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 9.8% | 4.2% | 4.2% | 2.0% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.1% | 0.2% | 0.0% |
| | **Total rural connections** | **32%** | **50%** | **62%** | **70%** |
| Village coverage | National grid | 44.2% | 83.2% | 87.4% | 94.7% |
| | Hydro mini-grid | 0.0% | 4.2% | 3.2% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 31.6% | 11.6% | 8.4% | 5.3% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing battery charging stations | 15.8% | 1.1% | 1.1% | 0.0% |
| | Solar battery charging stations | 0.0% | 0.0% | 0.0% | 0.0% |
| | **Total rural villages** | **92%** | **100%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| **Grid extension in rural areas** | **2011-2015** | **2016-2020** | **2021-2030** |
|---|---|---|---|
| MV lines for grid extension (km) | 49 | 11 | 41 |
| Grid demand of newly connected villages (GWh/year) | 6 | 0 | 2 |

**Grid extension figures in rural areas under the baseline scenario**

| | **Projects** | **Total Installed capacity (kW)** |
|---|---|---|
| Hydro mini-grid | 4 | 310 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 0 | 0 |
| **Total** | **4** | **310** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

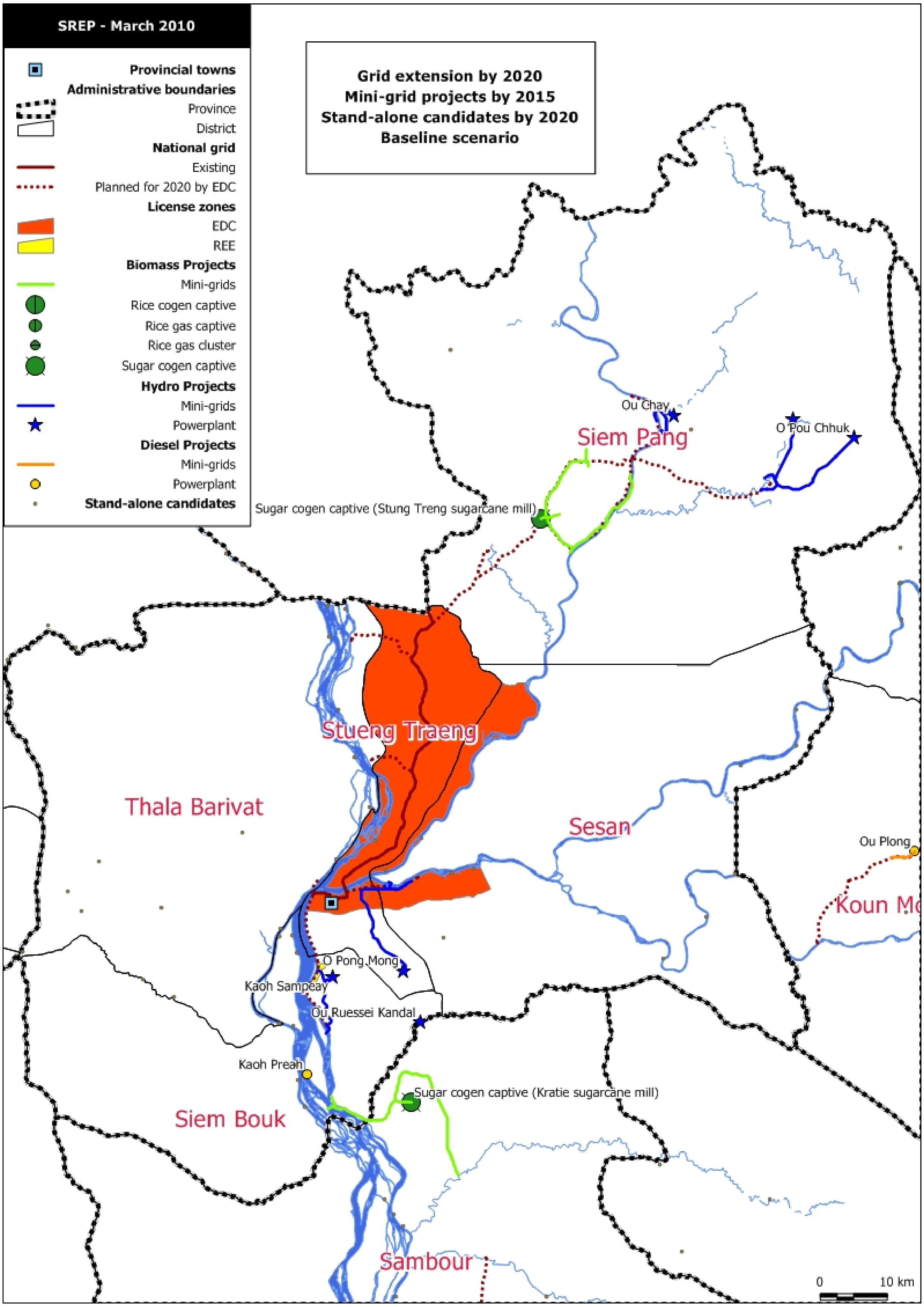
| | **2011-2015** | **2016-2020** | **2021-2030** |
|---|---|---|---|
| Solar home systems (new kits) | 30 | 38 | 0 |
| Community PV (new villages) | 0 | 1 | 0 |
| Solar battery charging stations (new villages) | 0 | 0 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | **2011-2015** | **2016-2020** | **2021-2030** |
|---|---|---|---|
| Sub-transmission network (MV lines) | 988 | 216 | 821 |
| Distribution (transformers, LV, meters) | 1,794 | 810 | 1,498 |
| **Subtotal grid extension** | **2,782** | **1,026** | **2,319** |
| Hydro mini-grid | 1,152 | 11 | 4 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 0 | 0 | 0 |
| **Subtotal mini-grid projects** | **1,152** | **11** | **4** |
| Solar home systems | 12 | 15 | 0 |
| Community PV | 2 | 2 | 0 |
| Solar battery charging stations | 0 | 0 | 0 |
| **Subtotal stand-alone systems** | **14** | **17** | **0** |
| **Total** | **3,949** | **1,054** | **2,323** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.20 STUNG TRENG



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 3.7% | 7.4% | 25.2% | 47.3% |
| | Hydro mini-grid | 0.0% | 6.1% | 2.4% | 0.0% |
| | Biomass mini-grid | 0.0% | 3.5% | 1.1% | 1.4% |
| | Existing diesel mini-grid | 5.8% | 9.3% | 9.3% | 7.1% |
| | New diesel mini-grid | 0.0% | 0.5% | 0.8% | 0.0% |
| | Solar home systems | 0.0% | 1.2% | 2.4% | 1.7% |
| | **Total rural connections** | **10%** | **28%** | **41%** | **58%** |
| Village coverage | National grid | 4.9% | 10.6% | 44.7% | 64.2% |
| | Hydro mini-grid | 0.0% | 12.2% | 0.8% | 0.0% |
| | Biomass mini-grid | 0.0% | 13.8% | 3.3% | 3.3% |
| | Existing diesel mini-grid | 31.7% | 26.0% | 17.9% | 10.6% |
| | New diesel mini-grid | 0.0% | 0.8% | 0.8% | 0.0% |
| | Existing battery charging stations | 23.6% | 14.6% | 11.4% | 7.3% |
| | Solar battery charging stations | 0.0% | 10.6% | 21.1% | 14.6% |
| | **Total rural villages** | **60%** | **89%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 20 | 164 | 91 |
| Grid demand of newly connected villages (GWh/year) | 0 | 3 | 4 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 6 | 341 |
| Biomass mini-grid | 1 | 650 |
| New diesel mini-grid | 1 | 57 |
| **Total** | **8** | **1,048** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

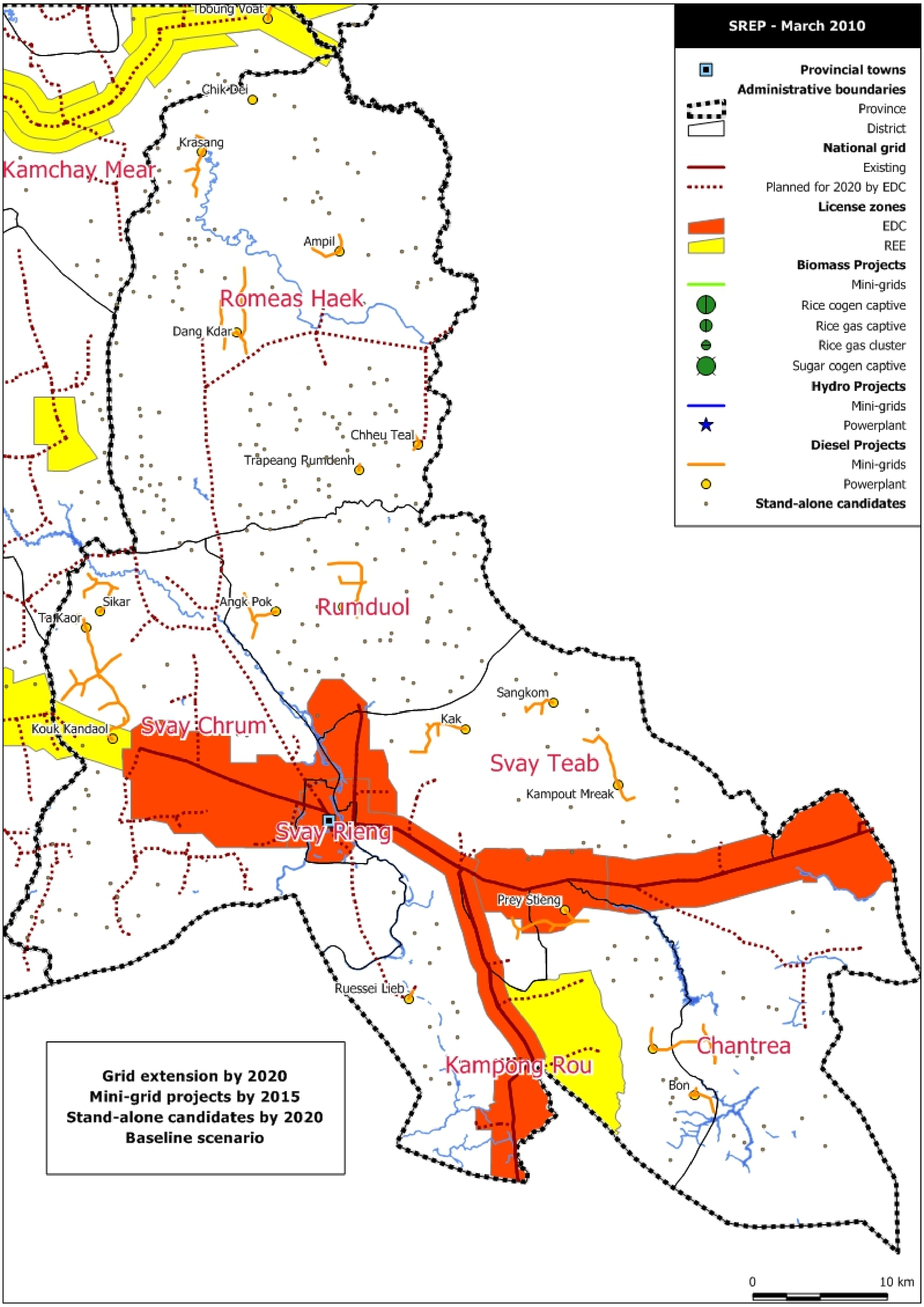
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 235 | 299 | 0 |
| Community PV (new villages) | 20 | 20 | 0 |
| Solar battery charging stations (new villages) | 13 | 10 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 404 | 3,276 | 1,826 |
| Distribution (transformers, LV, meters) | 303 | 1,752 | 2,427 |
| **Subtotal grid extension** | **707** | **5,028** | **4,253** |
| Hydro mini-grid | 2,736 | 70 | 13 |
| Biomass mini-grid | 2,434 | 30 | 13 |
| New diesel mini-grid | 57 | 12 | 6 |
| **Subtotal mini-grid projects** | **5,226** | **112** | **32** |
| Solar home systems | 94 | 120 | 27 |
| Community PV | 70 | 70 | 0 |
| Solar battery charging stations | 235 | 241 | 0 |
| **Subtotal stand-alone systems** | **399** | **430** | **27** |
| **Total** | **6,332** | **5,570** | **4,311** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.21 Svay Rieng



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 6.7% | 20.3% | 31.4% | 62.9% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 1.7% | 0.2% | 0.3% | 0.0% |
| | New diesel mini-grid | 0.0% | 6.3% | 7.4% | 0.0% |
| | Solar home systems | 0.0% | 2.0% | 4.1% | 0.1% |
| | **Total rural connections** | **8%** | **29%** | **43%** | **63%** |
| Village coverage | National grid | 9.9% | 32.2% | 48.3% | 98.2% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 4.3% | 0.9% | 0.7% | 0.0% |
| | New diesel mini-grid | 0.0% | 13.9% | 11.4% | 0.0% |
| | Existing battery charging stations | 40.5% | 22.0% | 18.6% | 0.3% |
| | Solar battery charging stations | 0.0% | 10.5% | 21.0% | 1.5% |
| | **Total rural villages** | **55%** | **79%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 262 | 134 | 591 |
| Grid demand of newly connected villages (GWh/year) | 14 | 5 | 29 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 18 | 3,631 |
| **Total** | **18** | **3,631** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

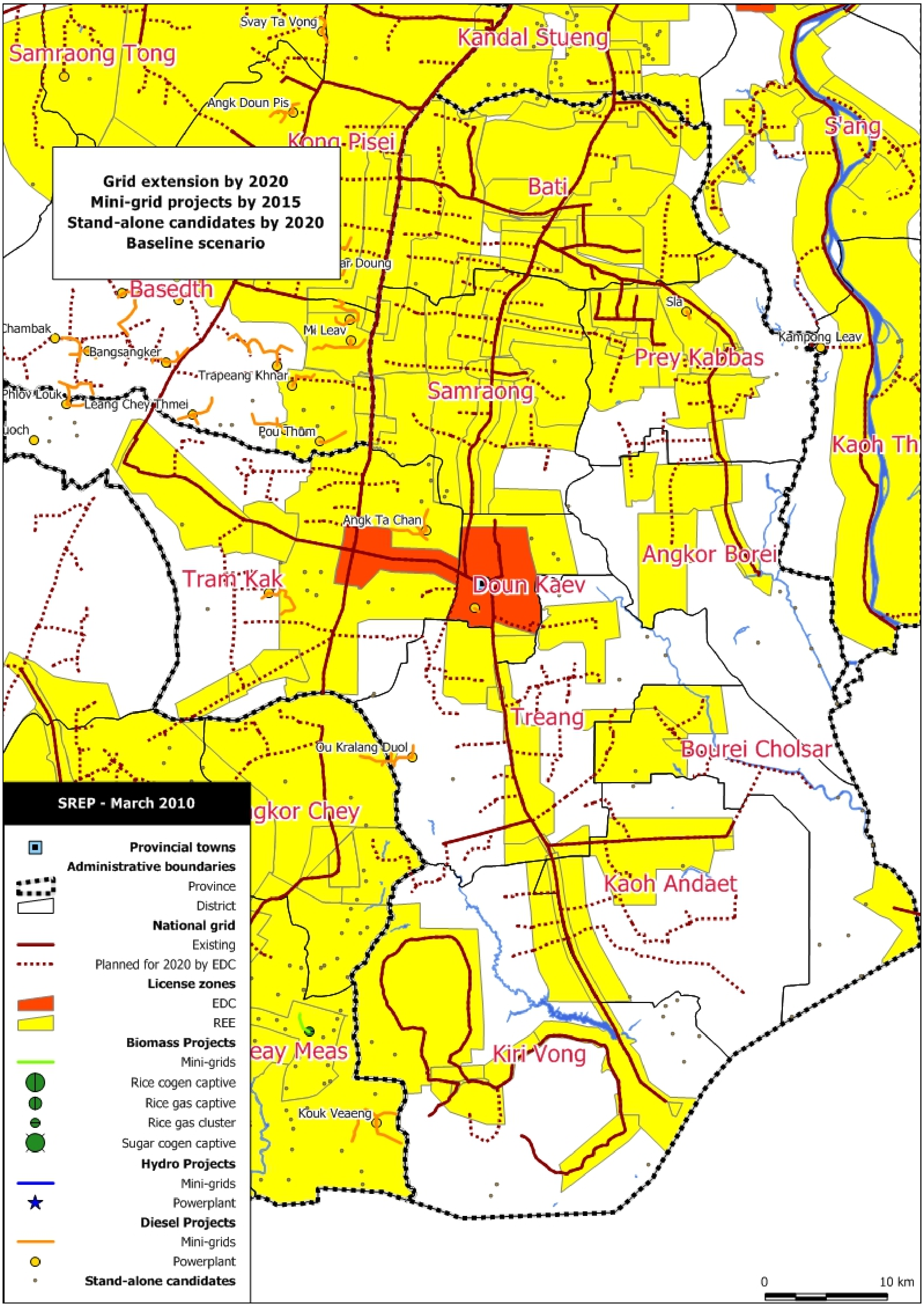
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 2,458 | 2,957 | 0 |
| Community PV (new villages) | 134 | 134 | 0 |
| Solar battery charging stations (new villages) | 71 | 57 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 5,243 | 2,674 | 11,823 |
| Distribution (transformers, LV, meters) | 5,859 | 4,261 | 20,067 |
| **Subtotal grid extension** | **11,102** | **6,934** | **31,890** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 3,763 | 529 | 116 |
| **Subtotal mini-grid projects** | **3,763** | **529** | **116** |
| Solar home systems | 983 | 1,183 | 8 |
| Community PV | 249 | 249 | 0 |
| Solar battery charging stations | 1,341 | 1,360 | 0 |
| **Subtotal stand-alone systems** | **2,573** | **2,792** | **8** |
| **Total** | **17,438** | **10,255** | **32,013** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.22 TAKEO


Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
0
10 km
Samraong Tong
Svay Ta Vong
Kandal Stueng
Angk Doun Pis
Kong Pisei
S'ang
Bati
Basedth
Sla
Kampong Leav
Prey Kabbas
Samraong
Mi Leav
Bangsangker
Trapeang Khnar
Leang Chey Thmei
Pou Thum
Kaoh Th
Angk Ta Chan
Angkor Borei
Tram Kak
Doun Kaev
Treang
Ou Kralang Duol
Bourei Cholsar
gkor Chey
Kaoh Andaet
eay Meas
Kiri Vong
Kouk Veaeng

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 9.1% | 33.1% | 53.2% | 68.7% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 1.4% | 0.4% | 0.3% | 0.1% |
| | New diesel mini-grid | 0.0% | 0.9% | 0.7% | 0.1% |
| | Solar home systems | 0.0% | 0.3% | 0.7% | 0.1% |
| | **Total rural connections** | **11%** | **35%** | **55%** | **69%** |
| Village coverage | National grid | 15.9% | 58.1% | 91.9% | 98.1% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 3.9% | 1.8% | 0.7% | 0.2% |
| | New diesel mini-grid | 0.0% | 2.4% | 1.0% | 0.2% |
| | Existing battery charging stations | 28.8% | 9.7% | 2.1% | 0.3% |
| | Solar battery charging stations | 0.0% | 2.1% | 4.3% | 1.3% |
| | **Total rural villages** | **49%** | **74%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 539 | 328 | 138 |
| Grid demand of newly connected villages (GWh/year) | 41 | 16 | 8 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 8 | 975 |
| **Total** | **8** | **975** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

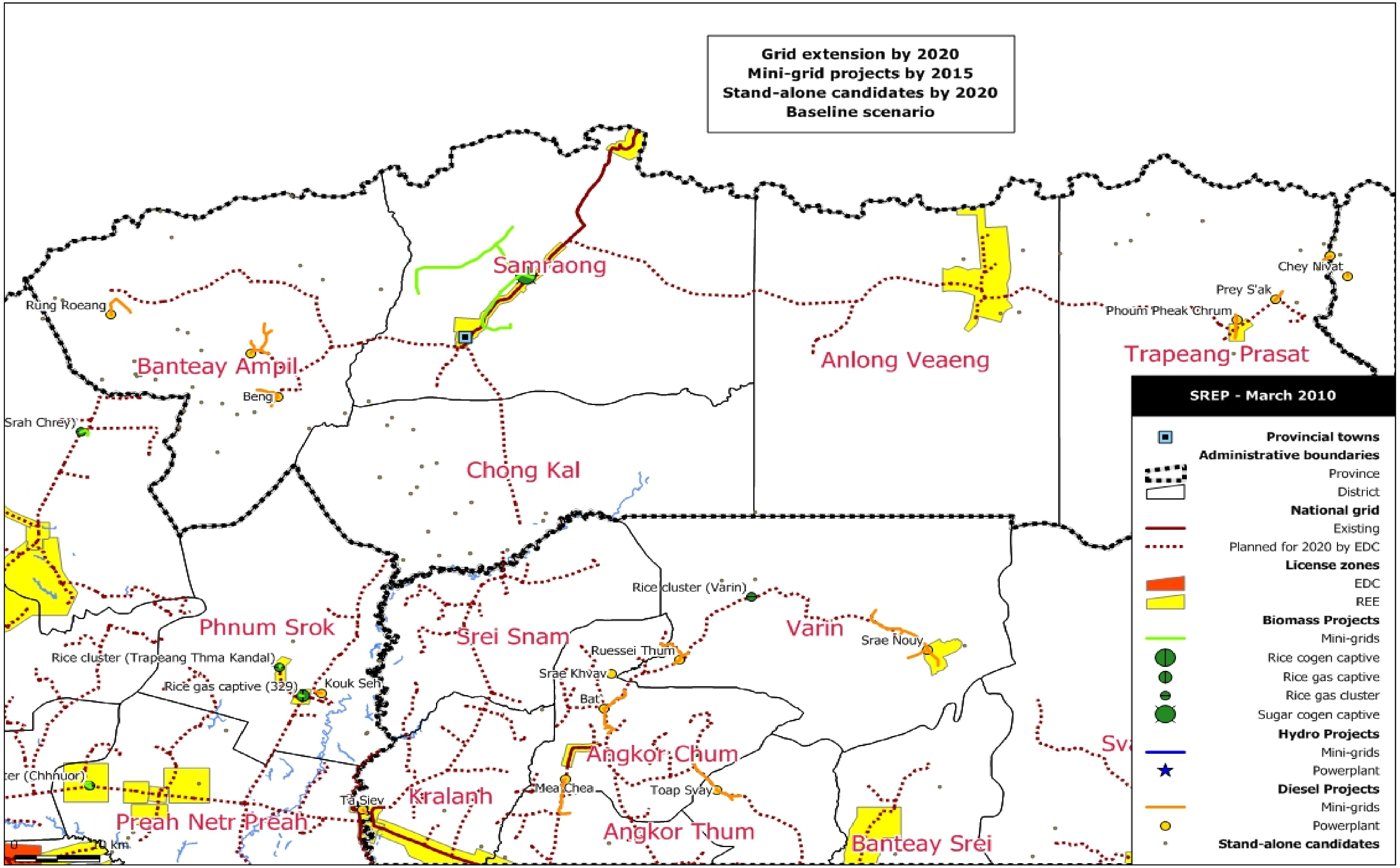
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 622 | 760 | 0 |
| Community PV (new villages) | 35 | 35 | 0 |
| Solar battery charging stations (new villages) | 24 | 19 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 10,789 | 6,560 | 2,752 |
| Distribution (transformers, LV, meters) | 16,409 | 12,725 | 9,762 |
| **Subtotal grid extension** | **27,199** | **19,285** | **12,514** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 846 | 106 | 12 |
| **Subtotal mini-grid projects** | **846** | **106** | **12** |
| Solar home systems | 249 | 304 | 0 |
| Community PV | 74 | 74 | 0 |
| Solar battery charging stations | 434 | 441 | 0 |
| **Subtotal stand-alone systems** | **756** | **819** | **0** |
| **Total** | **28,801** | **20,210** | **12,526** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.23 OTDAR MEANCHEY



| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 4.3% | 11.0% | 34.3% | 63.1% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 1.4% | 2.0% | 0.0% |
| | Existing diesel mini-grid | 5.4% | 7.3% | 2.6% | 0.6% |
| | New diesel mini-grid | 0.0% | 5.2% | 2.1% | 0.0% |
| | Solar home systems | 0.0% | 1.0% | 2.0% | 0.6% |
| | **Total rural connections** | **10%** | **26%** | **43%** | **64%** |
| Village coverage | National grid | 4.1% | 13.7% | 59.8% | 87.2% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 3.2% | 2.7% | 0.0% |
| | Existing diesel mini-grid | 17.8% | 15.5% | 5.0% | 1.4% |
| | New diesel mini-grid | 0.0% | 11.0% | 3.7% | 0.0% |
| | Existing battery charging stations | 35.6% | 23.3% | 12.3% | 2.7% |
| | Solar battery charging stations | 0.0% | 8.2% | 16.4% | 8.7% |
| | **Total rural villages** | **58%** | **75%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 37 | 252 | 197 |
| Grid demand of newly connected villages (GWh/year) | 2 | 10 | 10 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 1 | 800 |
| New diesel mini-grid | 5 | 967 |
| **Total** | **6** | **1 767** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

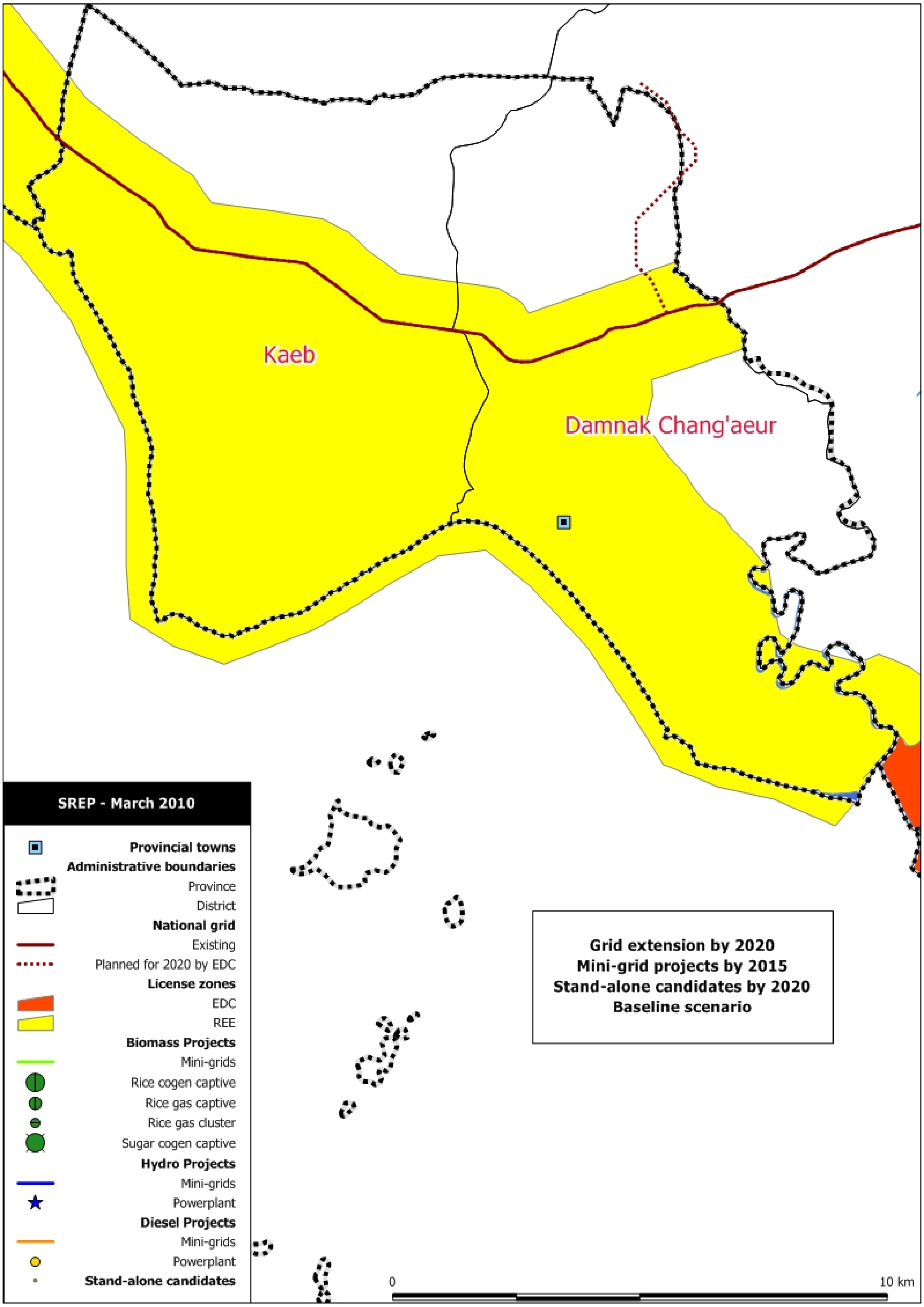
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 436 | 638 | 0 |
| Community PV (new villages) | 32 | 31 | 0 |
| Solar battery charging stations (new villages) | 18 | 14 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 740 | 5,036 | 3,945 |
| Distribution (transformers, LV, meters) | 1,163 | 5,663 | 9,507 |
| **Subtotal grid extension** | **1,903** | **10,699** | **13,451** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 1,837 | 82 | 16 |
| New diesel mini-grid | 1,192 | 240 | 27 |
| **Subtotal mini-grid projects** | **3,030** | **323** | **43** |
| Solar home systems | 174 | 255 | 0 |
| Community PV | 80 | 80 | 0 |
| Solar battery charging stations | 307 | 321 | 0 |
| **Subtotal stand-alone systems** | **561** | **656** | **0** |
| **Total** | **5,494** | **11,677** | **13,494** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.24 KEP


Kaeb
Damnak Chang'aeur
SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
0
10 km

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 15.2% | 44.3% | 60.9% | 70.0% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.0% | 0.0% | 0.0% |
| | **Total rural connections** | **15%** | **44%** | **61%** | **70%** |
| Village coverage | National grid | 50.0% | 100.0% | 100.0% | 100.0% |
| | Hydro mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing battery charging stations | 35.7% | 0.0% | 0.0% | 0.0% |
| | Solar battery charging stations | 0.0% | 0.0% | 0.0% | 0.0% |
| | **Total rural villages** | **86%** | **100%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 20 | 0 | 0 |
| Grid demand of newly connected villages (GWh/year) | 1 | 0 | 0 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 0 | 0 |
| **Total** | **0** | **0** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

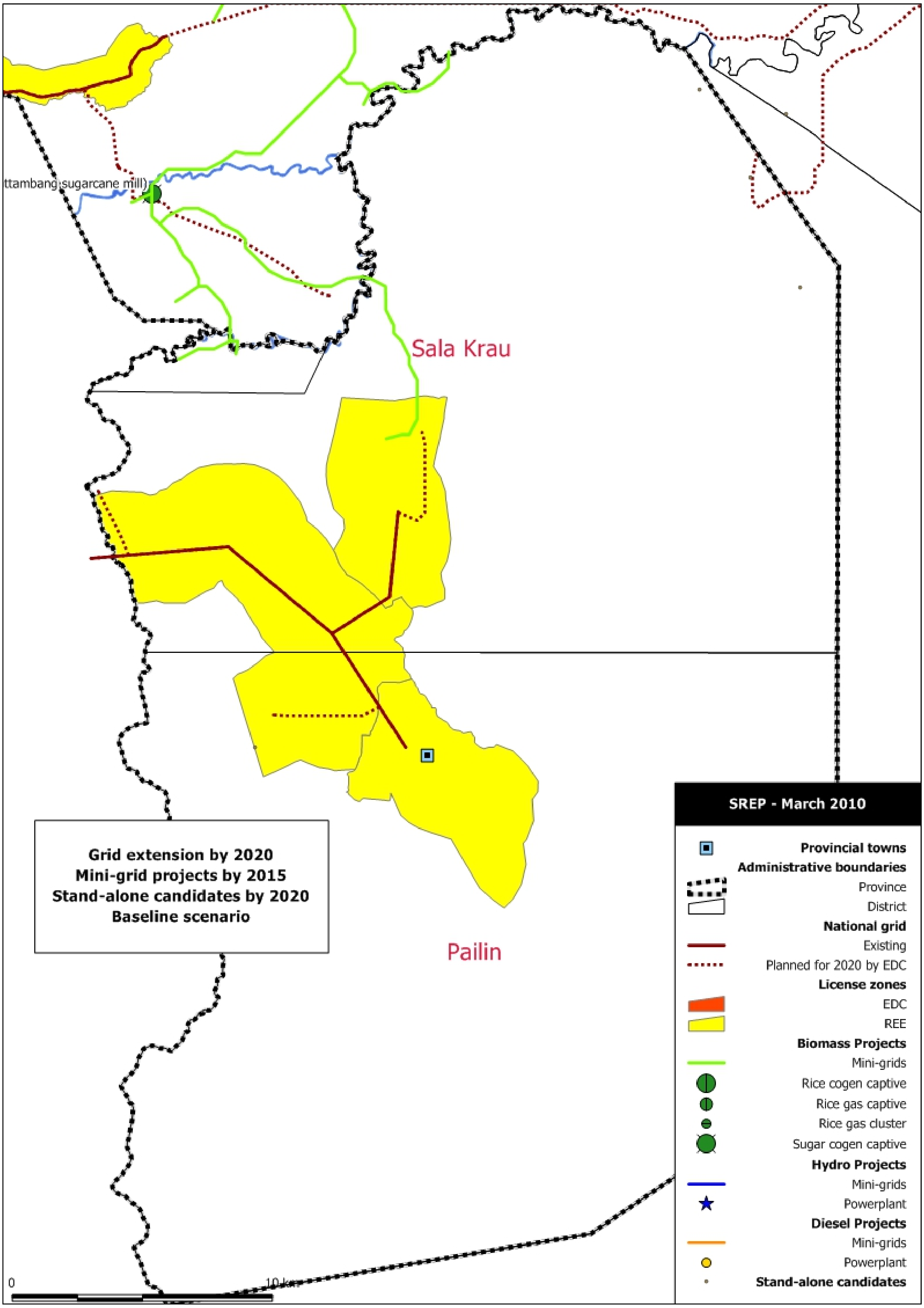
| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 0 | 0 | 0 |
| Community PV (new villages) | 0 | 0 | 0 |
| Solar battery charging stations (new villages) | 0 | 0 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 392 | 0 | 0 |
| Distribution (transformers, LV, meters) | 578 | 284 | 234 |
| **Subtotal grid extension** | **970** | **284** | **234** |
| Hydro mini-grid | 0 | 0 | 0 |
| Biomass mini-grid | 0 | 0 | 0 |
| New diesel mini-grid | 0 | 0 | 0 |
| **Subtotal mini-grid projects** | **0** | **0** | **0** |
| Solar home systems | 0 | 0 | 0 |
| Community PV | 0 | 0 | 0 |
| Solar battery charging stations | 0 | 0 | 0 |
| **Subtotal stand-alone systems** | **0** | **0** | **0** |
| **Total** | **970** | **284** | **234** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

## 6.25 PAILIN


ttambang sugarcane mill)
Sala Krau
Pailin
Grid extension by 2020
Mini-grid projects by 2015
Stand-alone candidates by 2020
Baseline scenario
SREP - March 2010
Provincial towns
Administrative boundaries
Province
District
National grid
Existing
Planned for 2020 by EDC
License zones
EDC
REE
Biomass Projects
Mini-grids
Rice cogen captive
Rice gas captive
Rice gas cluster
Sugar cogen captive
Hydro Projects
Mini-grids
Powerplant
Diesel Projects
Mini-grids
Powerplant
Stand-alone candidates
0
10 km

| | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Connections | National grid | 27.2% | 38.1% | 47.2% | 69.1% |
| | Hydro mini-grid | 0.0% | 0.7% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 0.6% | 0.7% | 0.0% |
| | Existing diesel mini-grid | 6.2% | 8.1% | 10.5% | 0.2% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Solar home systems | 0.0% | 0.2% | 0.5% | 0.0% |
| | **Total rural connections** | **33%** | **48%** | **59%** | **69%** |
| Village coverage | National grid | 47.1% | 63.2% | 72.1% | 98.5% |
| | Hydro mini-grid | 0.0% | 1.5% | 0.0% | 0.0% |
| | Biomass mini-grid | 0.0% | 2.9% | 2.9% | 0.0% |
| | Existing diesel mini-grid | 23.5% | 17.6% | 17.6% | 1.5% |
| | New diesel mini-grid | 0.0% | 0.0% | 0.0% | 0.0% |
| | Existing battery charging stations | 8.8% | 2.9% | 1.5% | 0.0% |
| | Solar battery charging stations | 0.0% | 2.9% | 5.9% | 0.0% |
| | **Total rural villages** | **79%** | **91%** | **100%** | **100%** |

**Coverage rates achieved in rural areas under the baseline scenario (percentage)**

| Grid extension in rural areas | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| MV lines for grid extension (km) | 29 | 28 | 28 |
| Grid demand of newly connected villages (GWh/year) | 1 | 0 | 4 |

**Grid extension figures in rural areas under the baseline scenario**

| | Projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 0 | 0 |
| Biomass mini-grid | 0 | 0 |
| New diesel mini-grid | 0 | 0 |
| **Total** | **0** | **0** |

**Mini-grid projects in rural areas to be installed by 2015 under the baseline scenario (only for projects, with the power source inside the province boundaries)**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Solar home systems (new kits) | 30 | 43 | 0 |
| Community PV (new villages) | 2 | 3 | 0 |
| Solar battery charging stations (new villages) | 2 | 2 | 0 |

**Stand-alone systems in rural areas under the baseline scenario**

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Sub-transmission network (MV lines) | 581 | 570 | 555 |
| Distribution (transformers, LV, meters) | 681 | 781 | 2,791 |
| **Subtotal grid extension** | **1,261** | **1,350** | **3,346** |
| Hydro mini-grid | 455 | 15 | 0 |
| Biomass mini-grid | 312 | 4 | 8 |
| New diesel mini-grid | 0 | 0 | 0 |
| **Subtotal mini-grid projects** | **767** | **19** | **8** |
| Solar home systems | 12 | 17 | 5 |
| Community PV | 6 | 6 | 0 |
| Solar battery charging stations | 23 | 24 | 0 |
| **Subtotal stand-alone systems** | **41** | **47** | **5** |
| **Total** | **2,069** | **1,417** | **3,359** |

**Investment schedule under the baseline scenario (in thousands of USD, investment costs for projects covering several provinces have been split proportionally to the number of villages in each province)**

# 7 CONCLUSIONS

In order to meet the following policy objectives, three scenarii have been defined:

Policy objectives:

- 100% village coverage by 2020 (including national grid, mini-grid and stand-alone systems)
- 70% households connected to grid-quality services by 2030 (mini grids and national grid only)

The three scenarii differ only by the rate at which the national grid will expand:

**Baseline scenario**:

In line with grid extension data from EDC and recent targets set by EAC:

- 80% villages to have **national grid connection** by 2020, remaining in mini-grids
- 95% villages to have **national grid connection** by 2030, remaining in mini-grids

Until 2015, this plan implies an additional 4400 grid connected villages, an expenditure of 327 MUSD and also construction, which means that the funds would have to be secured latest by end 2013, to leave time for engineering, tendering, construction. To date, it is understood that about 200 MUSD have been committed (not signed) for the next 5 years in grants and loans by international cooperation agencies

Until 2030, this implies a total of 891 MUSD in investments (MUSD, in 2010 prices)

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Grid extension (total) | 327 423 | 276 938 | 286 772 |
| *Incl. distribution (transformers, LV, meters)* | *183 994* | *158 735* | *203 490* |

**Intermediate scenario** (half of grid extension rate compared to baseline scenario):

Only half (2200) new villages are achieved in 2015, which implies fund mobilisation of 200 MUSD, and a national village connection rate of 28%.

Continuing on this trend, by 2020 46% village grid connection is achieved (100% including all types of electricity services following policy objectives). In 2030 the household connection rate for grid-equivalent supplies is 55% (slightly below the 70% target), and villages connected remain at 78%, below the recent 95% national target.

This implies a total of 683 MUSD in investments (MUSD, in 2010 prices)

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Grid extension (total) | 200 294 | 172 955 | 309 612 |
| *Incl. distribution (transformers, LV, meters)* | *116 008* | *113 812* | *191 409* |

**Conservative scenario** (half of grid extension rate compared to intermediate scenario):

Only a quarter (1100) new villages are achieved in 2015, which implies fund mobilisation of 123 MUSD, and a national village connection rate of 20%

By 2020, 28% village grid connection is achieved (the rest of villages are supplied with either mini-grid projects or stand-alone systems), and in 2030, the household connection rate for grid-equivalent supplies is 42%, and villages connected remain at 46%, well under the 95% target.

This implies a total of 423 MUSD in investments (MUSD, in 2010 prices)

| | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Grid extension (total) | 122 948 | 108 223 | 192 261 |
| *Incl. distribution (transformers, LV, meters)* | *73 163* | *73 722* | *133 119* |

After the grid extension has been simulated in each scenario, mini-grid projects using mini-hydro, biomass (rice gasification, rice cogeneration of sugarcane cogeneration) and diesel projects have been sized and optimised. The following tables summarise the results for the baseline scenario. In the intermediate and conservative scenarios, as the grid will be extended at a slower rate, the number of projects and investment requirements for mini grid and stand alone options will be much higher.

| Mini-grid projects in rural areas by 2015 – baseline scenario | Number of projects | Total Installed capacity (kW) |
|---|---|---|
| Hydro mini-grid | 33 | 6 449 |
| Biomass mini-grid | 25 | 10 317 |
| New diesel mini-grid | 150 | 21 663 |
| **Total** | **208** | **38 429** |

| Investment costs in rural areas ('000 USD) – baseline scenario | 2011-2015 | 2016-2020 | 2021-2030 |
|---|---|---|---|
| Hydro mini-grid | 31 492 | 861 | 233 |
| Biomass mini-grid | 16 363 | 581 | 171 |
| New diesel mini-grid | 23 906 | 2 382 | 392 |
| **Total mini-grid projects** | **71 761** | **3 824** | **796** |

Regarding mini-hydro projects, most potential sites are located in mountainous areas (mostly mountains in the Cardamoms Range and North-Eastern provinces), where there is little or no population, so they would probably be more suited to IPP and grid injection approaches, wherever the national grid is not too far and can absorb the power. However, given that a number of large hydro projects are being constructed and commissioned, it is doubtful that it would make any sense to develop such small hydro IPPs. In conclusion, there is very little mini hydro potential making economic sense for mini grids – where population is located. Smaller systems than the ones we studied (less than 50kW) may still offer some interest in mountainous regions, but this would be more considered as stand-alone systems rather than grid-quality electricity, considering issues with seasonality and overall reliability of these pico turbines.

For biomass mini-grid projects, three routes have been explored: biogas, cogeneration and gasification. To date, there are very few large agro-industries in the country having the quantity of humid waste required for biogas. There are only about 5 pig farms which could be potentials for such units in the medium term. Cogeneration (combined production of heat and power) again requires fairly large units, which also need the heat. Until recently, relevant agro-industries (large rice mills, sugar production) were not large enough to offer such opportunities. However, a few (5 to 10) such investments are being prepared in Cambodia. We have assumed that these multi megawatt deals would provide 500kW to 2MW for local mini grid electrification, the rest being used for own consumption or selling to the grid. Smaller scale gasifiers offer more potential, and SME Cambodia has been selling and installing gasifiers which have a fairly good track record. The rice mills typically consumes only 30% of the husk for own consumption and hence the balance could be used to sell to the local REE, which runs on diesel. However, agro-industries being usually located in areas already covered by the grid (or soon to be connected), these projects usually offer only short term opportunities for off-grid electrification, unless the regulatory framework evolves to allow easier injection of power on the national grid for such small-scale projects (which may prove competitive). The overall situation of the agro-industry sector and thus opportunities for biomass projects is expected to evolve very quickly over the next few years in Cambodia, as new policies aim to foster a modern, high added value and export based industry. Therefore the above conclusions might have to be revised significantly after a few years, depending on the effectiveness of such changes.

Diesel grids and potential for PV injection: Considering limitations in hydro and biomass projects, new diesel mini-grid projects had to be designed, in order to supply all the remaining villages identified as “Development Poles” or “growth centres”, and which require grid-quality service by 2015. All simulations have been performed assuming that these new projects would be indeed purely diesel based, although using slightly more modern and efficient equipments. However, international experience now shows that with the dropping of PV panel prices and the increase in reliability of technology, the PV production cost, with financing available over 15 years, could be between 20 and 70 UScents/kWh:

- The lowest range being for large  units feeding into the grid without any battery storage
- Mid range being for smaller capacities and feeding into a diesel grid typically, still without storage
- The most costly being for very small units and with up to 100% battery storage, the PV power being produced during the day, stored and then consumed in the night time.

Unfortunately, most new diesel mini-grid projects proposed under the rural electrification plan belong to the third category. Therefore, the costs are expected to be slightly high, but still competitive with current diesel generation costs under most circumstances.

| Capacity range (kW) | Proposed solution | Baseline | | |
|---|---|---|---|---|
| | | Number of projects | PV installed capacity (kWp) | Investment cost ('000 USD) |
| <30 | 100% storage | 7 | 37 | 237 |
| 30-100 | 50% storage | 43 | 523 | 2 934 |
| >100 | 0% storage | 100 | 3 773 | 17 846 |
| | **Total** | **150** | **4 333** | **21 017** |

In the longer term, it can be expected that, given the depth of the market of diesel operators (between 150 and 289 new projects depending on the scenario), and further cost reduction at the global stage, even projects currently comparing unfavourably with diesel may eventually become a better option.

Solar Battery charging stations and Solar Home Systems for isolated settlements and clusters:

Finally, for each of the scenarii, in order to reach the government village coverage targets by 2020, Solar Battery Charging stations and PV services for community facilities have been assumed. The depth of the market for such stand-alone systems looks rather significant, even under the most optimistic grid extension scenario, with 2,000 community PV to be installed, as well as solar battery charging stations in more than 1,100 villages. Although not mandatory to reach policy targets, the market for SHS has been assessed at 37,000 to 114,000 depending on the scenario.

A few key policy issues:

Though the present report is definitely not a regulatory study, it clearly highlights that the policy targets of the Cambodian government will be impossible to reach without an appropriate and conducive regulatory and incentives framework, covering at least the following key areas:

- Streamlining issues of interface with EDC regarding distribution, the price of bulk sale from EDC to the distribution licensees and the tariff at which the distributer will then sell to the end users;

- Issues of captive power generation for own use, and then terms and conditions of sale of excess power to the national grid or to a distribution company: if the framework is too complex or the power purchase agreement not favourable enough to the investor, then there will be no economic incentive for the private sector to invest for rural electrification;

- Specific attention should be paid to taxation and duties issues, to ensure that such innovative projects are not unduly burdened, especially during the first years;

- Long term financing mechanisms will have to be put in place, which is not the practice of local commercial banks – and the REF is not yet involved in these activities. Soft loans, long term, with appropriate grace periods are an absolute requirement ;

- Appropriate facilitation, in terms of capacity building, project identification and development is also a need;

- Finally, the load forecast has been done making the assumption that the average household demand is 34,1kWh /month, with an average bill of 6,4$/month. Though on average today, households may be able to afford this, it is only an average, and further, going into remoter areas of Cambodia, affordability will be lower: clearly, a national tariff policy will have to be thought through, if the current very ambitious household connection targets are to be met.

Updating:
Finally, it is important to highlight that the results presented in this report are only a reflection of the situation during the first quarter of 2011, data which was made available and possible to collect within a time frame of a few months in 2010, of the assumptions discussed and validated with MIME, in collaboration with EAC, EDC and REF. The Geosim tool which was used to produce these simulations has been installed at MIME and in a few Provincial offices; MIME staff was extensively trained to use the planning tool. As the situation and scenarios evolve, MIME is equipped to update the national and provincial plans for rural electrification of Cambodia.