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Cambodia Rural Electrification Strategy and Implementation Plan

Final Report

Ministry of Industry Mines and Energy

31 December 2009

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ECA

R&N Engineering Consultants

AECOM

Cambodia Rural Electrification Strategy and Implementation Plan

Final Report

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Abbreviations and Acronyms

AECOM NZ	AECOM NZ New Zealand Ltd
BCS	Battery Charging Stations
EAC	Electricity Authority of Cambodia
ECA	Economic Consulting Associates
EDC	Electricité du Cambodge
GIS	Geographic Information Systems
HH	Households
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
JICA MP	Master Plan on Rural Electrification by Renewable Energy (JICA-funded)
LCOE	Levellised Cost of Energy
MIME	Ministry of Industry, Mines and Energy
PAGE	Potential Area of Grid Extension
PIC	Project Implementation Consultant
PPA	Power Purchase Agreement
PSDP	Power System Development Plan
RE	Rural Electrification
REE	Rural Electricity Enterprise
REF	Rural Electrification Fund
RETP	Rural Electrification and Transmission Project (World Bank-funded)
RGC	Royal Cambodian Government
SCS	Solar Battery Charging Station
SHS	Solar Home Systems
TA	Technical Assistance

Electrical Terminology

V (Volt)	Unit of voltage
kV (kilovolt)	1,000 volts
W (Watt)	Unit of active power
kW (kilowatt)	1,000 watts
MW (Megawatt)	1,000 kW
Wh (watt-hour)	Unit of Energy
kWh (kilowatt-hour)	1,000 Wh
MWh (Megawatt-hour)	1,000 kWh
GWh (Gigawatt-hour)	1,000 MWh
TWh (Terawatt-hour)	1,000 GWh
VA (Volt-ampere)	Unit of apparent power
kVA (kilovolt-ampere)	1,000 VA
MVA (Megavolt-ampere)	1,000 kVA
VAr (volt-ampere reactive)	Unit of reactive power
High Voltage (HV)	Voltage level exceeding 35 kV
Medium Voltage (MV)	Voltage level exceeding 0.6 kV and less than 35 kV
Low Voltage (LV)	Voltage level less than 0.6 kV
HV Transmission System	500 kV (Planned), 230 kV, 115 kV lines
MV Subtransmission System	22 kV lines supplying distribution substations
LV Distribution	400/230 V distribution and service lines
Grid Substation	Substation with primary voltage of 230 kV or 115 kV
Distribution Substation	Substation with primary voltage of 22 kV and secondary voltage of 400/230 V

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Executive Summary

Background

The Royal Government of Cambodia (RGC) has set ambitious targets for expanding electricity supplies:

- 100% of villages receiving grid-equivalent supplies by 2020
- 70% of rural households receiving grid-equivalent supplies by 2030.

Current electrification rates in Cambodia are very low. Based on licensing data from the Electricity Authority of Cambodia (EAC), the proportion of households receiving grid-equivalent electricity supplies may be only around 15%[1]. Access to electricity is very inequitably distributed. Only 5% of rural households have access to grid-equivalent electricity compared to 55% of urban households.

The low electrification rate in Cambodia compares to electrification rates in neighbouring Lao PDR and Vietnam of 60% and 95% respectively. The pace of electrification in Cambodia also lags behind its neighbours. In the past 10 years, electrification rates in Lao PDR and Vietnam have grown by 30%.

The state-owned Electricité du Cambodge (EDC) supplies around 287,000 customers across the country. Around 155 small Rural Electricity Enterprises (REEs) supply a further 130,000 customers. Of these, 140 REEs operate isolated mini-grids supplying 85,000 customers in total or an average of 600 customers per licensee[2].

Meeting the RGC's targets implies connecting around 100,000 rural households annually to 2030, or 2.1 million rural households in total. The vast majority would be through grid connection, representing over 80% of all additional connections to 2030. The total cost of an electrification programme of this magnitude is estimated at US$ 1.5 billion. During the first five years of the electrification programme, 320,000 rural households would be connected to grid electricity supplies, 130,000 to mini-grids supplied by renewable energy sources and diesel generation and a further 30,000 would receive electricity from solar power. The rural electrification rate would increase to 27%. The investment cost over this initial five years would be US$ 275 million or around US$ 55 million annually of which US$ 195 million or US$ 40 million annually is needed for grid expansion. The programme is shown graphically below.

Figure 1 - Rural Household Electrification Rates

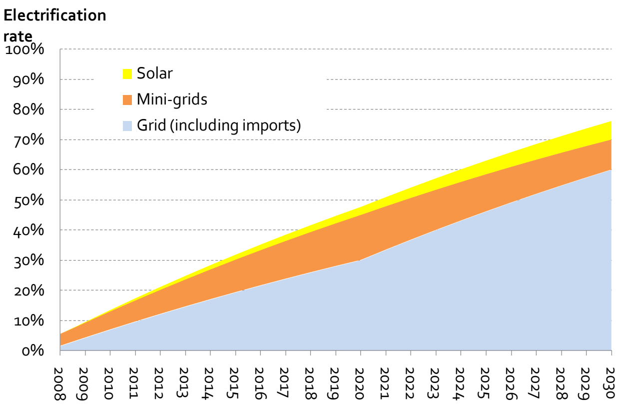
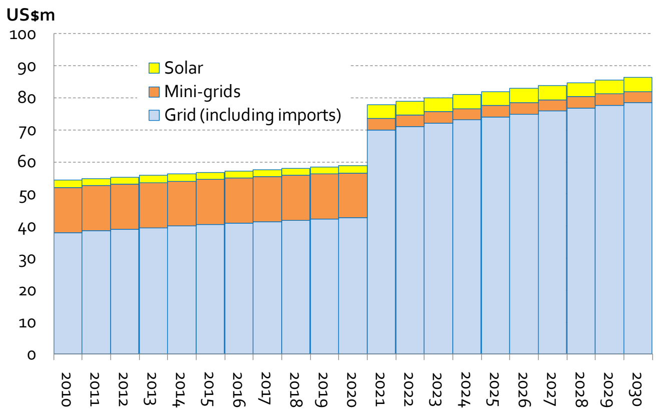


Figure 2 - Rural Electrification Capital Costs



[1] The 2008 Census implies much greater rates of access to grid and mini-grid electricity of around 26% of households in total and 13% of rural households. The reasons for the significant difference from EAC data are unclear.

[2] EAC data as at end-2007. The number of licensees has subsequently increased to around 175 REEs operating mini-grids and 23 operating grid-connected distribution networks. However, corresponding customer numbers are not readily available.

Strategy

Sector Structure

The large-scale grid electrification programme required will need to be centrally co-ordinated and planned. EDC is the only existing institution with the necessary capacity and remit to undertake this role. The strategy therefore envisages that:

- EDC will be responsible for grid electrification planning, under the overall direction of the Ministry of Industry, Mines and Energy (MIME), and for investing in and operating the rural MV subtransmission network. Existing MV lines owned by REEs will be incorporated into EDC's network as this expands - initially by leasing of these lines with a subsequent option to purchase.
- REEs will supplement EDC's electrification efforts by investing in new LV distribution networks, connected to EDCs subtransmission network, and in isolated mini-grids and off-grid electricity solutions where grid electrification is either not planned or will take significant time.
- Where REEs fail to develop distribution networks adjacent to the subtransmission network, EDC will construct these networks and lease them to REEs to operate.

In the longer-term, as electrification rates increase, attention will shift to ensuring long-term sustainability of rural electricity supplies. It is expected that this will require gradual consolidation of REEs into EDC, although some larger REEs may continue. As the terms of REE licences expire, they would generally be expected to transfer their assets to EDC on payment of suitable compensation. REEs would continue to provide billing, collection and some maintenance services under contract to EDC.

Within EDC, electrification should be the responsibility of a separate Rural Electrification Office (REO), with ring-fenced finances. As well as improving management focus and providing a centre of expertise, this will make clear the costs of the electrification programme and its impacts on EDC's commercial performance. The REO should include within it a unit responsible for the promotion of productive electricity uses in rural areas in order to increase demand and improve the affordability of electricity supplies.

Financing and Subsidies

Subsidies for part of the capital costs of the programme will be required, in order to ensure the affordability of supplies. Subsidies are expected to largely come from donors and international financing institutions and would be coordinated through RGC.

Subsidies will be provided through three routes:

- **EDC** - Subsidies to EDC will generally take the form of concessionary onlending and grants from the Ministry of Economy and Finance (MEF). EDC's tariffs must be sufficient to recover all reasonable costs meaning that there will be a clear trade-off between tariff levels and the degree of concessionality in such financing.
- **REEs** - Subsidies to REEs will be channelled through the existing Rural Electrification Fund (REF). Subsidies are expected to comprise a mixture of direct grants, delivered on an output-based aid (OBA) basis, and partial guarantees to commercial lenders allowing these to offer loans to REEs at lower cost and for longer duration than are currently available. The combination of grants and near-market loans will reduce capital costs recovered from customers while helping maintain incentives for REEs to ensure investments are commercially viable[3].
- **Customers** - Direct subsidies to customers will take the form of connection loans provided on concessionary terms for poorer households. These will be provided from the REF via suppliers (EDC and REEs). Rural customers will also benefit from capital cost subsidies to EDC and REEs and cross-subsidies from urban customers.

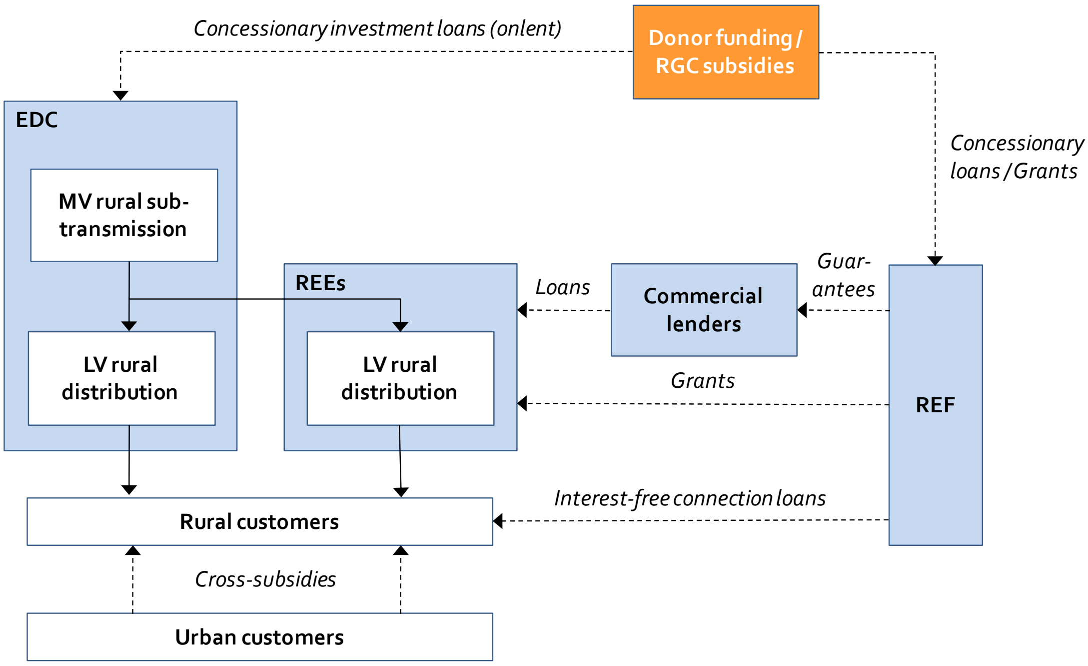
The allocation of funds between these uses will depend on need. Initially, allocations should be prepared on the assumption that REEs will be responsible for the connection of around 75% of rural LV distribution

[3] Alternative approaches may be needed in some instances, such as funding for off-grid solutions such as Solar Home Systems (SHS) . REF has recently shifted from an OBA approach to funding SHS to bulk procurement of systems for distribution to rural entrepreneurs. The appetite for commercial banks in Cambodia to provide part-guaranteed loans to REEs is currently being investigated under an AusAID project supporting REF.

households. If this figure proves too high or low in practice, funds should be reallocated to or from EDC and the REF.

The subsidy mechanisms for grid electrification are illustrated below.

Figure 3 - Grid Electrification Funding



Tariffs

The costs of supply to rural customers exceed those of supplies to urban customers. The costs of grid electricity supplies may be around USc 23/kWh and the costs of mini-grids will be higher than this. By comparison, initial estimates of the ability of rural customers to pay for grid electricity supplies are around USc 13-17/kWh.

Costs can be expected to fall as supplies from hydro and coal generation located in Cambodia and from imports increase, displacing existing oil-fired generation. Reductions will be possible in EDC's own costs, and tariffs should be designed to provide the appropriate incentives for this. Electrification costs can also be reduced through the adoption of a) a higher degree of standardisation and b) lower-cost technologies where feasible[4].

However, subsidies will remain necessary to reduce rural electricity prices to affordable levels. Capital cost subsidies will help but there may also be a need for cross-subsidies from urban customers. Making such cross-subsidies sustainable requires that urban customers are not seen to be unfairly treated relative to rural customers who are more expensive to serve and that tariffs do not fall below the levels required for EDC and REEs to remain viable.

The strategy therefore establishes a number of principles for setting rural electricity tariffs:

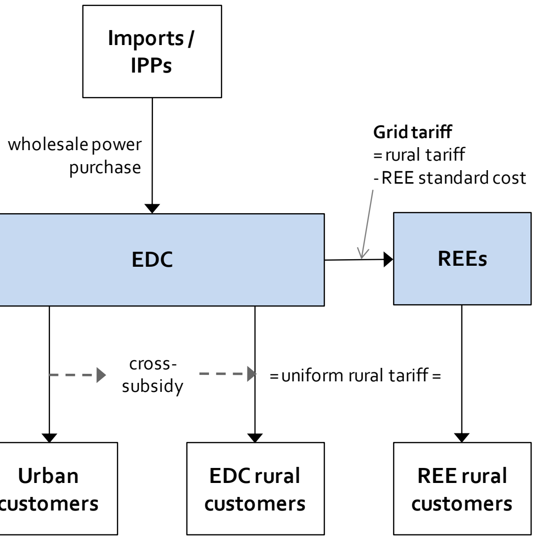
- Most importantly, tariffs across EDC and REEs should allow the full recovery of costs
- Rural tariffs for grid-connected customers should be uniform across rural households, to avoid favouring those supplied through EDC or REEs
- Rural household tariffs should be set at an affordable level, subject to their:
    - Covering at least the ongoing costs (i.e. excluding capital costs) of supply
    - Not being lower than the most expensive equivalent urban household tariff
- Tariffs for mini-grids will generally continue to be set on the basis of actual costs, subject to an assessment of reasonableness.

[4] For example, Single Wire Earth Return (SWER) lines may be appropriate for supplying smaller rural loads at low cost. However, the scope for their use is limited during the early stages of the RE programme as more densely populated areas will be initially targeted.

Current EDC tariffs may well fall below the full costs of supply. There is an urgent need for an independent assessment of EDC's costs and required tariffs and of the ability of rural customers to pay for electricity supplies.

Grid or bulk supply tariffs for sales from EDC to REEs will be set as the uniform rural tariff less a standard REE cost allowance. This will provide incentives for REEs to be efficient and to seek to reduce costs (for example, through mergers). This arrangement is illustrated below.

Figure 4 - Grid Charging Arrangements



Implementation Plan

The implementation plan is divided into immediate policy decisions, that must be taken before the strategy can be implemented, and follow-up actions that will support the strategy's implementation.

Policy Decisions

Recommended policy decisions include:

- EDC will take the lead role in rural grid electrification
- Rural electrification rates will be one of the indicators used to assess EDC's performance
- REEs will continue to develop LV distribution networks and mini-grids, as a complement to EDC's efforts. EAC will be responsible for coordinating the activities of REEs with EDC through the licensing process in order to avoid duplication of effort
- In the longer-term, government policy is to encourage consolidation of REEs into EDC or larger regional companies. Such consolidation is to be voluntary and REEs are to receive fair compensation for assets transferred
- Capital subsidies to EDC will be provided through onlending and grants and to REEs through a combination of grants from the REF and the provision of REF partial guarantees to commercial lenders. Poorer customers will be eligible for connection loans provided from REF
- EDC's tariffs are to be set at a level that recovers its full costs of supply and EDC is not required to incur losses as a result of its rural electrification programme
- Rural household tariffs for grid-connected customers will be based on affordable tariffs, subject to requirements that they will always cover ongoing costs at a minimum and are not below equivalent urban tariffs. A uniform tariff will apply for all rural household customers
- In the medium-term, grid or bulk supply tariffs charged by EDC to REEs will be set by deducting a standard cost allowance, determined by EAC, from the uniform rural retail tariffs[5].

[5] For the short-term, the recently-approved mechanism developed by EAC and based on discounts for distance of REEs from load centres can remain in effect.

Follow-up Implementing Actions

These actions follow once the key policy decisions have been made. Many of the actions are likely to require support in the form of Technical Assistance projects. These are identified by a (TA) in parentheses below.

MEF / MIME

- Convene a donor conference to establish availability of funds over a 5-10 year period to support electrification activities
- Update electrification programme targets based on funding availability (TA)
- Establish initial allocation of funds between EDC and REF (TA).

MIME / EAC

- Commission full study of EDC's costs and required tariffs (TA)
- Commission study of affordability of rural electricity supplies (TA).

EAC

- Define rules for allocation of new distribution areas, including provision for allocation to EDC where REEs fail to express willingness to develop areas in a timely fashion
- Amend rules as required to facilitate future consolidation of licensees and leasing of assets
- Develop and enforce rules for approval of REE plans for ensuring full coverage of licensed areas[6]
- Develop rules for setting rural grid-connected tariffs and, in the medium-term, grid / bulk supply tariffs. Following completion of the tariff study and affordability study, prepare and issue new tariffs (TA).

EDC

- Implement the MV planning TA under the RETP and begin provincial planning activities (TA)
- Assess capacity-building requirements for implementation of expanded rural electrification role and undertake capacity-building programme (TA)
- Establish a separate REO to lead rural electrification activities (TA)
- Identify REE MV assets required for use as part of the subtransmission network and negotiate to lease these.

REF

- Finalise partial guarantee mechanism for commercial lending to REEs, based on ongoing AusAID work (TA)
- Update existing grant mechanism for REE distribution network extensions to include new REEs (TA)
- Review success of revised support mechanisms for micro-hydro and SHS and develop appropriate future mechanisms for these and for other mini-grid technologies based on OBA grants and commercial lending (TA)
- Develop customer connection loan scheme (TA).

World Bank and other donors / international financing institutions

- Provide necessary financing commitments
- Support RGC in investigating access to additional sources of finance (e.g. CDM /Carbon Fund)
- Support implementation of the strategy through identified TA activities.

[6] This is already a licence obligation but does not appear to be enforced in practice.

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1.0 Introduction

1.1 Background to the Project

This **Final Rural Electrification Strategy and Implementation Plan Report** is submitted to the Ministry of Industry Mines and Energy (MIME) and the World Bank by AECOM NZ New Zealand Ltd (Aecom NZ) in association with Economic Consulting Associates (ECA) Ltd. and R&N Engineering Consultants under the **Cambodia: Rural Electrification Strategy and Implementation Plan**.

The purpose of this study is to develop a National Rural Electrification Strategy for Cambodia. Based on appropriate technical, economic, financial and social analysis and organisational requirements, the study is expected to provide a detailed five year **Rural Electrification Implementation Plan** for Cambodia. The study plans to integrate grid and off-grid planning, and isolated technologies to see how to most effectively achieve the electrification target.

Consultation was undertaken with all Working Group members throughout the project, as well as with other stakeholders including multilateral financing institutions and bilateral donors. A full list of persons met during the preparation of the Strategy is provided in Appendix 1. Aecom NZ would like to take this opportunity to express thanks to all those whom the team met and who contributed during the development of this strategy plan.

This introductory section describes the project objectives, context and implementation arrangements. Subsequent sections provide a review of the sector and identify the major issues addressed in preparing the strategy.

1.2 Activities

The contract between the World Bank and AECOM NZ New Zealand Ltd for the study was signed on 07 July 2009. The project commenced with an inception visit to Cambodia from 13 to 25 July 2009. A further visit occurred from 01 September to 08 September 2009 for the Inception Workshop which was held on 04 September in Phnom Penh. Subsequent to the workshop the findings of the Inception Workshop were presented in the Inception Report which was issued on 28 September 2009.

The final scheduled visit occurred from 01 to 05 December 2009 for the Rural Electrification Strategy and Implementation Plan Workshop which was held on 04 December 2009 in Phnom Penh. This was attended by representatives of all major stakeholders involved in rural electrification in Cambodia including Working Group members. The workshop was used to present the draft findings of the Aecom NZ team on the key issues and challenges facing rural electrification in Cambodia. A copy of the workshop agenda and list of participants is provided in Appendix 2 and notes from the workshop discussions are provided in Appendix 3.

The principle conclusions from the Workshop, together with comments received from the World Bank, are included in this **Final Rural Electrification Strategy and Implementation Plan Report**.

The Terms of Reference for this project require that the Rural Electrification Strategy is based on existing documentation and that further primary studies should not be undertaken as part of this project, excepting limited field research by local members of the consultant team. The project is expected to synthesise and integrate existing recommendations developed from previous studies. The issues relating to rural electrification policy and approach have been extensively reviewed in Cambodia in recent years and numerous reports exist. A large number of documents were collected for review during the formulation of the Rural Electrification Strategy; these are discussed further in Section 1.5

The purposes of the Rural Electrification Strategy and Implementation Plan are to:

- Provide a draft Rural Electrification Strategy for review
- Provided a 5 year Rural Electrification Implementation Plan based on the recommended rural electrification strategy
- Confirm the key issues to be addressed under the rural electrification (RE) distribution and implementation strategy

- Provide initial thinking on responses to these issues. At this stage, this is provided as a basis for review by stakeholders. The stakeholders' recommendations will be confirmed in the Final Report.

1.3 Project Objectives

The objectives of the Rural Electrification Strategy and Implementation Plan are to assist the Royal Government of Cambodia (RGC) in:

a) Preparing a comprehensive strategy for increasing rural access to electricity to the meet the electrification targets set by the RGC
b) Preparing an implementation plan for the next five years to achieve strategy objectives
c) Preparing alternatives and options for financing the investment plan for meeting rural electricity needs
d) Reviewing the roles of the institutions involved in rural energy such as MIME, Electricité du Cambodge (EDC), the Electricity Authority of Cambodia (EAC), the Rural Electrification Fund (REF) and the private sector and redefine these roles if necessary
e) Determining capacity building needs of the major sector institutions in order to achieve the strategy objectives.

The overall objective of the project is to support MIME in the development of a rural energy strategy and accompanying initial implementation plan which will set out the future policy to be adopted with respect to grid extension and off-grid technologies for rural electrification in Cambodia. The strategy and plan, if adopted by the RGC are expected to form a basis for co-ordinating the activities of stakeholders involved in rural electrification - in particular MIME, EDC, EAC, REF and existing and potential donors.

In 2006, RGC established the following electrification targets:

- 100% of villages receiving electricity supplies by 2020
- 70% of households receiving grid-equivalent electricity supplies by 2030.

The figure of 100% of village receiving **electricity supplies** by 2020 includes supply through battery charging stations served by diesel generators (BCS), solar battery charging stations (SCS) and solar home systems (SHS).

These targets were reviewed in the JICA-supported Master Plan for Rural Electrification by Renewable Energy (JICA MP), issued in 2006. This noted that, as the 2020 target included electrification by technologies such as batteries which offer less than grid-equivalent supply quality, the targets should be revised to express them in terms of household electrification rates as follows:

- 47% level of households receiving grid-equivalent electrification by the year 2020
- 70% level of households receiving grid-equivalent electrification by the year 2030.

Discussions of electrification strategies and plans frequently suffer from confusion over what „electrified' actually means. The terms used in this Report with respect to electrification status and source are set out in Table 1. In this Report, reference is made to both the targets established by RGC and the proposed interim target contained in the JICA MP in assessment of the feasibility of these targets.

Table 1 - Rural Electrification Definitions

Nº	Term	Definition
1	Rural Area	A district or commune which is not part of a provincial capital or designated municipality.
2	Potential Area of Grid Extension (PAGE)	A rural area which has the potential to be supplied by grid electricity. At present, in Cambodia, this is defined as areas within a 40 km radius of provincial capitals with the exception of the Phnom Penh-Kandal and Kampot-Kep conurbations, which cover a greater contiguous area due to higher population density. The appropriateness of this defined area is discussed later in this report
3	National Grid	The HV inter-connected transmission grid owned and operated by EDC

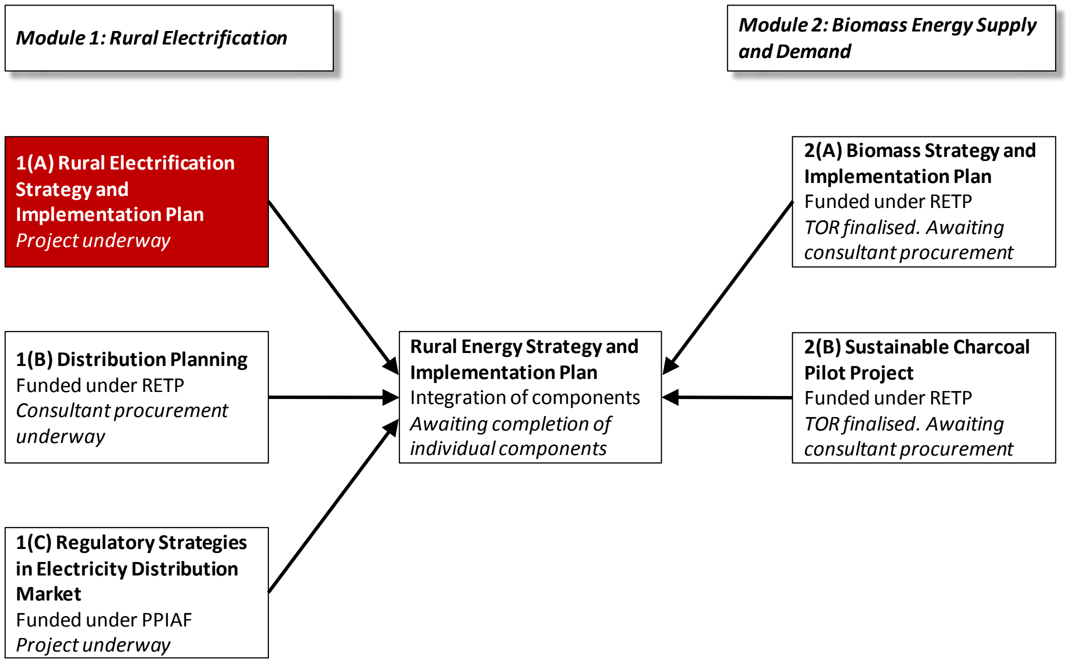
Nº	Term	Definition
4	Grid Substation	A HV (230 kV or 115 kV) substation, connected to the national grid, There are plans to build a grid substation at each provincial capital.
5	Subtransmission	The MV grid extending into rural areas from Grid Substations, and which is connected to LV distribution grids in these areas
6	On-Grid Area	Those areas supplied by grid electricity. Depending on the context, this may either refer to areas currently supplied by grid electricity or areas that are expected to be supplied by grid electricity in future (i.e., including PAGEs)
7	Off-Grid Area	Those areas outside the On-Grid Area. These are areas which, depending on the context, are either not currently supplied by electricity or that, for economic reasons, are never likely to be connected to grid electricity
8	Grid Electricity	Supply either from the National Grid through the Subtransmission network or through electricity imports over an inter-connection to the national grid in a neighbouring country
9	Grid-Connected Household	A household receiving supply from Grid Electricity
10	Pre-Grid Household	An Electrified Household supplied from a source other than Grid Electricity and which are expected to be connected to Grid Electricity
11	Grid Conversion	The conversion of Pre-Grid Households to Grid-Connected Households
12	Off-Grid Household	An Electrified Household supplied by electricity from a source other than Grid Electricity and which is not expected to be connected to Grid Electricity. The sum of Pre-Grid Households and Off-Grid Households represents Electrified Households without a current Grid Electricity connection
13	Grid Extension	Extension of the area supplied with Grid Electricity
14	Grid Intensification	The connection of households to Grid Electricity within areas already supplied with Grid Electricity
15	Mini-Grid	A LV distribution grid that is isolated from both the National Grid and from imported grid electricity supplies and instead has its own electricity generation source
16	Grid Equivalent Supply	An electricity supply capable of supplying a household with more than 20 kWh per month. Supply by batteries, solar lanterns or smaller size SHS which supply less than 20 kWh per month would not generally be considered to provide a Grid Equivalent Supply
17	Electrified Household	A household receiving Grid Equivalent Supply
18	Electrified Village	A village in which when most community facilities and more than 50% of households are electrified.

1.4 Project Context

This project is one among a number of studies commissioned by the World Bank to support the development of an overall Rural Energy Strategy and Implementation Plan. These various studies are shown in Figure 5. The current project is component 1(A) of the overall Rural Energy Strategy.

It was originally intended that this project would involve both the preparation of the Rural Electrification Strategy and Implementation Plan and the integration of this and the various other strategies and plans being prepared under the World Bank-supported Rural Electrification and Transmission Project (RETP) and under PPIAF support into a single Rural Energy Strategy and Implementation Plan. However, to date work has only commenced on one other of the various components of the Rural Energy Strategy - component 1(C) on the preparation of Regulatory Strategies in the Electricity Distribution Market. In recognition of this, it was agreed during the inception phase of this project that its scope would be limited to the preparation of the Rural Electrification Strategy and Implementation Plan alone, although reference will be made to other components of the overall Rural Energy Strategy to the extent that these become available as this project progresses.

Figure 5 - Components of the Rural Energy Strategy and Implementation Plan



1.5 Major Documents Consulted

The Rural Electrification Strategy and Implementation Plan is primarily based on a) field research by Aecom NZ, ECA and local counterparts, b) interviews with local practitioners in specialist areas (solar PV, biomass gasification) and c) a review of secondary literature,

Aecom NZ assembled and reviewed the following major documents which formed the basis for preparing the Rural Electrification Strategy and Implementation Plan:

- Power Sector Development Plan (PSDP, 2006). The PSDP provides a detailed plan to meet demand by thermal and hydro power generation and high voltage transmission lines until year 2024
- Master Plan for Rural Electrification by Renewable Electrification (2005) provides a blue print to increase rural access by 40% by 2020 with a financing plan of $427 million by utilising site specific, least cost renewable energy technologies as well as grid extension.
- Power Transmission Master Plan and Rural Electrification Strategy - HECEC Australia Pty. Ltd., June 1998
- Cambodia Energy Sector Strategy - MIME, 2006, Outlines the rural electrification household and village targets
- Energy Sector Strategy Review: Issues Paper - World Bank, April 2006
- Electricity Law, February 2001
- Royal Decree on Rural Electrification Fund, December 2004
- Rural Electrification Fund Operations Manual
- Draft Renewable Energy Policy, May 2005
- Renewable Energy Tax Rationalisation Report, World Bank - ESMAP, January 2007
- Overview of the Cambodia Power Sector, JICA, issued June 2009
- EDC Annual Report 2007, issued December 2008
- EAC Report on the Power Sector Cambodia 2007, issued September 2008
- Provisional population totals, 2008 population census of Cambodia, NIS.

1.6 Electrification Rates

Two main sources for current national electrification rates are available:

- The 2008 Census Final Results
- The Annual Report on the Electricity Sector, issued by EAC (2007 edition).

According to the 2008 Census, 87% of urban and 13.1% of rural households have access to electricity supplies defined as the use city power (which are taken as equivalent to grid electricity supply) or diesel generators (which are taken as equivalent to mini-grids) or both as the main source of lighting. Nationally, 24.7% of households have access to city power (including those supplied by both grid and mini-grid sources) while 1.7% are supplied by mini-grids.

The 2007 Annual Report gives numbers of customers supplied by licensees and located in different areas. These will slightly overstate the numbers of households supplied, as customer numbers include non-household customers, but not by much.

In 2007, the number of customers supplied by grid electricity, which are defined as those supplied by either EDC or distribution licensees, was 325,000. A further 90,000 customers were supplied by mini-grids, defined as those supplied by consolidated and retail licensees.

The customer data available in the 2007 Annual Report does not distinguish between urban and rural areas on the same basis as the 2008 Census. It is assumed that urban areas are comprised of the Phnom Penh system and other provincial towns, with other areas, including those supplied by cross-border lines, being considered rural. This gives a total of 290,000 urban customers and 125,000 rural customers.

Unfortunately, the resulting estimated electrification rates are far lower than those reported in the 2008 Census, as shown in the comparison in Table 2. The 2007 Annual Report gives a national estimated household electrification rate of 15% and of 5% in rural areas compared to the 2008 Census figures of 26% and 13% respectively. Within these totals, the 2007 Annual Report appears to suggest twice as many customers are supplied from mini-grids as the 2008 Census reports (assuming definitions in this Report are correct). These differences are very significant in estimating the additional connections required to meet the Government's electrification targets and, consequently, the costs of reaching those targets.

Table 2 - Estimates of Electrification Rates in Cambodia

	Total			Urban	Rural
All households	2,817,637			531,300	2,286,337
Supply source	**Grid**	**Mini-Grid**	**Total**	**Total**	**Total**
2008 Census: Electrification rate	24.7%	1.7%	26.4%	87.0%	13.1%
Electrified households	695,111	48,463	743,574	462,231	299,510
2007 EAC Annual Report: Electrification rate	11.5%	3.2%	14.7%	54.8%	5.4%
Electrified households	325,121	90,020	415,141	291,358	123,783

The sum of electrified urban and rural households for 2008 Census data does not equal the national total due to rounding in reported percentage figures.

Possible reasons for these differences might include:

- ***The existence of large numbers of unlicensed electricity suppliers***. However, unlicensed suppliers would generally be expected to take the form of mini-grids in rural areas which are actually higher under the Annual Report data (assuming city power is correctly categorised as equivalent to grid supply).
- ***Multiple households being supplied from a single customer connection***. It is not known how widespread this is in Cambodia. However, such multiple or „house to house' connections in rural areas might help explain the much higher rates of rural electrification reported in the 2008 Census, which measures household access to electricity, relative to the 2007 Annual Report, which measures the number of formal connections.
- ***Inaccuracies in the customer numbers reported by licensees***. The accuracy of these numbers cannot be verified but it is unlikely that actual numbers would differ from reported numbers to the extent implied by the census data.
- ***Inaccuracies in the census returns***. Again the accuracy of the numbers reported in the census cannot be verified, but it is assumed that a rigorous auditing and verification process will have been applied and the numbers are, therefore, reliable.

- ***Differences in definitions of electricity***. It is possible that some households have misreported their supply source due to a misunderstanding of the census requirements. It may also be that the classification „city power' used in the census includes customers supplied from isolated mini-grids but not from their own diesel generator. This might explain the very high levels of city power supply reported in the 2008 Census relative to estimates of grid-connected customers from the 2007 Annual Report.
- ***Differences in definition of areas***. The 2008 Census defines urban areas by population density (primarily). As such, its definition of urban areas differs from that used for administrative purposes which is the basis for the split between urban and rural areas applied in the 2007 Annual Report. This may partly explain the differences in reported urban electrification rates - assuming the total number of households considered to lie in urban areas is lower in the 2007 Annual Report than the 2008 Census, then the electrification rate in urban areas as defined in the 2007 Annual Report will be higher than shown in Table 2. However, this also implies the rural electrification rate is even lower.

In this Report, estimates of connection rates and investment needs are calculated assuming electrification rates equivalent to those in the 2007 Annual Report, rather than in the 2008 Census. This approach has been adopted for the following reasons:

- The 2007 Annual Report gives much lower electrification rates and, therefore, higher required connection rates and investment needs to meet Government targets. They, therefore, represent a high-end estimate of these needs. If actual electrification rates prove to be higher than estimates then the additional estimated investment needs, if fully financed, are not wasted but would simply lead to electrification rates exceeding Government targets.
- If the differences between the reported electrification rates are due to unlicensed suppliers and/or multiple households using a single connection then it appears unlikely that this represents grid-equivalent supplies (the requirement under the Government targets). Unlicensed suppliers will generally offer very poor quality supply while multiple household connections will also suffer from unreliable supplies and limits on consumption.

To obtain the number of households connected through different means in rural areas, it is assumed that all urban customers are grid-connected. This gives the following baseline electrification rates which form the starting point for projections of required connection rates and investment needs to meet RGC's targets.

Table 3 - Baseline Electrification Rates

	Total			Urban			Rural		
All households	2,817,637			531,300			2,286,337		
Supply source	**Grid**	**Mini-Grid**	**Total**	**Grid**	**Mini-Grid**	**Total**	**Grid**	**Mini-Grid**	**Total**
Electrification rate	11.5%	3.2%	14.7%	54.8%	0.0%	54.8%	1.5%	3.9%	5.4%
Electrified households	325,121	90,020	415,141	291,358	0	291,358	33,763	90,020	123,783

2.0 Technical, Economic and Financial Analysis

This section provides an analysis of the scale of electrification programme required to meet the RGC's targets, the mix of technologies and the costs of the programme. The section initially provides an overview of the electrification technologies considered and their costs. It then reviews available supply and demand forecasts for the Cambodian power system to assess whether supply constraints may limit the electrification programme. Based on this analysis, the proposed selection of technologies for different components of the electrification programme is described. The section concludes by providing projections of the costs of meeting the RGC's targets and an assessment of the reasonableness of these compared to available financing.

2.1 Electrification Technologies and Costs

Electrification technologies and their associated costs are indicative in nature as the costs associated with different technologies can be rapidly outdated. For example the cost of diesel generation has been particularly affected by the recent volatility of diesel fuel prices, the cost of diesel fuel peaked at $1.11/litre[7] in July 2008, dropped to USc 34 /litre in December 2008 and presently sits at USc 55-60/litre (April 2010). Going forward the diesel fuel price is forecast to rise to USc 73 /litre by 2015[8]. Such changes in fuel prices lead to major changes in the costs of diesel-generated electricity and, as a result, its affordability and competitiveness relative to other electrification technologies. Other major sources of uncertainty over costs include the distance from the existing grid, population density, presence of community facilities and productive energy uses and changes in the costs of technologies as the scale of use increases (of particular significance for some renewable energy technologies).

2.1.1 Grid Equivalent Supply Costs

The estimated costs of the main technologies identified as offering grid-equivalent electricity supplies as presented in the JICA MP are shown in Table 4 and Figure 6. These are shown on a levellised cost of energy (LCOE) basis with costs declining as load factors and, therefore, utilisation of capital increases. During 2005, the year covered by these estimates, diesel prices in Singapore (FOB basis) were around USc 30 to 43 /litre or somewhat below current levels (as at April 2010) of USc 55-60/litre FOB Singapore and USc 91/litre Phnom Penh retail. That implies the cost of diesel mini-grids will have increased from that shown here making it less competitive against the use of other technologies. The cost of current grid supplies, which rely heavily on generation using fuel oil, will also have risen somewhat although the impacts will be mitigated by increased use of imported power.

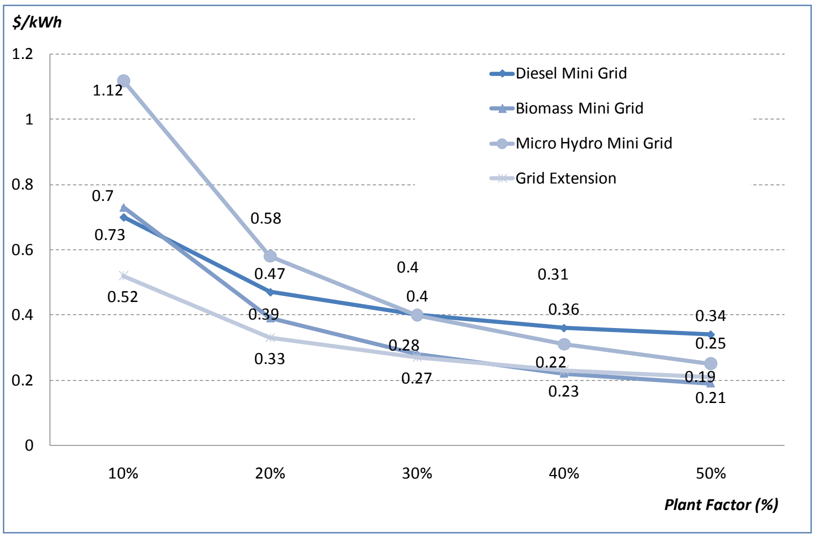
Table 4 - Grid Equivalent Electrification Costs, Energy Cost and Plant Factor

	Unit	Diesel Mini-Grid	Biomass Gasification Mini-Grid	Micro-hydro Mini-Grid	Grid Extension
Capital Cost	$/household	424	592	1,229	467
Levellised Cost of Energy	$/kWh @ PF=10%	0.7	0.73	1.12	0.52
Levellised Cost of Energy	$/kWh @ PF=20%	0.47	0.39	0.58	0.33
Levellised Cost of Energy	$/kWh @ PF=30%	0.40	0.28	0.40	0.27
Levellised Cost of Energy	$/kWh @ PF=40%	0.36	0.22	0.31	0.23
Levellised Cost of Energy	$/kWh @ PF=50%	0.34	0.19	0.25	0.21

Source: Master Plan for Rural Electrification, MIME, 2006. Capital costs for grid extension do not include the capital costs of HV transmission and grid-connected generation.

7 Singapore Gasoil Spot Price ,FOB, Energy Information Administration, http://tonto.eia.doe.gov/dnav/pet/hist/rgosin5d.htm
8 Electric Power Distillate Fuel Oil, Petroleum Product Prices, EIA, March 2009, http://www.eia.doe.gov/oiaf/forecasting.html

Figure 6 - LCOE for Grid Equivalent Electrification



Source: Master Plan for Rural Electrification by Renewable Electrification (2005), MIME

Electrification solutions offering less than grid-equivalent supplies, such as centralised diesel or solar battery charging stations or SHS have a different cost structure that is not as dependent on plant factor. The costs of these various technologies are highlighted in Table 5.

Table 5 - Household Level Electrification Solutions, LCOE Energy Cost

	Unit	Diesel BCS	Solar BCS	SHS
Capital Cost	$/household	84	351	460
Levellised Cost of Energy	$/kWh	1.02	1.37	1.07

Source: Master Plan for Rural Electrification, MIME, 2006

The LCOE grid equivalent solutions noted in the *Master Plan for Rural Electrification by Renewable Energy* have been calculated on the basis of a household demand of 50 kWh/month. The LCOE of household level solutions have been calculated on the basis of a reduced demand of 3 kWh/month.

During the course of the study and as pointed out in the final workshop the cost of solar PV panels[9] have declined markedly since the *Master Plan for Rural Electrification by Renewable Energy* was published in June 2006. Accordingly the LCOE has been recalculated for SHS systems to reflect the reduction in costs of PV using a future estimated cost of $2.00 per watt peak for a SHS system including BOS components and installation. The cost of batteries for SHS are in addition to PV and BOS costs, the costs and assumptions used to derive the LCOE for SHS are outlined in Appendix 4. The resulting SHS LCOE calculations are summarised in Table 6.

Table 6 - Solar Home Systems, SHS, Revised LCOE Energy Cost

	Unit	3 kWh/hh/month	20 kWh/hh/month	50 kWh/hh/month
Capital Cost	$/household	90	570	1,450
Levellised Cost of Energy	$/kWh	0.40	0.39	0.39

Source: Consultant's Calculation, December 2009

The SHS LCOE derived of approximately 0.39 $/kWh indicates grid extension is lower cost than SHS for a grid equivalent supply in areas of medium and high population density. This analysis is based on a LCOE for grid extension in rural areas of 0.23 $/kWh

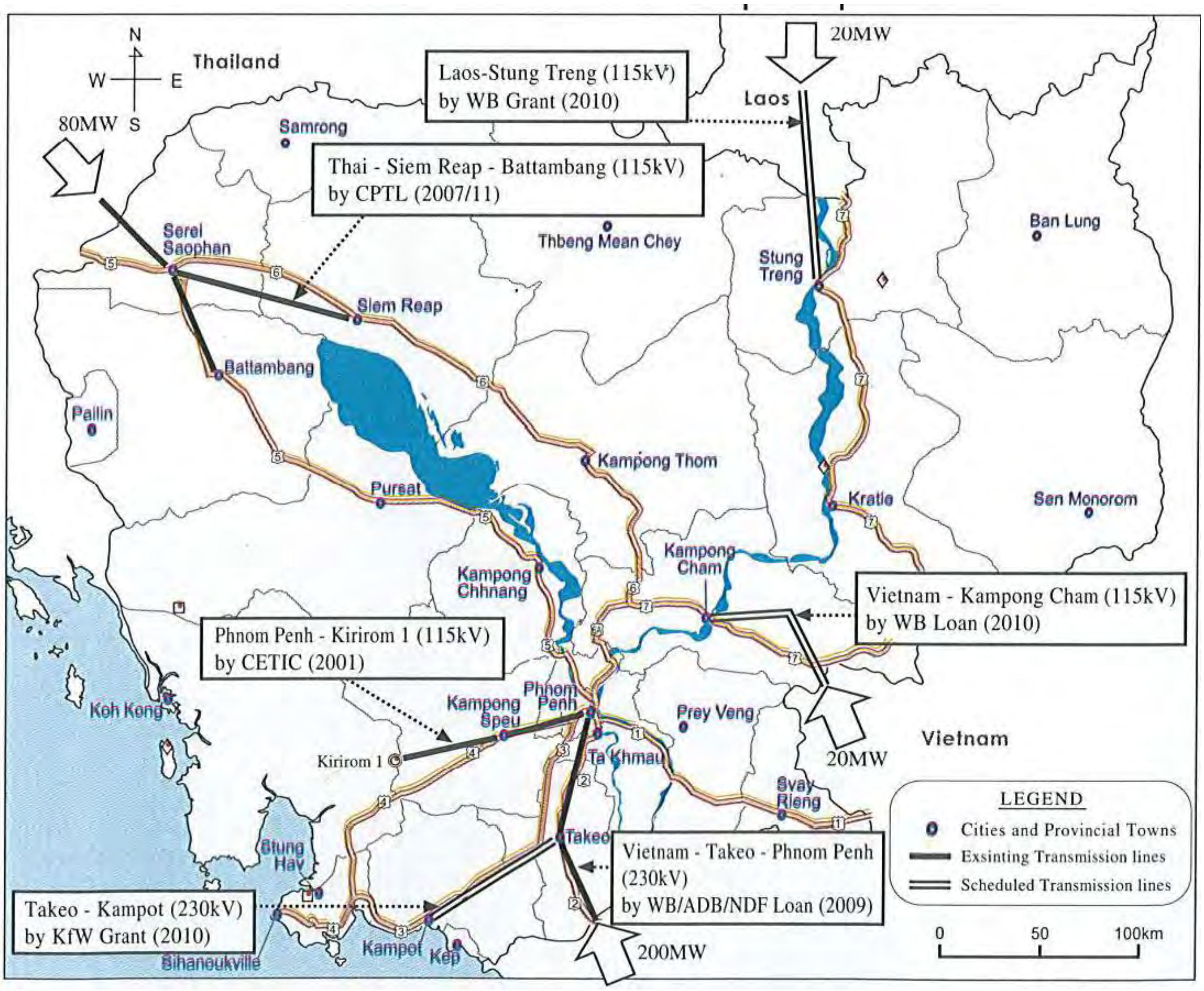
[9] The CIF cost of PV panels was advised as $1.75 USD/ Wp CIF Sihanoukville - source J. Vershelling, Kamworks, Cambodia.

2.2 National Grid Plans

2.2.1 National Grid and Interconnections

The major ongoing development in the Cambodian electricity industry is the development of a national transmission network. Initially this is taking the form of a number of HV transmission lines connecting to neighbouring countries of Vietnam and Thailand, followed later by cross-border connections to Lao PDR. This will allow the import of lower-priced power to the north-western grid and a new southern grid. Over time, these lines are expected to be extended to create a single interconnected national grid.

Figure 7 - Transmission Expansion Plan - 2010



Source: JICA Power Sector Overview, 2009

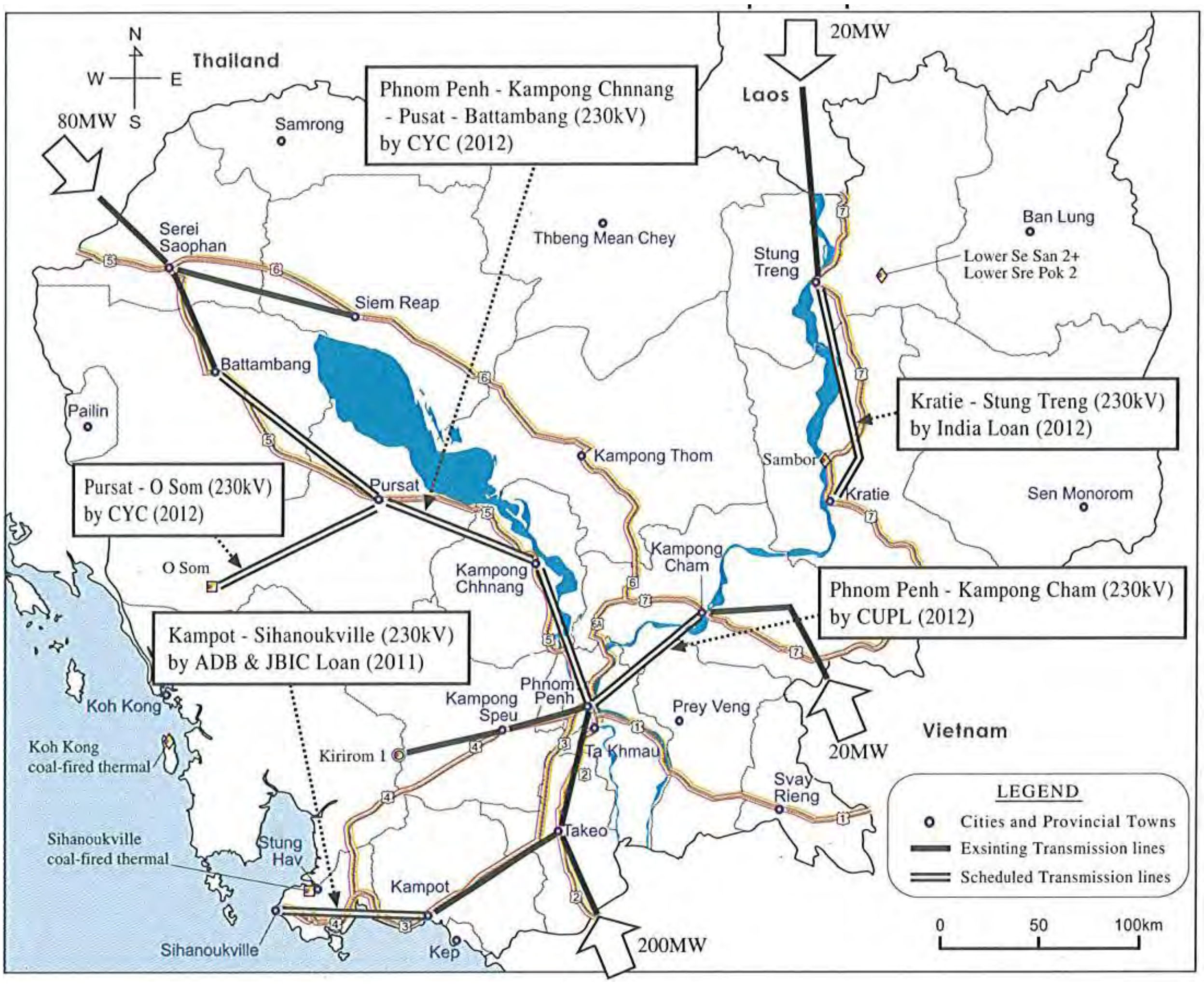
Figure 7 shows the planned transmission line expansion plan to 2010. The major transmission lines in operation or under development are as follows:

- The existing 115 kV system serving Phnom Penh
- The 115 kV north-western grid of 203 km in length connecting Thailand to Bantey Meanchay, Siem Reap and Battambang. This entered service in 2007. The line was financed and is operated by Cambodia Power Transmission Co Ltd (CPTL) under a 30-year BOT agreement with EDC. The import capacity is 80 MW
- A new 220 kV line of 110 km connecting Vietnam to Takeo and Phnom Penh (not 230 kV as noted on the maps). This line was commissioned in August 2009. The import capacity is 220 MW although initially imports will be at a lower level due to supply constraints in southern Vietnam
- The extension of transmission network at 230 kV from Takeo to Kampot and Sihanoukville, totalling 169 km. The section to Kampot is due to commission in 2010 and that to Sihanoukville in 2011

- A new 110 kV line of 68 km connecting Vietnam to Kampong Cham, due to commission in 2010. The import capacity is 20 MW
- A new 115 kV line of 56 km connecting southern Lao PDR to Stung Treng, due to be commissioned in 2010. The import capacity is 20 MW.

The next stage in the development of the grid is planned to be a 230 kV transmission line connecting Phnom Penh to Kampong Cham and on to Battambang. This will link the north-western and southern grids, creating a national grid. The scheduled operating date for this link is 2012. Also in 2012, new transmission lines linking Phnom Penh to Kratie and on to Stung Treng are planned, associated with the development of new IPPs, as outlined in Figure 8.

Figure 8 - Transmission Expansion Plan - 2012



Source: JICA Power Sector Overview, 2009

2.2.2 Generation

The other major development in the industry is the introduction of IPP generators, initially allowing the replacement of existing oil-fired IPPs and, in time, allowing Cambodia to move from an importer of electricity to an exporter as part of the developing Greater Mekong Sub-Region (GMS) power market. It is expected that this will allow reductions in EDC's average power purchase costs as a result of the reducing share of oil-fired generation.

IPPs at an advanced stage of development include:

- Kamchay hydro power plant (193 MW). This plant is under construction by Sinohydro. It will sell power to EDC's southern grid and is due to commission in 2010

- Kirirom III hydro power plant (18 MW). This is an expansion of the Kirirom hydro power plant, previously rehabilitated as an IPP by CETICI of China. The plant is due to be commissioned in 2010 but construction had not started as of end-2008
- Sihanoukville coal plant (200 MW). This plant is to be developed by Power Synergy Corporation, a Cambodian-Malaysian joint venture. A PPA and Implementation Agreement have been signed and were approved in mid-2008. It is due to commission in 2011-12. The base tariff is 7.212 USc/kWh. This project may be implemented as 2x100 MW plants with each partner being responsible for one of the plants.
- Stung Atay hydro power plant (120 MW). A concession has been awarded to a consortium led by China's Datang International Power Generating Company. Construction started in mid-2008 and the project is due to commission by 2012
- Stung Tatay hydro power plant (246 MW). An agreement was signed in June 2008 with China National Heavy Machinery Corporation. The scheduled commissioning date is 2015
- Lower Stung Russey Chrum hydro power plant (338 MW). An agreement was signed in June 2008 with Michelle Corporation of China. The scheduled commissioning date is 2014
- Stung Chhay Areng hydro power plant (260 MW). A feasibility study is underway by China Southern Power Grid. The scheduled commissioning date is 2015.

2.2.3 Supply and Demand Projections

The demand outlook has most recently been comprehensively examined in the Power Sector Development Plan (PSDP 2006) prepared by KEPCO. Three demand forecast scenarios were assumed 1) a low growth scenario, 2) a base case scenario and 3) a high growth scenario. MIME have more recently developed their own power demand forecast and this is compared with the PSDP forecast in Table 7.

The existing demand forecasts have been outdated by the latest EDC maximum demand for the year 2007 of 262 MW[10] which is in excess of the previous highest demand forecast of 192 MW.

Table 7 - Comparison of Power Demand Forecasts for Cambodia

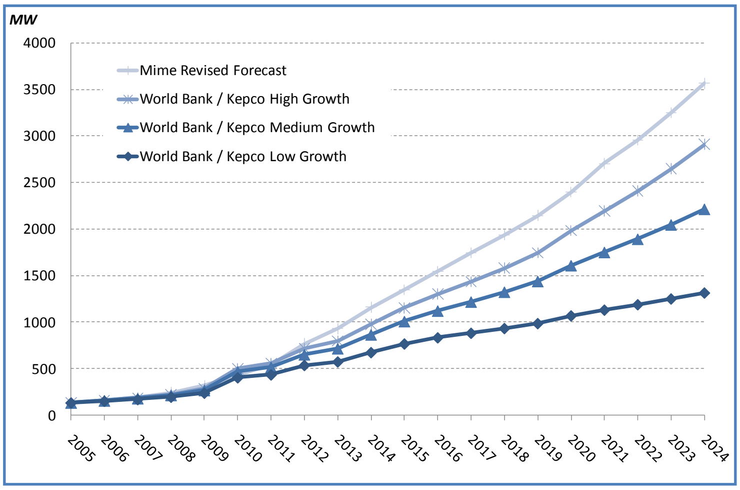
Year	World Bank / Kepco						MIME Revised	
	Low Growth		Base Case		High Growth			
	Demand	Growth Rate	Demand	Growth Rate	Demand	Growth Rate	Demand	Growth Rate
	(MW)	(%)	(MW)	(%)	(MW)	(%)	(MW)	(%)
2005	134		134		134		130	
2006	152	13.43	156	16.42	159	18.66	158	22.25
2007	170	11.84	180	15.38	186	16.98	192	21.33
2008	196	15.29	215	19.44	225	20.97	240	25.00
2009	239	21.94	268	24.65	284	26.22	318	32.43
2010	404	69.04	467	74.25	502	76.76	432	35.69
2011	435	7.67	516	10.49	561	11.75	546	26.35
2012	537	23.45	652	26.36	719	28.16	768	40.87
2013	575	7.08	717	9.97	800	11.27	931	21.10
2014	675	17.39	866	20.78	979	22.38	1,160	24.68
2015	768	13.78	1,009	16.51	1,155	17.98	1,349	16.27
2016	834	8.59	1,122	11.20	1,302	12.73	1,546	14.57
2017	883	5.88	1,219	8.65	1,435	10.22	1,746	12.94
2018	934	5.78	1,325	8.70	1,582	10.24	1,937	10.98
2019	987	5.67	1,440	8.68	1,746	10.37	2,148	10.84
2020	1,070	8.41	1,610	11.81	1,985	13.69	2,401	11.80
2021	1,132	5.79	1,752	8.82	2,195	10.58	2,708	12.78
2022	1,190	5.12	1,894	8.11	2,409	9.75	2,958	9.26
2023	1,252	5.21	2,048	8.13	2,647	9.88	3,254	9.98
2024	1,316	5.11	2,216	8.20	2,912	10.01	3,571	9.77

Source: Power Sector Overview, June 2009

[10] Table 6: Breakdown of Yearly Peak Demand, MW, EDC Annual Report 2007, published December 2008

The various demand forecasts are compared graphically in Figure 9.

Figure 9 - Comparison of Power Demand Forecasts



Source: Master Plan for Rural Electrification by Renewable Electrification (2005), MIME

The generation expansion plan set out in the EDC 2007 Annual Report is the most recent plan; this is shown in Table 8. It is understood that this plan is derived from the PSDP 2006.

Table 8 - Generation Expansion Plan 2009-20021

Year	Project	Type	Capacity (MW)	Total (MW)
2009	Existing Installed Capacity plus Imports (EDC 2007)	Existing	437	437
2010	Stung Treng - Lao Import	Import	10	650
	Kamchay	Hydro	193	
	Kampong Cham - Vietnam Import	Import	10	
2011	Kirirom III	Hydro	18	768
	200 MW Coal Power Plant in Sihanoukville (I) (phase 1)	Coal	100	
2012	Stung Atay Hydro Power Plant	Hydro	110	978
	200 MW Coal Power Plant, Sihanoukville (I) (phase 2)	Coal	100	
2013	Retirement - C3	Diesel	-3	1413
	700 MW Coal Power Plant, Sihanoukvule (II) (phase 1)	Coal	100	
	Lower and Upper Russey Chhrum Hydro Power Plant	Hydro	338	
2014	700 MW Coal Power Plant, Sihanoukville (II) (phase 2)	Coal	100	1,513
2015	Stung Tatay Hydro Power Plant	Hydro	246	1,901
	700 MW Coal Power Plant, Sihanoukville (II) (phase 3)	Coal	100	
	Stung Treng - Lao Import	Import	20	
	Kampong Cham - Vietnam Import	Import	22	
2016	Lower Se San II + Lower Sre Pok II	Hydro	420	2,321
2017	Stung Chay Areng Hydro Power Plant	Hydro	240	2,561
2018	700 MW Coal Power Plant, Sihanoukville (II) (phase 4)	Coal	300	2,861
2019	Sambor Hydro Power Plant	Hydro	450	3,311
2020	Kampong Cham - Vietnam Import	Import	31	3,342
2021	Coal Power Plant (III) or Gas Power Plant	Coal/NG	450	3,792

Source: Power Sector Overview, June 2009 & EDC 2007 Annual Report

This plan does not separately identify the imports to the Phnom Penh system from Vietnam which are due to commence in 2009. It is assumed that these are included in the existing installed capacity assumed for 2009. These imports are expected to commence at a level of around 80 MW (due to supply constraints on the Vietnamese side) rising over time to the planned capacity of 200 MW.

The MIME revised demand forecast, representing the highest growth case, has been compared with the generation expansion plan and the resulting generation reserve margin estimated. This is shown in Table 9 and Figure 10. The reserve margin includes power imports but does not include generation that is planned to be developed for export.

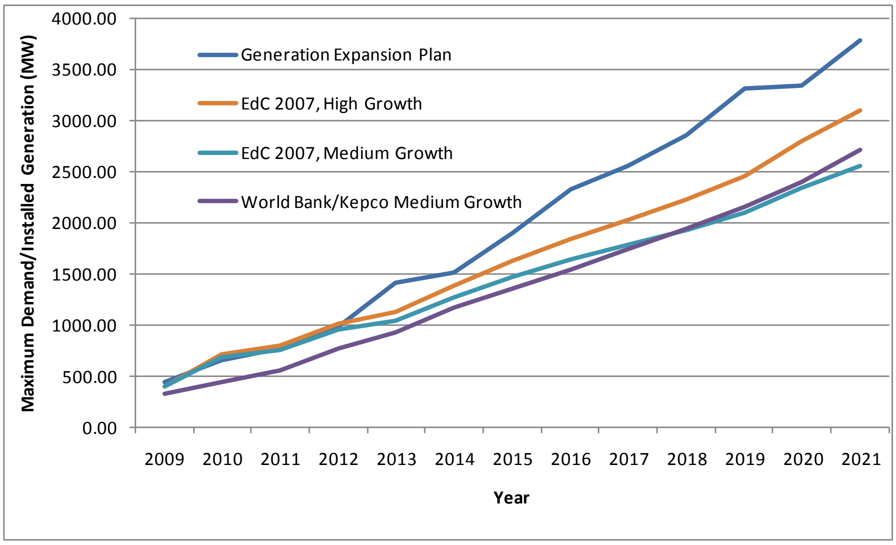
Table 9 - Forecast Generation Reserve Margin 2009-2021

Year	MIME Revised Demand Forecast		EDC Annual Report Gen. Exp. Plan		Reserve Margin	
	Demand (MW)	Growth Rate (%)	Capacity (MW)	Growth Rate (%)	(MW)	(%)
2009	318	32.43	437		119	37.34
2010	432	35.69	650	48.74	218	50.55
2011	546	26.35	768	18.15	222	40.79
2012	768	40.87	978	27.34	210	27.27
2013	931	21.10	1,413	44.48	482	51.83
2014	1,160	24.68	1,513	7.08	353	30.39
2015	1,349	16.27	1,901	25.64	552	40.91
2016	1,546	14.57	2,321	22.09	775	50.15
2017	1,746	12.94	2,561	10.34	815	46.70
2018	1,937	10.98	2,861	11.71	924	47.67
2019	2,148	10.84	3,311	15.73	1,163	54.18
2020	2,401	11.80	3,342	0.94	941	39.20
2021	2,708	12.78	3,792	13.46	1,084	40.04

Source: Power Sector Overview, June 2009, EDC 2007 Annual Report

While on first impressions there appears to be a high reserve margin in all years to 2021, this may be misleading. Legal disputes between the developers have stalled progress on the 200 MW coal plant in Sihanoukville which is planned to commission in two phases in 2011 and 2012. If this is delayed to 2013 or beyond, then the reserve margin in 2012 would be just 10 MW or 1%. The expansion plan also envisages another 700 MW coal plant in Sihanoukville, to be commissioned in phases between 2013 and 2018. If this is delayed, then the reserve margin in 2018 would be around 120 MW or 10%. This suggests that, unless major efforts are made to speed up development of planned coal-fired capacity (hydro plant development appears to be further advanced) then Cambodia may face significant supply problems given its rapid demand growth.

Figure 10 - Electricity Supply and Demand Projections



Source: Power Sector Overview, June 2009, EDC 2007 Annual Report

However, this is not expected to have a significant impact on RE. An additional 700,000 rural households might need to be connected to grid electricity by 2020. If each household has a peak demand of 0.3 kW, then, after assumed transmission and distribution losses of 15%, this would represent a total additional load of 260 MW or an increase of 11% of demand in 2020. The benefits from curtailing electrification activities in order to better balance supply and demand if generation expansion is delayed would, therefore, be relatively small. Under lower projections for electricity demand growth, reserve margins are higher and concerns over the availability of supplies are less significant.

2.3 Choice of Electrification Approach

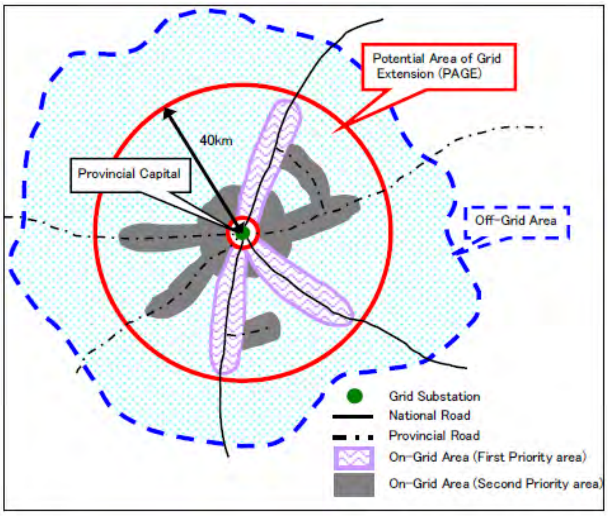
2.3.1 Electrification Approach

The JICA MP provides a blue print to increase rural access utilising site specific, least cost renewable energy technologies as well as grid extension. Also detailed in this report is a broad outline for extension of the grid on the basis that renewables and grid extension where possible should be mutually exclusive to avoid stranding any investments in off-grid technologies. As a broad summary of the Master Plan, the grid will supply approximately 80% of Cambodian households with the remainder of rural households being supplied by diesel mini-grids, biomass gasification, micro-hydro, solar home systems and solar battery charging systems.

The plan identifies “potential areas for grid electrification” (PAGEs) as a 40 km radius around provincial capitals. It is expected that each provincial capital will be served by a substation connected to the HV national grid. Within the PAGEs, the grid in the form of 22 kV lines will first expand along main roads with an electrified area up to 1 km on either side of the road and will subsequently expand throughout the PAGE. Villages in Cambodia are largely linear in nature and aligned along major roads.

A number of reasons have been advanced for the selection of the 40 km distance. The JICA MP notes that more than 80% of the population live within such areas. EDC has suggested that this radius is a reasonable approximation of half the average distance between provincial capitals. It also represents the nominal technical limit for transferring electric power at 22 kV[11]. The PAGE concept is illustrated stylistically in Figure 11. Figure 12 shows the PAGEs in relation to provincial capitals in Cambodia, illustrating the resulting geographic coverage.

Figure 11 - Potential Areas for Grid Extension (PAGE)

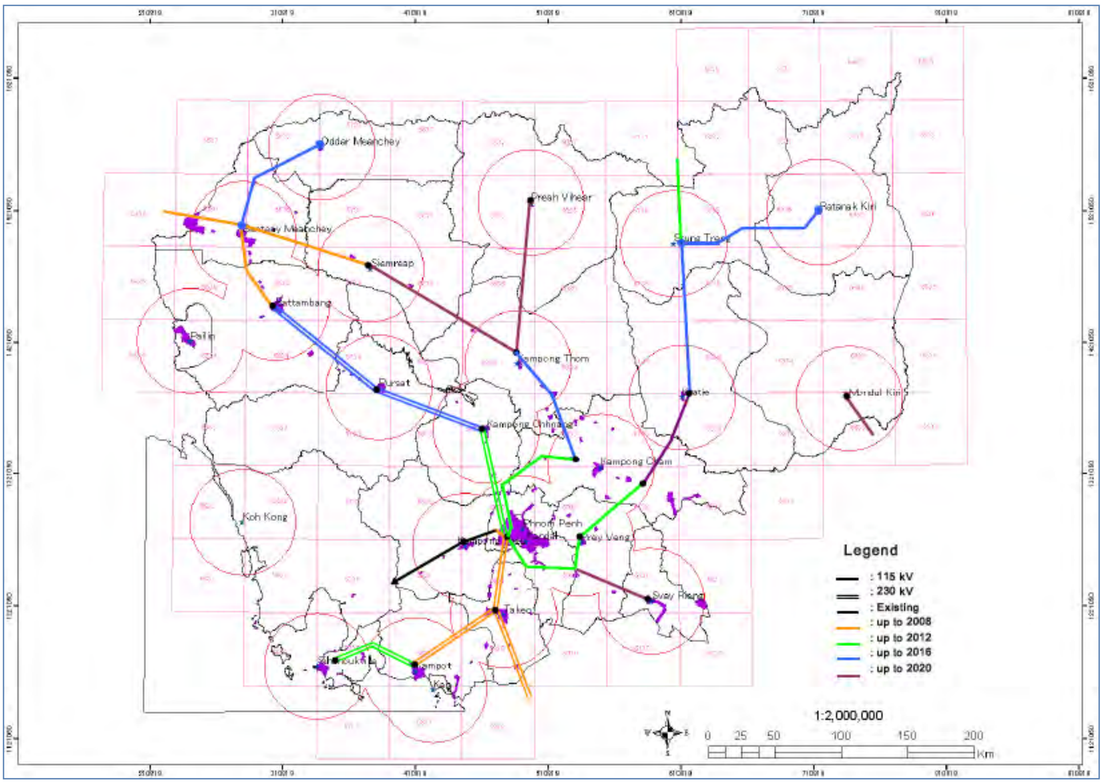


Source: Master Plan for Rural Electrification by Renewable Electrification (2006), MIME

The PAGE is a slightly crude way of identifying which communities would be suitable for grid electrification. As part of the planning process, it is expected that GIS mapping will be used to help determine those communities with the greatest demand potential and which can be connected at reasonable cost. Such analysis is outside the scope of this report which relies on existing material but an assessment of the adequacy of EDC’s existing GIS software for this purpose is provided in Appendix 5.

[11] The maximum distance that power can be transferred at any voltage is dependent on the maximum allowable voltage drop. For rural areas this is a function of the forecast household after diversity maximum demand in the horizon planning year and household density. The 22 kV feeder peak demand calculation should also include allowances for any large single point industrial or commercial loads.

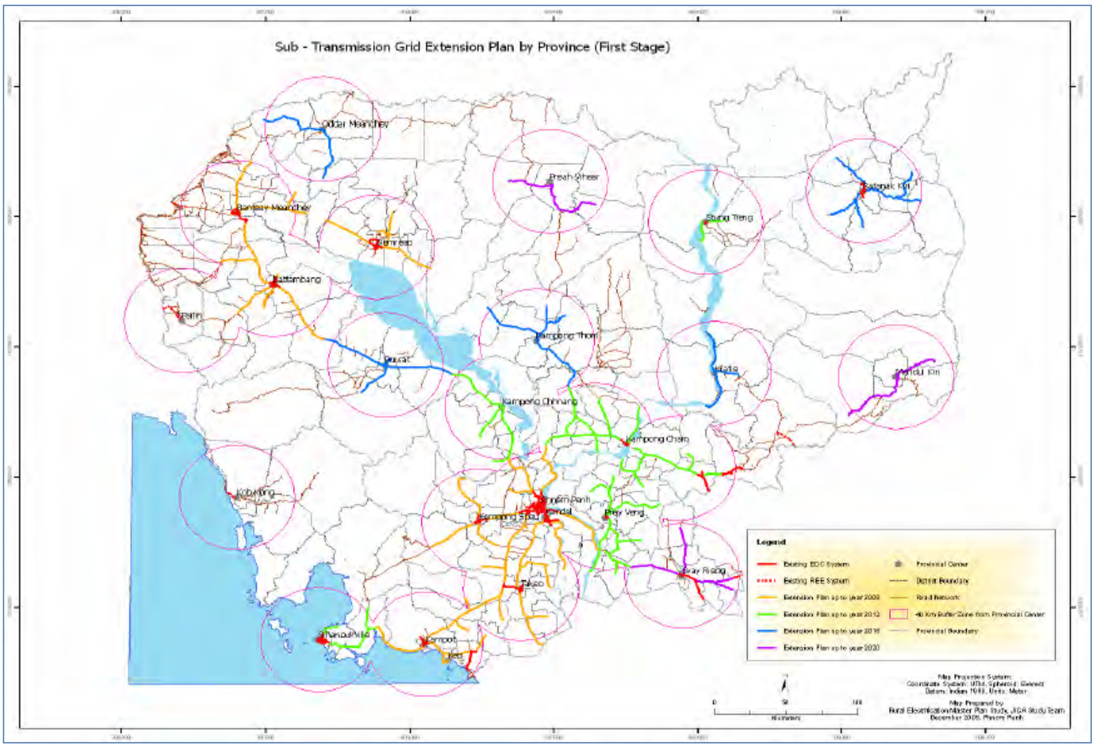
Figure 12 - Planned Areas for Grid Electrification



Source: Master Plan for Rural Electrification by Renewable Electrification (2006), MIME

The initial subtransmission (22 kV) lines associated with the indentified PAGEs are shown in Figure 13. These are taken from the JICA MP and more detailed planning being conducted by EDC may lead to some changes in the planned routes and timing of expansions.

Figure 13 - Power System Planning, 22 kV Lines for Rural Electrification

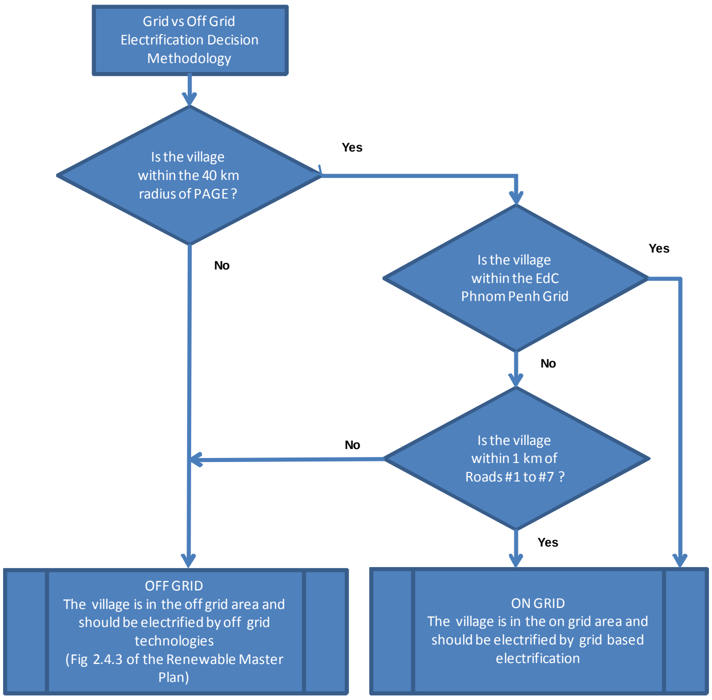


Source: Master Plan for Rural Electrification by Renewable Electrification (June 2006), MIME

By default the households and villages located outside the PAGE are targets for off-grid solutions. There may also be some pre-grid connections within PAGEs during the time required for the grid to extend to cover the full area.

An overview of the methodology recommended for determining whether to electrify a village by grid or Off-Grid using the PAGE methodology is outlined in Figure 14.

Figure 14 - Grid vs Off-Grid Decision Methodology



The methodology outlined in Figure 14 for determining the technology for electrifying a rural village is indicative. At the design phase of a project to electrify a village or group of villages detailed technical, financial and economic analysis would be carried out to confirm the optimal solution. In addition Fig 2.4.3 of the renewable master plan goes into more detail of the factors that will decide which Off-Grid technology should be used for a specific case.

2.3.2 Electrification Approach - Grid Extension

Within the PAGE area the following staged approach should be followed for rural electrification:

First Stage - Extend the 22 kV backbone along the main roads from the Grid Substations within the PAGE; and extend the 22 kV backbone radially from the Provincial Capitals to the District Centres within the PAGE
Second Stage - Define and electrify logically contiguous licensed areas inside the PAGE in the approximate order of rolling out the MV network
Third Stage - Extend the MV outside the PAGE subject to technical considerations (voltage drop and losses) and economic/financial considerations. Economic villages to be supplied by EdC if no REE interest, non-economic villages to remain with off-grid electrification.

2.3.3 Electrification Approach - Off-Grid

The principle source of generation for mini-grids at present is diesel generation. The JICA MP identifies the following generation technologies as being most applicable for future rural electrification in Cambodia:

- Micro-hydro power in the mountainous or hilly areas
- Biomass gasification power in the plain areas with land available for biomass plantations
- Diesel power in those areas that have neither micro-hydro potential nor land for biomass plantations
- Solar power for BCSs.

The potential of renewable energy in off-grid areas and its characteristics are presented in Table 10.

Table 10 - Renewable Generation Potential as a Source for Rural Electrification

Nº	Energy Source Type	Characteristics of Potential
1	Micro-hydro power (mini-grid)	Mixed: Micro-hydro power (MHP) potential is limited to mountainous or hilly areas mainly in the eastern and south-western part of the country in which only a small part of the population live. The plain areas, which cover more than half of the country, have minimal MHP potential[12].
2	Biomass Gasification (mini-grid)	Abundant: Good solar irradiation, precipitation, and land resources mean promising biomass potential (grassland and shrub land alone are sufficient to grow the required fuel trees),
3	Solar (BCS, SHS)	Abundant: Across Cambodia there is an annual average monthly minimum of 4.7 $kWh/m^2/day$
4	Wind (mini-grid, BCS)	Scarce: The average wind speed 20 m above ground level is 2.6 m/s. The wind potential in Cambodia is low and limited to local wind corridors.

Source: Master Plan for Rural Electrification, MIME, 2006

To date, use of renewable energy technologies appears to be very limited. In 2008, 25 biomass gasification units were installed, primarily for use by rice millers, brick makers and ice makers in rural areas. AECOM NZ was also advised that biomass gasifiers have started to be manufactured in Cambodia rather than importing them from India as was previously the case.[13] Also active in Cambodia in the non-electric energy field is the National Biodigester Programme which promotes the production of bio gas predominately for cooking and lighting.

By default the households and villages located outside the PAGE are targets for off-grid solutions. There may also be some pre-grid connections within PAGEs during the time required for the grid to extend to cover the full area. In more detail the staged approach for electrification for off-grid electrification is nominated as follows in the JICA MP:

Outside the PAGE area and for low density areas within the PAGE area the following staged approach should be followed for rural electrification

First Stage - Targets diffusion of battery lighting by installing solar battery charging stations (BCS). This is aimed at achieving 100% village electrification by 2020
Second Stage - Targets electrification for lighting, TV etc. with an average after diversity maximum demand of 100 W per household, this stage would favour mini-grids supplied by a range of generation technologies
Third Stage - Grid Electrification or remaining as individual household solutions / mini-grids depending on the economics of connecting to the grid.

The optimal off grid generation technologies for mini grids were commented on in detail in the Master Plan for Rural Electrification, MIME, 2006, The generation technologies that were favoured included biomass gasification, solar and microhydro. It is noted however that some of the cost structures have changed significantly since 2006, principally for solar PV. Due to the volatile nature of the capital costs for renewable technologies it is recommend that the LCOE from each technology be updated annually.[14]

2.4 Costs and Financing

This sub-section describes estimates of the costs of achieving the RGC's target electrification rates and an assessment of how these compare with available financial resources. Together with the analysis above, this is used to assess the feasibility of these targets.

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[12] Section 5.1, Master Plan Study on Rural Electrification by Renewable Energy...." Interim Report July 2005, JICA, Nippon Koei.
[13] As advised by SME Renewables, Tony Knowles.
[14] See also Appendix 4 which reviews the levellised cost of energy for solar home systems, using updated costs.

2.4.1 Electrification Rates

The projections assume the electrification rates shown in Table 11. The overall target for 2030 is that established by RGC with the split between grid and mini-grid connections being taken from the 2006 JICA MP. The intermediate 2020 target for household electrification is based on that in the 2006 JICA MP, slightly adjusted downwards to allow for a later starting date than assumed in the 2006 JICA MP. The target levels of solar installations are also taken from the 2006 JICA MP. These are shown separately as they are not considered to count towards the achievement of the target electrification rates but instead to supplement these.

Table 11 - Target Electrification Rates for Projections

Rural households only	Current	2020	2030
Grid electricity	1.5%	30%	60%
Mini-grids (grid-equivalent supplies)	3.9%	15%	10%
SHS and BCS	-	72,000 households	190,000 households

2.4.2 Cost Assumptions

The average initial capital cost for rural subtransmission and distribution is estimated at US$ 589 per household, comprising US$ 253 per household for the rural MV subtransmission network, US$ 238 per household for LV distribution lines and US$ 97 per household for the costs of service drops[15], meters and meter boxes. This does not include the costs of internal house wiring, which might add a further US$ 20 per household for single-phase supply and US$ 200 for three-phase supply (based on cost estimates for Lao PDR). The costs of investment in generation and the HV transmission grid are also excluded and are assumed to be incorporated into the costs of bulk supplies from the HV grid.

These costs can be expected to increase over time as the grid is extended to more remote areas with lower population densities. Therefore it is assumed that the total household capital cost will increase to US$ 750 by 2030. This is equivalent to the current cost of grid electrification in Lao PDR, which has achieved electrification rates in line with those targeted by RGC.

The costs of other electrification technologies are drawn from the 2006 JICA MP. These may somewhat overstate the capital costs of solar technologies given recent declines in solar panel costs, which will mean more households can be electrified by solar technologies for a given budget.

The assumed capital costs for different technologies are shown in Table 12. Capital costs exclude costs of house wiring. For grid electrification, the costs also exclude the costs of generation and the HV national transmission grid.

Table 12 - Capital Cost Assumptions for Projections

Technology	Capital cost per household (US$)
Grid electrification	589 rising to 750
Mini-grids	
Micro-hydro	1,229
Biomass	592
Diesel	424
Solar	
BCS	351
SHS	460

2.4.3 Projected Connections and Investment Costs

The resulting projected electrification rates, numbers of connections and estimated capital costs are shown in Figure 15 and Figure 16. The projections of connections include an allowance for rural population growth of 1.4% annually, the average between the 1998 and 2008 censuses.

15 An average service drop length of 10 metres has been assumed.

Figure 15 - Projected Rural Household Electrification Rates

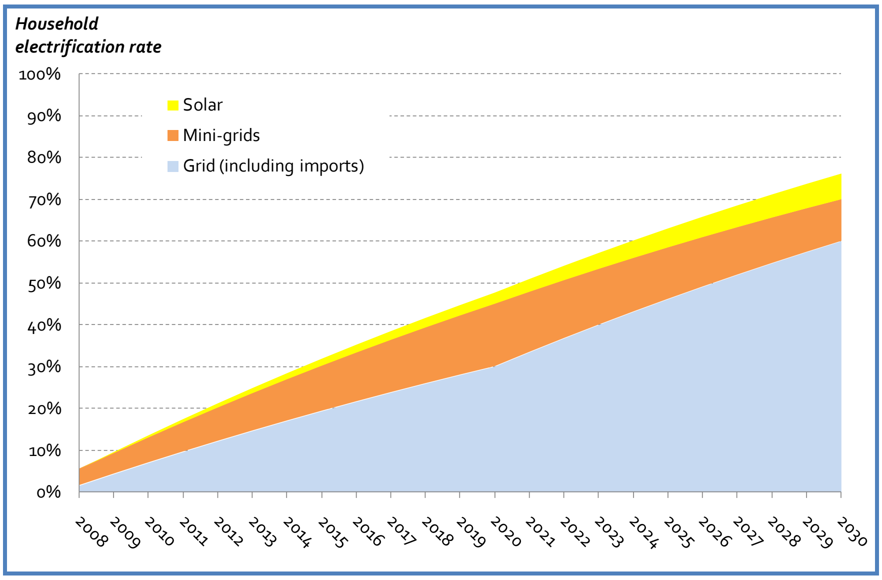
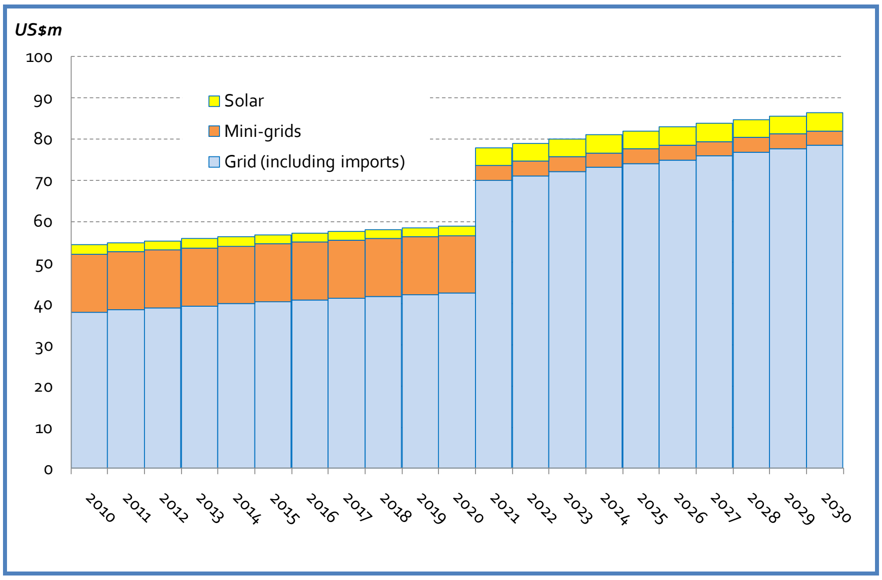


Figure 16 - Projected Rural Electrification Capital Costs



The large step-up in investment requirements post-2020 is obvious. This derives from the assumed electrification targets which see a gradual expansion of grid electrification to 2020 followed by an intensified programme of connections to reach the 2030 targets. It also reflects the assumed rising cost of grid connections over time.

What is also obvious is the projected large reduction in mini-grid investments post-2020. This reflects the assumption that mini-grids will initially play a major role in expanding electricity supplies - reaching 15% of rural households by 2020. Subsequently, as the grid expands further, mini-grids will gradually be absorbed into the main grid and their role in electrification, in both absolute and relative terms, will decline.

A summary of the connections and costs over the period to 2030 is provided in Table 13.

Table 13 - Summary of Projections

Tech-nology	2010-20				2021-30			
	Connections		Capital costs (US$m)		Connections		Capital costs (US$m)	
	Total	Annual average	Total	Annual average	Total	Annual average	Total	Annual average
Grid	710,191	64,563	444.0	40.4	1,046,047	104,605	744.0	74.4
Mini-grid	288,052	26,187	154.6	14.1	-95,164	-9,516	35.7	3.6
Solar	66,000	6,000	24.4	2.2	118,000	11,800	43.6	4.4
Total	**1,064,243**	**96,749**	**623.0**	**56.6**	**1,068,883**	**106,888**	**823.2**	**82.3**

2.4.4 Financing

It is assumed that around 80% of investment costs under the programme will be funded by debt or grants and the remaining 20% by equity - either in the form of retained cashflows or by owners' equity, with the former being the main means of financing for EDC investments and the latter for REE investments. This figure is somewhat arbitrary and higher or lower proportions of debt and grant financing are possible. However, it represents a realistic split of financing and is consistent with similar programmes elsewhere.

Implementing the programme from up to 2020 would, therefore, require around US$ 45 million annually in debt and grant financing of which US$ 32 million would be needed for the grid electrification component. The annual equity contribution would be around US$ 11 million of which US$ 8 million would be used for grid electrification. From 2020 to 2030, the annual debt and grant financing requirement would rise to US$ 66 million with US$ 60 million used for grid electrification and equity financing to US$ 16 million with US$ 15 million used for grid electrification.

To provide some context, in 2007, total RGC expenditures were US$ 1.3 billion, of which US$ 536 million represented capital expenditures. In this year, RGC ran a budget deficit of US$ 103 million financed by foreign borrowing (largely from donor sources). In 2006, EDC's operating revenues were around US$ 175 million and its available cashflows (depreciation plus profit after tax) around US$ 13 million.

The estimated debt and grant annual financing requirements between 2010 and 2020 would, therefore, represent 3% of annual RGC expenditures, 8% of annual RGC capital expenditures and a 44% rise in the government budget deficit. The estimated equity financing requirements for the grid electrification component would be 5% of EDC's operating revenues and 65% of available cashflows.

It seems reasonable to conclude that RGC will be unable to make little or no financial contribution to the costs of a rural electrification programme out of tax revenues, given its current large budget deficit. Instead, debt and grant financing will need to come from donor sources - either directly or by funding other RGC activities, freeing up funds to be redirected to rural electrification. However, it does appear possible that the industry will be able to provide the assumed equity contribution with limited impacts on tariffs overall (although this may conceal significant differences in tariffs for different customer groups).

As regards available donor financing, it is understood from information provided by the World Bank that current donor commitments of funding for electrification (of various degrees of firmness) are as follows:

- ADB - US$ 30 million
- AusAID - US$ 10 million
- China EXIM - US$ 50 million
- World Bank - US$ 40 million.

In total this represents around US$ 130 million in donor funds, or sufficient for three years funding of the scale of electrification programme required to meet RGC's targets (or four years funding if allocated solely to the grid electrification component).

2.5 Achieving the Recommended Targets

The electrification targets set by RGC are challenging. Achieving them requires connecting 65,000 rural households annually to grid electricity over the period to 2020 and electrifying a further 26,000 households annually through mini-grids (with a further 6,000 electrified through solar systems but not contributing to the achievement of the targets). From 2020, the average annual connection rate needs to increase to 105,000 households.

For comparison, the increase in electrified households (those with access to city power and diesel generators) in the 10 years between 1998 and 2008 according to the national census was 417,000 households or under 42,000 households annually. Using the statistics collected by EAC on customers supplied by licensees, increases in total numbers of electricity customers averaged 46,000 annually between 2002 and 2007 and in rural areas averaged 21,000 customers annually. The required connection rates, therefore, imply a scaling-up of historic connection rates of between two and four times.

2.5.1 Financing Constraints

Financing is likely to be the major constraint on such scaling-up. There will be additional planning, licensing and project management requirements for MIME, EDC and EAC but these should be capable of being accommodated within a short period of time through limited recruitment and capacity-building activities. The REF may face resource constraints depending on the extent to which it is responsible for managing electrification funds. This is reviewed later in this report.

As discussed above, any large-scale electrification programme is likely to rely heavily on donor funding given the existing RGC budget constraints and the limits on customer funding due to affordability concerns. Assuming that 80% of capital expenditures are funded by donors, committed funds represent around three years of the planning electrification programme. The preparation and disbursement of donor funds is generally an extended process due to the need to ensure funds are used efficiently, in accordance with project objectives and in compliance with environmental and social safeguards. It is reasonable to expect preparation of new donor projects as part of an electrification programme to take up to two years and disbursement of funds to take a further four years. The available commitments would, therefore, be equivalent to around US$ 32 million of funding annually over a four-year period. This would allow 80% of the capital costs of grid expansion to be funded for these years or around 60% of the full electrification programme with the remainder being funded from customer tariffs. At the end of the four-year period, the electrification programme would largely come to a halt unless new donor funding can be attracted.

The need for donor funding if the electrification programme is to come anywhere near reaching the RGC targets and the long lead-times for such funding mean urgent action is needed to obtain longer-term donor commitments to the electrification programme. Without this, the programme is unlikely to achieve the requisite level of connections in the next few years and, within four years or so, connection rates are likely to drop back to current rates which are only 25-50% of the rates required to achieve the targets.

Obtaining longer-term and new donor commitments is likely to require a number of actions by RGC. The electrification programme, its objectives and estimated funding needs will need to be presented to donors. This might best be done through a donor conference which will also help donors co-ordinate their offers of funding. Regular reviews of the programme’s progress will be needed to help identify connection rates against targets, progress towards achievement of the RGC’s objectives and allow donors to identify well in advance the need for additional funding of the programme.

2.5.2 Capacity Constraints

The strategy as outlined will rapidly increase electrified households in rural Cambodia. The capacity in key institutions will have to be enhanced in concert with this.

Lessons learnt from rural electrification programmes in adjacent countries show that capacity constraints can be overcome at the distribution level relatively easily as it is essentially a logistics issue rather than an engineering one. For example during the World Bank-financed Lao Southern Provinces Rural Electrification project actual and perceived capacity constraints were overcome as follows:

- Contracts for the manufacture of concrete distribution poles with domestic preference which resulted in Thai-owned concrete pole manufacturing plants being established in Lao PDR using Lao labour. The contract also allowed for delivery to site of poles by the manufacturer which eased the logistics burden for EdL

- International procurement for materials and works of a more technically advanced nature e.g. high voltage substations and transmission lines which resulted in international expertise being transferred to local companies
- Procurement of tools, vehicles and equipment to enhance the construction and maintenance capacity of the key institutions. This included computers, office equipment, software etc
- Training programmes, technical assistance and study visits to enhance capacity
- Advanced procurement to ensure the materials, equipment and services are available when required.

Technical assistance will be required to help identify capacity-building support required for MIME, EDC and REF to carry out their required functions under the electrification programme:

- For MIME and EDC, these will largely represent a scaling-up of current responsibilities and, therefore, capacity-building is about adding to existing resources rather than creating new types of skills
- For REF, the proposed responsibilities are broader than those currently discharged and so capacity-building is likely to be more extensive in nature
- For EAC, little or no change in responsibilities is envisaged although technical assistance will be needed in some areas such as a new tariff study and revisions of regulations
- REEs would benefit from further capacity-building with or without the electrification programme. Given their number, such capacity-building is likely to involve regional training workshops, preparation and distribution of written materials and, as at present, the provision of informal support and guidance from EAC (and, in future, EDC) as needed.

As a component of technical assistance to identify a detailed electrification programme a readiness assessment of MIME, REF, EDC, EAC and REES should also be carried out in Phnom Penh and also in Province/District offices.. This would include reviewing the office accommodation necessary for these institutions to manage and oversee the electrification program

3.0 Institutional Responsibilities and Roles

This section sets out the proposed changes to existing institutional responsibilities and roles to support the implementation of the electrification programme. The aim has been to keep required changes to a minimum and to avoid those changes that might require time-consuming and controversial changes to existing legislation. However, there may be a requirement for public statements on future policy.

The changes proposed can be divided into two main areas - responsibility for planning and responsibility for rural grid development. This section is organised accordingly.

3.1 Rural Grid Development

Responsibility for the development of the rural electricity grid is currently split between EDC and REEs. In part, this is a reflection of EDC's reluctance to undertake extensive electrification activities given the implications for its commercial position. REEs, by default, have come to fill the gap and lead much of the rural electrification programme.

It is assumed that REEs will remain responsible for the development of mini-grids. Proposals on future institutional responsibilities are, therefore, focused on the development of the rural electricity grid.

3.1.1 Subtransmission Responsibilities

It is important that a single entity leads the rural grid expansion. This will lead to greater co-ordination in planning and implementation and will allow what economies of scale exist to be realised. It should be recognised that internationally, successful large-scale electrification programmes have been led by a single utility. Within South-East Asia, for example, the ongoing electrification programmes in Vietnam and Lao PDR are being led by Electricity of Vietnam (EVN) and Electricité du Laos (EDL) respectively - although Vietnam has also made extensive use of local distribution utilities, the equivalent of REEs, to invest in LV networks[16].

EDC is the only credible candidate to lead a major grid electrification programme. It has a national presence, is the only holder of a national transmission licence (of which only one can be awarded), and has the largest financial and human resources of any existing or potential electricity licensee. EDC's government ownership also means it can readily access the large volumes of donor funding likely to be required to implement the electrification programme.

EDC should, consequently, be the sole entity responsible for the development of the rural subtransmission grid. This should not prevent REEs from constructing their own MV lines to connect their service areas to the national grid, but such lines should be for own use only. As and when they are absorbed into the „backbone' grid, control of these lines should pass to EDC. It is proposed that EDC should have powers to require REEs to lease their MV lines to EDC where these are required to form part of the subtransmission network. The lease terms would be designed so that REEs earn the same revenues from such leasing as they would expect to earn if the lines were included in the regulated asset base used to determine their tariffs.

3.1.2 Distribution Responsibilities

There is much less requirement for co-ordinated development at the level of LV distribution networks. There may also be advantages to greater local involvement in the management of these networks, in particular for collections.

While EDC is the entity with the greatest resources in the electricity industry, it is still relatively small and will face resource constraints in implementing an electrification programme of the scale required. This suggests that maximum use should be made of the human, technical and financial resources that REEs can bring to electrification during the initial electrification programme period.

It is therefore proposed that REEs should be encouraged to continue to finance, own and operate new distribution networks connected to the grid, as well as to expand existing networks. EDC's available resources for investment in distribution networks should be concentrated where they are most required. This

[16] Appendix 6 contains a summary of country case studies and rural electrification principles for successful programmes, included are summaries of the RE programmes in Lao PDR and Vietnam

would be those areas which REEs are reluctant to serve. In effect, EDC would become the developer of last resort for rural electricity distribution.

Where EDC does finance and own distribution networks, it should contract the operation and management of these out to REEs. Such contracts are likely to be more attractive to REEs in many cases than financing the construction of their own networks. It is envisaged that REEs in these cases would lease the EDC-owned distribution assets, with lease payments set equal to the revenues that EDC would otherwise expect to earn from these assets.

Over time, the strategy envisages that there will be a gradual consolidation of REEs into much larger licensees or into EDC. This will increase the efficiency and sustainability of rural electricity supplies following the initial investment in expanding the grid.

Such a consolidation is considered desirable to ensure the longer-term sustainability of supplies. In the longer-term, smaller REEs can be expected to find it difficult to remain viable. Their cost base is high relative to their revenues, due to their small size, they lack financial reserves or borrowing capacity to cover the costs of replacements, enhancements and expansions and the technical skills of their staff are inevitably limited. The results are higher prices, low margins and poor service quality. Earlier reports have already highlighted the small size of REEs and of Cambodia's rural electrification market as a whole relative to distributors in other markets.

The process of consolidation is seen, for example, in Vietnam. Prior to 1995, distribution in rural areas was largely the responsibility of commune-level local distribution units (LDUs), either developed as cooperatives, by individuals or by local governments. In 1995, following the establishment of the state utility Electricity of Vietnam (EVN), rural MV assets were required to be transferred to EVN. In 2001, all LDUs were required to be formalised, being established as either cooperatives or companies and being licensed. LDU tariffs were capped, although at a level above EVN's tariffs, and a regulated bulk supply tariff from EVN to LDUs was introduced. Most recently, in 2009, LDUs have been required to reduce tariffs to the same level as those charged by EVN with their margins consequently being reduced[17]. It is expected that many LDUs will subsequently be taken over by EVN. This consolidation process has been driven by concerns over the poor performance of LDUs and a significant change in financing sources as EVN increasingly assumes a central role in electrification.

Such consolidation in Cambodia should be voluntary as far as possible. This implies waiting until existing licences expire before assets are transferred from REEs to EDC, which could be a lengthy period. There is also the difficulty that, even where existing licences have expired, the original licensee may not have recovered their initial investment in full and may have reasonable expectations of a licence extension to allow them to do so[18]. It is proposed that licensees be compensated for the remaining undepreciated value of their assets on any such transfer which should address this concern.

In the short to medium-term, REEs should be allowed and indeed encouraged to continue to invest in new rural distribution networks. REEs provide a means to rapidly mobilise investment funds in more attractive areas and, thereby, allow EDC to concentrate its resources on the expansion of the MV subtransmission grid and on LV distribution in less attractive areas. Consolidation at the LV distribution level is driven by concerns over long-term sustainability and efficiency rather than immediate investment needs. The new investments made by such REEs will be protected through the requirements for future asset transfers to be voluntary, to generally take place following the expiry of licence terms and for suitable compensation to be paid. The development of the MV subtransmission grid would be consolidated under EDC from the start, however, given the greater need for coordination of its planning, funding and use.

Some changes to current arrangements for licensing of new REEs are also desirable, to implement the proposed strategy. These would be to cease issuing new subtransmission licences to REEs and to require REEs to apply for licences in new areas within a given time frame, otherwise they will be allocated to EDC to develop distribution networks. Licence amendments would be made to facilitate mergers and acquisitions among licensees, including in particular establishing criteria for the valuation and recovery of licensees'

17 In 2001, a cap on LDU tariffs was established at VND 700/kWh (provincial governments could allow tariffs in excess of this) and a bulk supply tariff to LDUs at VND 420/kWh giving a margin of VND 280/kWh (approximately USc 1.5/kWh). In 2009, the LDU tariff for the first block (up to 50 kWh) was reduced to VND 600/kWh with the margin falling to VND 180/kWh (approximately UCs 1/kWh).

18 As of end-2007, 12 out of 148 consolidated licences had a term of 10 or more years. Thirteen out of 16 distribution licences were for a term of 10 or more years. Distribution assets, under EAC's tariff regulations, are depreciated over a life of 25-30 years and diesel generators over 18 years.

assets which are not fully depreciated at the time of a licence's expiry or termination. The strategy also proposes that MIME should issue a public policy statement on the future institutional and market structure for rural electrification - which will give EAC broad powers to amend licences to implement this policy if needed. Detailed proposals for licensing amendments have been developed under the separate project component on the Rural Electricity Distribution Strategy.

3.1.3 EDC Organisation

To date, EDC has been reluctant to engage in significant rural electrification. This appears to be largely due to concerns that it will be unable to raise tariffs to recover the additional costs of rural electrification. As a result, EDC's commercial viability would be undermined. EDC has, in particular, drawn attention to the failure of RGC to pass on to it the full concessionary terms of World Bank loans for rural electrification, raising its financing costs and the risk that it is unable to recover these.

Proposals on future tariff policies for rural electrification are set out in the following section. The need for EDC, and other licensees, to be able to recover all reasonable costs from tariff revenues is emphasised, although this is already required under existing legislation. It is also emphasised that failure to pass on the concessionary terms of donor financing for electrification will result in higher customer tariffs.

While concerns over the adequacy of tariffs are central to EDC's reluctance to undertake a major electrification programme, other measures can also be taken to facilitate such a programme. A relatively minor measure would be to make progress in electrification one of the performance indicators against which EDC's success can be measured. A more significant measure would be to introduce a degree of „ring-fencing' of EDC's electrification operations. This could involve the establishment of a dedicated office within EDC who would lead the electrification programme. More far-reaching changes would be to create a separate rural electrification division operating as a separate cost or profit centre.

The purposes of such ring-fencing would be to:

- Create an internal team of electrification experts, with the experience and skills required to manage the electrification programme and with authority to do so
- Establish a route by which electrification experts within EDC can develop their careers
- Increase management focus on electrification through the use of a dedicated team.

The proposed rural electrification office (REO) should also include within it a unit responsible for the promotion of productive electricity uses in rural areas. Promotion of productive uses of electricity will help increase demand among rural customers and, as a result, improve the affordability of electricity supplies by increasing sales and increasing incomes of rural households.

If ring-fencing of electrification activities extends to the creation of a separate cost or profit centre, then this will have the added advantage of making clear to what extent EDC's commercial performance is affected by its electrification activities. Losses resulting from electrification activities can be quantified and EDC's financial results assessed with and without the impact of these.

The creation at this time of a separate utility with responsibility for electrification is not proposed. Any ring-fenced entity would continue to be part of EDC, its staff would be EDC employees and it would be subject to the normal EDC budgeting and financial control processes.

Financial ring-fencing in the form of a cost or profit centre would not, of course, be a substitute for ensuring proper financing of EDC's electrification activities. However, it would provide a means of helping identify the impacts on the rural electrification programme on EDC's costs and revenues and thereby help address concerns that EDC will be unreasonably criticised for poor commercial performance resulting from inadequately-funded electrification activities.

3.2 Planning and licensing

3.2.1 Transmission Planning

There is no requirement for significant changes to the current national Power System Master Plan arrangements covering all generation and the national high voltage (HV) transmission system. This should continue to be prepared by MIME as at present.

However, two changes to the current process are proposed which are intended to assist potential rural electrification licensees:

- The national plan should include a forecast of grid-connected demand from rural areas, broken-down by province
- The Power System Master Plan should be made publicly available, including the underlying demand forecasts.

Together, these changes would allow potential licensees to assess the size of the electrification market and the availability and costs of grid electricity supplies to meet this demand.

3.2.2 Subtransmission Planning

From a network planning aspect, it is essential that all subtransmission lines be designed and adequately sized for future extension, both within the licence area and to adjacent areas. Whilst the HV and MV main lines generally follow major routes, the design should also allow for future tee-offs to the lateral areas. Renewable energy schemes should also be considered and encouraged where appropriate. Accepting this, the major question is who should be responsible for planning of the subtransmission?

Subtransmission planning, by its nature, requires knowledge of local conditions and system requirements. When undertaken for rural electrification, the demand to be served is relatively small and has limited impact on national grid planning requirements.

EDC is the most obvious entity to prepare subtransmission plans, following the overall power system master plan developed by MIME and consistent with RGC policy and priorities. Responsibility for planning at this level already largely lies with EDC, although it is understood that this is undertaken on a route-by-route basis rather than as part of a national co-ordinated plan. While MIME has overall planning responsibility, it would require a large expansion of MIME's planning staff for it to assume the role of undertaking detailed planning at the subtransmission level. The understanding is also that MIME's planning role is primarily related to its responsibility for national energy policy. Under the electrification strategy, EDC would also be the main entity responsible for development of the planned subtransmission network.

Subtransmission plans[19] should be prepared at province-level by EDC provincial offices supported by EDC's central office in Phnom Penh, which would also be responsible for consolidating and verifying the various provincial plans. These province-level subtransmission plans should assess the likely power demand over a ten-year period based on population data, and how this could be served by a combination of off-grid (using renewable energy sources) and on-grid supply. They should include the designs for a 22 kV backbone subtransmission network emanating from the nearest grid substations to match the demand forecasts and identify a staged programme for implementation. As with the national Power System Master Plan, these province-level subtransmission plans should be publicly available.

The timetable for electrification of different districts and provinces should be consistent with the overall master plan and the expansion of the national transmission grid.

3.2.3 Electrification Priorities

A critical issue in any electrification programme is how to establish priorities for electrification of communities. This can be a very contentious process. Ideally, selection and prioritisation of communities for electrification should link to the broader objectives of the electrification programme.

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[19] The use of provinces as the basic planning „block' is proposed for convenience. In some cases it may be optimal to supply part of a province from a subtransmission line located in another province and the planning arrangements will need to reflect this.

EDC has prepared an internal design manual for electrification as part of the World Bank-supported Rural Electrification and Transmission Project (RETP), but this is not publicly available. The manual appears to be focused on technical requirements and specifications and does not specify in any detail the criteria used to select areas for inclusion in the electrification programme[20].

While it is expected that EDC will be applying a set of selection criteria in any event, formalising and publishing such selection criteria is generally desirable. In particular, it allows communities to understand when they might expect to be connected and the basis for such decisions - rather than leaving these to appear to be arbitrarily determined. Typically, such criteria are used to first target those communities with the higher potential demand and willingness-to-pay who are also lowest-cost to reach and might include:

- Village size
- Potential demand (such as presence of government and social facilities)
- Population density
- Willingness-to-pay (where evidence exists)
- Distance from existing grid
- Ease of grid access
- Availability of financing.

In some cases, these criteria might be balanced by social measures designed to ensure equitable distribution of electrification. For example, priority might be given to provinces or districts with lower income and human development indicators or to those villages with existing health care centres and schools.
To reduce financial pressures and costs, communities might be able to move themselves up the priority list for electrification if they can either arrange external financing or are prepared to make significant in-kind contributions to electrification costs.

Possible criteria to be used are contained in the 2006 JICA MP, which focuses on market size and accessibility, and the example planning carried out in Kampong Cham province by Innovation Energie Développement (IED) as part of the Capacity and Institutional Strengthening for Rural Electrification and Development - Decentralised Energy Option (CAP-REDEO) project[21]. The latter develops a priority development indicator based on the level of health care facilities, schools and local markets in each village.

3.2.4 Distribution Planning

Planning of distribution networks would be undertaken by licensees - either REEs or, where EDC takes responsibility for investment in the network, by EDC.

Distribution licences already include a condition requiring licensees to extend and improve their service in accordance with a plan approved by EAC to ensure supply to customers within the licensed area. It is suggested that EAC enforces this condition more rigorously than currently appears to be the case by requiring licensees to produce plans at two or three-yearly intervals showing:

- Which part(s) of their service area remains unelectrified
- Proposed priority for electrification of remaining parts of their service area and the basis for this prioritisation
- Proposed electrification plan with timetable. Where funds are not adequate to complete the plan, the licensee can identify the timing of investments as dependent on funding.

It is recognised that this may be a burdensome requirement for the smaller REEs. However, in these cases, EAC should encourage these licensees to take necessary measures to ensure they have the capacity to prepare and implement such plans, including merging into larger REEs, rather than relieve them of their electrification obligations.

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[20] The Design Manual does contain a reference to areas being selected based on load, load density and ease of construction.

[21] IED. October 2007. *Indicators of Rural Electrification and Development: Workshop Report*. CAP-REDEO Project.

3.2.5 GIS Planning Tools

The use of Geographic Information Systems (GIS) is fundamental to electrification planning, allowing the identification of communities and households to be supplied and the optimal electrification approach to be applied taking into account access, existing infrastructure, population densities and distance from the electricity grid and local renewable energy resources. GIS is already used extensively in power system, planning in Cambodia and the ToR for this project require an appraisal of the suitability of the existing software and processes for use in electrification planning, as well as recommendations for improvements where necessary.

AECOM NZ reviewed the existing application of GIS in power system planning by EDC as well as the GIS database approach that was developed for rural electrification planning as part of the preparation of the JICA Master Plan. The conclusions of this review are provided in Appendix 5. The main concerns identified include:

- The population data used by EDC appears to be derived from the 1998 census and has not been consistently updated subsequently. Population data from the 2008 census should be acquired by EDC preferably in electronic format
- There is no coordination in the preparation of the data which could result in duplication of effort. For example a "GIS user group" or similar could coordinate responsibility and data sharing for differing GIS layers
- Ongoing support and training is required to a) update the GIS Arc based software b) purchase computers, scanners, printers and plotters, c) provide ongoing training for ArcFM inside an ArcGIS Desktop environment and c) roll out GIS to Provincial EDC offices
- Updated satellite imagery should be acquired to accurately geographically locate rural households considered for electrification.

Appendix 5 highlights GIS data that could be further used to prioritise grid and off grid expansion including. household density and expenditure, hospital, school and administrative centres, suitability for irrigated agriculture etc. During the detailed project identification phase key GIS data, weighting and GIS optimisation algorithms should be established to further prioritise and optimise the RE programme.

3.2.6 Licensing Arrangements

The proposed split of institutional responsibilities for grid electrification has implications for future licensing arrangements. These are:

- No more special purpose transmission (subtransmission) licences should be issued to REEs. Existing licences should remain in force but might be subject to a requirement for licensees to commission the licensed assets within a given time period or lose the licence
- As part of the planning of grid extensions, licensee areas should be defined in advance. REEs should be given the opportunity to apply for these licences within a given time period (eg, one year). Where no application is received, EDC would become responsible for the financing of distribution networks in these areas and would subsequently contract with a REE for the management of these assets
- The size of new licensed areas should be gradually increased, as part of the process of promoting larger REEs.

4.0 Financing and Subsidies

This section sets out proposals for the financing of the electrification programme. It first summarises proposals on tariff policies for rural electrification. The grid-connected element of these is developed in more detail under the separate project component on the Rural Electricity Distribution Strategy. Next, estimates of the affordability and costs of electricity supplies for rural customers are given and, based on this, projections provided of the possible mix of financing between donors funds, rural electricity customers and urban electricity customers. The section then discusses how and where donor funds should be used before concluding with proposals on the future operation of the REF through which it is expected a significant proportion of donor funding will be channelled.

4.1 Tariff Policies

The proposed tariff regulation methodology is based around three key principles, consistent with good practice and the understanding that affordability of electricity is a key concern in Cambodia. These are that:

- Rural grid-connected electricity tariffs should be set, at a minimum, to cover the ongoing costs of electricity supplies
- Subject to this, rural grid-connected electricity tariffs should be set at a level that is affordable for the majority of customers
- Any resulting shortfall between revenues from grid-connected rural customers and the costs of rural grid electricity supply should be recovered through a cross-subsidy from urban electricity customers, thus ensuring licensees can recover their costs in full.

The more detailed discussion below focuses on grid-connected tariffs. Tariffs for mini-grids would continue to be set on an individual basis using the actual costs of each licensee as at present.

4.1.1 Setting Retail Grid-Connected Electricity Tariffs

Proposals for retail electricity tariffs for rural grid-connected household customers are that these should be set as the maximum of:

- The ongoing costs of rural electricity supplies
- The average affordable rural electricity tariff
- The highest urban household tariff applied in the interconnected system.

It should be noted that implementing this proposal requires an assessment of the affordable level of rural electricity tariffs. The estimates above are indicative only and a full willingness-to-pay study should be conducted for this purpose. Even if the proposed methodology is not implemented, the conclusions from such a study will be very valuable for the purposes of determining future tariff policies and setting rural electricity tariffs.

It is proposed that non-household consumers in rural areas are charged the full costs of electricity supply. It is recognised that this may act as a deterrent to industries to locate in rural areas. However, it is generally neither desirable nor efficient to use electricity (and other infrastructure) charges as a means of providing subsidies to firms to establish themselves in rural locations. Instead, subsidies for this purpose are better delivered through more targeted means such as grants, concessionary financing and tax incentives.

Retail tariffs should be uniform across all grid-connected rural customers. If the average rural tariff is affordable then the assumption is that increases in rural tariffs above this level will deliver unaffordable tariffs.

However, rural tariffs need not be uniform with urban tariffs (i.e., there need not be a uniform national tariff). Establishing a uniform retail tariff conceals the higher costs of supply in rural areas from customers. While it is unlikely to be possible to pass through these higher costs in full, setting rural tariffs above urban tariffs does provide some signal of these cost differences and hence limits excessive demand growth in rural areas which imposes high costs on the system as a whole. This also reduces the need for cross-subsidies from urban customers and, as a result, the risk of opposition from existing urban customers to rural electrification expansion.

Rural customers will be required to pay the costs of the service drop, meter and internal house wiring. Requiring customers to pay these costs will reduce the investment costs borne by EDC and REEs, freeing up funds for other purposes.

It should be noted that, at present, it is unclear whether EDC's current tariffs for urban customers and those connected to the Phnom Penh system are sufficient to recover its full costs of service. In particular, the application of VAT to retail electricity sales was not matched by a commensurate increase in retail tariffs. A full tariff study to assess the costs of supply of EDC and the required tariffs to recover these is desirable.

There is also a need for a comprehensive study of the willingness and ability to pay of rural households for electricity supplies. This will be a necessary input to the determination of an affordable rural tariff.

4.1.2 Setting Grid Tariffs

Grid tariffs or bulk supply tariffs are charged for sales from the subtransmission network to REEs. The proposed overall approach to establishing tariffs for grid-connected REEs derives from the assumption that retail tariffs should be uniform between EDC in rural areas and grid-connected REEs. Given this, the setting of retail tariffs for these REEs is simple - they equal those of EDC. What becomes of importance is the price at which these REEs are allowed to purchase bulk power supplies from EDC. The difference between this price and retail tariffs will determine their revenues.

It is proposed that „standard' costs be determined for different classes of REE and used to set this discount. Provision already exists for this in the tariff regulations issued by EAC, which state[22] that:

> *EAC may aim to move towards issuing same tariffs for groups of licensees. This would require grouping of Smaller Licensees with similar operational, technical or geographic characteristics.*

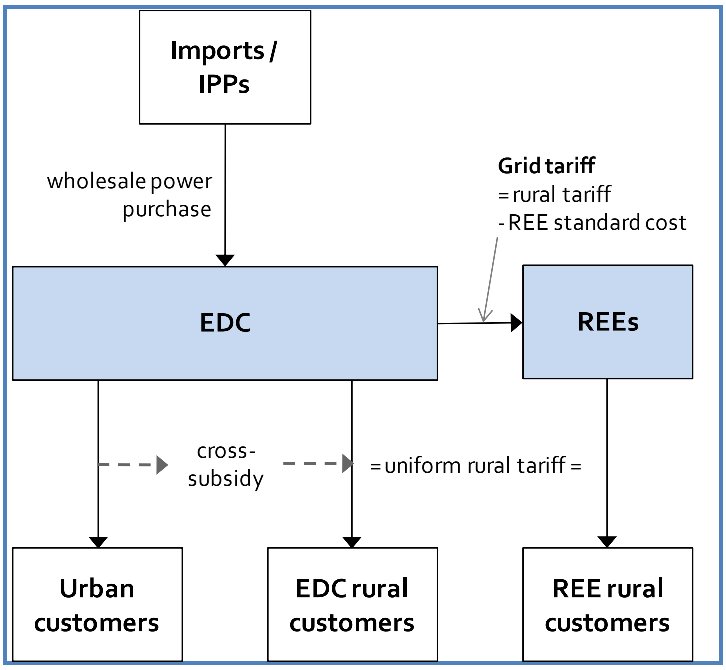
Using standard costs has the advantages of reducing the regulatory workload for EAC and REEs, increasing transparency in cost determination and encouraging efficiency in REEs. Assuming that the standard costs used to determine the REE discount are broadly equivalent to EDC's own costs in providing LV distribution services in rural areas, this should also have the advantage of leaving EDC indifferent whether it is directly supplying end-customers or selling to an REE who does so.

One concern is that REEs whose networks are of lower technical standards could gain under this approach. An REE whose network uses lower quality materials but which is allowed to recover a standard cost would make an additional profit. Overcoming this may require a certain minimum network quality to be obtained before an REE can be placed on a standard cost tariff, with the assumption being that qualities below this level would be lower cost and, therefore, the REE tariff or bulk supply discount would also be lower. In this context, quality is defined by compliance with the technical standards established by EAC.

It is proposed that standard costs would be established by grouping REEs with similar characteristics and use these to establish a standard cost. This could be, for example, the average of the costs of the individual REEs or, to promote greater efficiency, the upper quartile of costs. This will require EAC to continue to collect cost data on all individual REEs. However, there would be savings in time and expense to EAC and REEs in that some of the need for detailed investigation of individual REE costs would be reduced.
For reasons of fairness and due process, EAC would probably have to be obliged to continue to offer REEs the option of an individual review where their costs fell outside a reasonable range around the standard cost (for example, being higher or lower by more than 20%). EAC would also need to conduct audits at intervals of costs submitted by REEs to confirm their validity. Figure 17 summarises the proposed overall charging approach.

[22] Clause 3.3, Regulations on General Principles for Regulating Electricity Tariffs approved 26 October 2007.

Figure 17 - Proposed Charging Approach



4.2 Comparison with Current Methodology

EAC is currently implementing the following approach to establishing rural electricity tariffs:

- Imports are allocated initially to rural customers, with the grid tariff applied for bulk sales to REEs from EDC being calculated on this basis. This reduces rural tariffs relative to those of urban customers (who pay the higher costs of supply from IPPs)
- The grid tariff charged is inversely related to the distance of the REE from EDC's grid and, consequently, the length of MV line constructed by the REE to connect it to the grid. A customer supplied directly from EDC's rural subtransmission grid would pay a tariff of USc 16.05/kWh. The proposed grid tariffs would offer a discount of USc 1.5/kWh for REEs up to 8 km from the EDC grid to a maximum of USc 3/kWh for REEs located more than 20 km from the EDC grid
- The retail tariff would be established as the sum of the grid tariff, determined as above, plus the tariff required to recover the costs of the individual REE.

While the general approach has been agreed, it is understood that the final values to be used in setting tariffs have still to be confirmed.

For the short-term, the current methodology is reasonable and there is no immediate requirement to change to the proposed methodology. Implementing the proposed methodology will, in any case, take time given the need, crucially, to establish agreed affordable rural tariff levels based on willingness-to-pay studies.

However, in the medium-term, such a change is appropriate for the following reasons:

- The methodology reduces the costs of rural tariffs and brings them closer to urban tariff levels, but does not target affordability of rural supplies
- The reduction in wholesale supply costs for rural electricity customers relative to urban customers has the potential to create additional „headroom' between the ongoing costs of supply and affordable tariff levels within which rural tariffs can rise to fund the capital costs of an electrification programme. However, this headroom currently appears inadequate and further cross-subsidies will be required from urban customers
- The electrification strategy proposes that EDC is responsible for development of the subtransmission network. It would, therefore, be unnecessary and potentially counter-productive to provide incentives to REEs to construct lengthy MV lines which will subsequently need to be incorporated into EDC's grid

- While there appears to be sufficient import capacity to meet rural demand[23], the longer-term political sustainability of the methodology is uncertain. There may also be considerable opposition from urban customers if they believe they are not receiving the benefits of lower-cost imported electricity supplies.

4.3 Rural Tariff Limits

4.3.1 Affordability

Estimates of the affordability of electricity supplies in rural areas have been prepared, using evidence on rural household incomes from a 2008 study for MIME supported by UNDP[24]. This surveyed energy use and incomes for rural households in Kampong Speu and Svay Rieng provinces. The survey grouped households into classes depending on the materials used to construct their residence.

It is estimated affordable grid electricity costs in two ways:

- Assuming that expenditures on electricity by rural households should not exceed 10% of household income[25], and that grid connected households will consume, on average, 50 kWh per month (as applied in the JICA MP)
- Assuming that households will pay for grid electricity up to the cost of the alternative energy sources displaced.

It should be noted that both these approaches are approximate in nature and do not substitute for the more accurate estimates of willingness and ability-to-pay that a targeted household survey might be expected to provide. The resulting estimates for affordable electricity prices to rural households are shown in Table 14.

As can be seen, the estimates vary significantly between the two approaches; particularly in Kampong Speu province where it seems richer households currently spend significantly less than 10% of their income on electricity for lighting and appliances. Conversely, some poorer households appear to pay more than 10% of their income at present for these services.

For comparison, the 2008 survey by the Independent Evaluation Group of the World Bank's rural electrification support[26] reported estimates for the willingness to pay for grid electricity of rural households from USc 47-111/kWh for lighting uses and USc 26-146/kWh for TV. The same survey estimated that total household willingness to pay based on the benefits of electrification was from $10-30 per household per month which, at an assumed consumption of 50 kWh per month corresponds to around USc 20-60/kWh. Willingness to pay and affordability are not the same, but this does provide an indication of what sorts of prices customers may accept to receive high-quality electricity supplies.

Table 14 - Affordability of Rural Grid Electricity Supplies

Housing Material	Household Income	10% of income affordability limit		Substitution affordability limit	
		10% of income	Affordable price	Lighting and appliance expenditure[a]	Affordable price
	US$/month	US$/ month	USc/kWh	US$/ month	USc/kWh
Kampong Speu					
Brick	146	14.6	29.2	8.8	17.6
Brick / wood	113	11.3	22.6		
Wood / tile	79	7.9	15.8	6.4	12.8
Wood / corrugated iron	66	6.6	13.2		

[23] Our projections are that an import capacity of 80 MW (the current constrained import level) would meet rural demand until 2013, even under a major electrification programme, and the full import capacity of 200 MW until 2019. Import capacity will also increase over time.

[24] UNDP. 2008. *Residential Energy Demand in Rural Cambodia: An empirical study for Kampong Speu and Svay Rieng*.

[25] This may overstate the affordability of electricity supplies. A 10% affordability limit is commonly used to apply to energy supplies as a whole. If electricity is used primarily for lighting then the costs of other energy sources for cooking should also be included within this limit.

[26] Independent Evaluation Group. 2008. *The Welfare Impact of Rural Electrification: A reassessment of the costs and benefits*.

Housing Material	Household Income	10% of income affordability limit		Substitution affordability limit	
		10% of income	Affordable price	Lighting and appliance expenditure[a]	Affordable price
	US$/month	US$/ month	USc/kWh	US$/ month	USc/kWh
Thatch	35	3.5	7.0	5.2	10.5
Svay Rieng					
Brick	74	7.4	14.8	8.2	16.4
Brick / wood	73	7.3	14.6		
Wood / tile	63	6.3	12.6	6.3	12.7
Wood / corrugated iron	47	4.7	9.4		
Thatch	33	3.3	6.6	4.2	8.4

Source: UNDP, 2008. Monthly household expenditure is used as a proxy for monthly income.

a Monthly average expenditures on electricity, batteries and kerosene

4.3.2 Costs of Supply

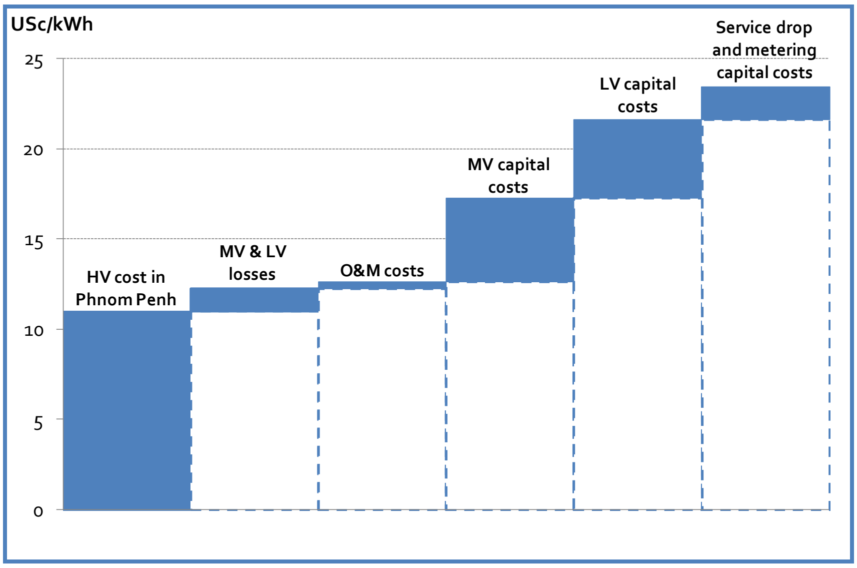
Our estimated cost of rural grid electricity supplies is shown in Figure 18. The assumed cost of electricity delivered at HV is USc 11/kWh. This represents an average of the cost of wholesale power purchases fuel oil-fired generators located in Phnom Penh, of around USc 14.7/kWh, and of wholesale imports from Vietnam, with an estimated delivered cost of USc 8/kWh. Losses on the rural subtransmission and distribution networks are assumed at 13.4% in line with the World Bank's analysis for the Rural Electrification and Transmission Project (RETP).

An average capital cost for rural subtransmission and distribution of US$ 589 per household is used, comprising US$ 253 per household for the rural MV subtransmission network, US$ 238 per household for LV distribution lines and US$ 97 per household for the costs of service drops[27], meters and meter boxes. This does not include the costs of internal house wiring, which might add a further US$ 20 per household for single-phase supply and US$ 200 for three-phase supply (based on cost estimates for Lao PDR).

In converting capital costs to a unit energy cost, it is assumed that a required return of 10% (nominal, US$) and asset life of 25 years. For comparison, current EAC regulations permit the depreciation of distribution lines on concrete poles over 30 years, transformers over 25 years and meters over 15 years.

An average consumption for rural households of 50 kWh per month is assumed, consistent with the JICA MP. In practice, as incomes grow, rural electricity demand will increase which will lower the average costs of supply (as capacity costs grow less than proportionally with consumption).

Figure 18 - Costs of Rural Grid Electricity Supplies



Source: ECA and AECOM NZ estimates

27 An average service drop length of 10 metres has been assumed.

The total estimated average cost for rural electricity supplies is USc 23.4/kWh. Of this, slightly less than half is comprised of the capital costs of the rural subtransmission and distribution network while the remainder, around USc 12.5/kWh comprises ongoing costs.

These estimates can only be indicative. There are many uncertainties related to the actual costs of rural electricity supplies. These include:

- Value added tax (VAT) at a rate of 10% has recently been imposed on electricity sales by EDC. Currently, EDC is required to pay VAT but is not permitted to recover this from retail customers. This situation appears to contradict the requirement that licensees are permitted to recover reasonable costs, of which VAT is one, and which is assumed will not be sustained in the long-term. If VAT is passed through to retail tariffs then the costs of rural electricity supplies would increase to around USc 26/kWh
- Over time, electrification costs can be expected to rise as the grid is extended to more remote areas with lower load density. For comparison, recent cost estimates for grid electrification in Lao PDR - which has achieved much higher electrification rates than Cambodia - are around US$ 750 per household. This would see rural electricity supply costs rising to around USc 28/kWh
- Import costs may rise. The current price is to be renegotiated and is expected to increase. An increase to USc 10/kWh, for example, would lead to rural electricity supply costs rising to USc 25/kWh
- Rural consumption levels may be lower than is assumed. The load forecasts for Kampong Cham province prepared by IED under the CAP-REDEO project assume an average initial household monthly consumption of around 30 kWh[28]. Applying this and assuming that investment costs are unchanged with the lower demand, the average cost of rural grid electricity supplies would rise to USc 26/kWh
- The costs of wholesale power supplies for rural customers may fall over time, as supplies from imports and domestic hydro and coal-fired IPPs increase and the proportion of supplies from fuel oil-fired IPPs falls. This process would be accelerated under current regulatory arrangements for tariffs which would see imports allocated first to supply to rural electricity customers. If wholesale power costs fall to USc 8/kWh, the cost of rural electricity supplies declines to around USc 20/kWh
- Capital costs might be reduced through the use of SWER technologies and the adoption of lower technical standards for rural distribution networks serving smaller loads. While the initial potential for such lower-cost technologies appears low, given the load densities in initial areas of grid connection, it may be possible to apply them in later extensions of MV lines to less densely populated areas. Estimates for Lao PDR are that the costs of SWER are around 30-35% lower than single-phase lines[29] which, if applied to the capital costs of rural MV distribution lines, would see the average cost fall to around USc 22/kWh
- The operating costs of EDC and REEs can be reduced over time. Distribution network losses may also be reduced with suitable investments to upgrade existing systems. Such reductions will require appropriate incentives to be put in place (for example, the proposed use of standard cost allowances for REEs) as well as for tariffs to adequately cover the up-front costs of loss-reducing investments. A reduction in assumed subtransmission and distribution from 13.5% to 10% would reduce average costs to just over USc 23/kWh.

It therefore appears reasonable to assume that the average cost of rural grid electricity supplies probably falls in a range from around USc 23-26/kWh. Reductions below this level may be possible as existing oil-fired generation is increasingly displaced by domestic hydro and coal-fired generation and by imports, and further reductions are possible with the use of lower-cost distribution technologies and efficiency improvements. These will be offset to some extent by rising costs as the rural network expands to less densely populated areas, by possible future increases in import prices and by the need to include VAT in retail electricity tariffs.

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28 IED. April 2008. *Load Forecast Report*. CAP-REDEO Project. The report assumes three household classes with monthly consumption ranging from 13-68 kWh in the initial year of connection. The *Final Supply Options Report* (November 2008) adds a fourth class with monthly consumption of 8 kWh. The figure shown is the weighted average of consumption across the four classes, using their share of population as given in the reports. This will understate actually achieved consumption levels as richer households with higher consumption levels will be expected to connect first and consumption levels will be expected to rise over time.

29 NRECA. February 2000. *Reducing the Cost of Grid Extension for Rural Electrification*. Report prepared for ESAMP.

4.3.3 Cost and Affordability Estimates Compared

Table 15, summarises estimates of the costs of rural grid electricity supplies and compares these to estimated affordable tariff levels. These numbers are all indicative in nature given the large uncertainties involved in preparing these estimates and the extent to which costs and affordability vary by location, income and electricity demand. The uncertainty of this is reflected by rounding all cost estimates to the nearest whole number.

Table 15 - Summary Cost and Affordability Estimates

Costs of rural grid electricity	**USc/kWh**
Ongoing costs	13
Ongoing costs + MV capital costs + LV capital costs	22
Ongoing costs + MV capital costs + LV capital costs + service drop capital costs	23
Affordable tariffs	**USc/kWh**
High-income rural households (brick construction)	15 - 29 (mid-point 22)
Mid-income rural households (wood construction)	9 - 16 (mid-point 13)
Low-income rural households (thatch construction)	
50 kWh monthly consumption	7 - 11 (mid-point 9)
25 kWh monthly consumption	13 - 21 (mid-point 17)

For the poorest households, estimates of affordability are shown both for assumed average rural household consumption level of 50 kWh per month and for a lower consumption level of 25 kWh. This would cover the use of two to three 40 W bulbs for four hours per day as well as similar use of small appliances such as a fan. The poorest rural households would be able to afford tariffs of USc 13-20/kWh at this consumption level without breaching the affordable expenditure levels calculated. As a comparison, the IED CAP-REDEO project assumes the poorest households consume between 8 kWh and 13 kWh monthly.

The comparison suggests that:

- All rural households can afford to pay the ongoing costs of electricity supplies, of around USc 12-13/kWh (assuming lower levels of consumption for the very poorest households).
- Only the richest households in the richer of the two provinces surveyed (Kampong Speu) appear to be able to afford the full cost of rural grid electricity supplies (including capital costs).
- An average rural electricity tariff for grid supplies of USc 13-17 /kWh would be generally affordable, assuming the poorest households have lower consumption levels.

These affordability concerns are limited to grid electricity supplies. It is assumed that much lower average levels of monthly consumption for mini-grid and solar system customers, of 10 kWh and 3 kWh respectively, again taken from the JICA MP. At these consumption levels, affordable tariffs for the lowest income groups in Kampong Speu and Svay Rieng provinces would range from USc 30/kWh to USc 70/kWh for mini-grids and USc 110/kWh to USc 220 /kWh for solar systems. This compares with estimated costs of supply, as shown in Section 2.1, of USc 40/kWh to USc 60/kWh for mini-grids[30], depending on technology, and USc 110/kWh to USc 140/kWh for solar systems (a cost which may have fallen given the recent large falls in solar component costs). This suggests affordability might be a concern for mini-grids in some cases, although not to the same extent as for grid supplies, but is not a concern for solar systems.

Such high estimates of affordable tariffs for mini-grid and solar system customers are comparable with estimates of willingness-to-pay in other countries[31]. They are also consistent with tariffs currently applied by mini-grid REEs in Cambodia - which average USc 67/kWh and range up to USc 117/kWh[32]. However, it does not necessarily mean that these customers should be expected to pay the full costs of electricity supply. The assumed 10% affordability limit on electricity expenditures as a share of household incomes already represents a significant share of household budgets, particularly as this would only cover lighting, radios and so forth and excludes the costs of energy for cooking. There are also questions of equity - mini-grid and solar system customers will generally be poorer households and it would seem inequitable to expect them to pay

[30] At a load factor of 20%.
[31] The IEG's 2008 report, for example, includes estimates of willingness-to-pay for lighting from off-grid supplies of USc 190-300/kWh.
[32] As at December 2007.

much higher prices for electricity supplies than richer households receiving higher-quality grid electricity supplies. The strategy, therefore, assumes subsidies will be provided for mini-grid REEs at least, and potentially for solar systems, for reasons of equity.

4.4 Funding the Electrification Programme

Estimates have been prepared of the funding costs of the scale of rural electrification programme required to meet the RGC's targets, focusing in particular on the need for and level of cross-subsidies from urban to rural customers. These estimates suggest that, assuming extensive donor funding of up to 80% of capital costs of the programme, cross-subsidies can be kept at relatively low levels representing only around 1-2% of urban tariffs.

The analysis presented in this sub-section is limited to the grid component of the electrification programme. Whether donor funding of investments should be extended to mini-grids and solar systems is less clear. This is discussed in more detail later in this section.

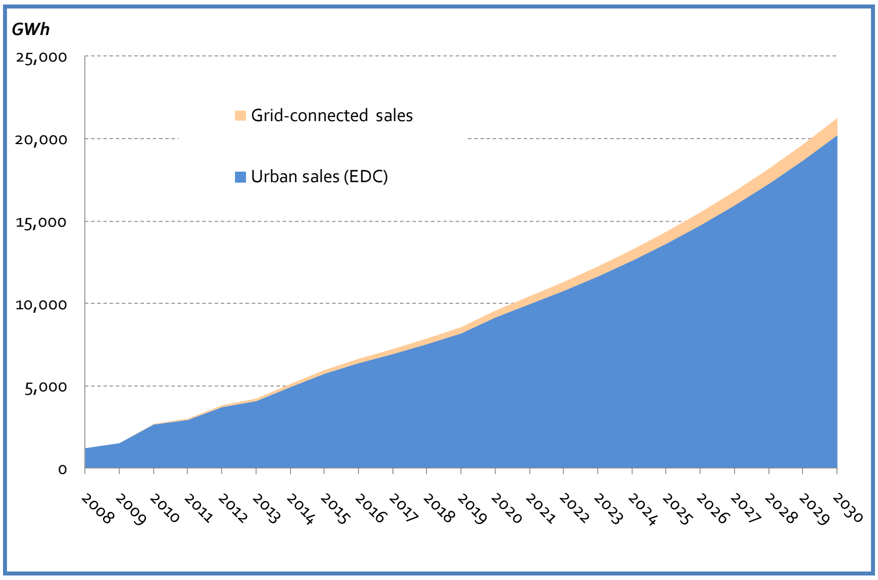
4.4.1 Demand Projections

The projections assume the rural household connection rates estimated in Section 1.6 as being required to meet the RGC's targets. Households are assumed to consume, on average, 50 kWh monthly. A proportion of non-household rural demand is also assumed.

Urban electricity demand is assumed to grow at the rates projected in the base case in the 2006 Power System Development Plan, averaging 13.2% annual growth to 2020 and 8.3% thereafter. The starting point for urban demand is taken as actual EDC sales in 2008.

The very rapid projected growth in urban demand and the low assumed consumption of rural households mean that urban demand dominates the future sales mix despite the rapid growth in rural connections. Sales to rural consumers represent less than 5% of total projected sales. The sales projections used are illustrated in Figure 19.

Figure 19 - Sales Projections



4.4.2 Financing Assumptions

It is assumed that 80% of the capital costs of subtransmission and distribution investments under the electrification programme are met from donor loans. The average funding terms are assumed to be equivalent to an interest rate of 2%, term of 25 years and grace period of 7 years (as for World Bank loans onlent to EDC for rural electrification under the ongoing RETP)[33]. The funding provided may be in the form of

[33] This would reduce the average cost of grid electricity from USc 23/kWh to around USc 18.5/kWh. This is above the upper end of the estimated affordability range, but it is expected that that increased reliance on imported supplies and domestic hydro and coal generation will help reduce costs.

a mix of grants and loans at market or near-market terms or concessionary loans. The delivery of capital subsidies is discussed later in this section.

Rural household customers are assumed to pay their direct connection costs (service drop, meter and house wiring). In addition, rural customers are assumed to make a contribution towards the capital costs of subtransmission and distribution investment equal to the difference between an „affordable' tariff and the ongoing costs of supply.

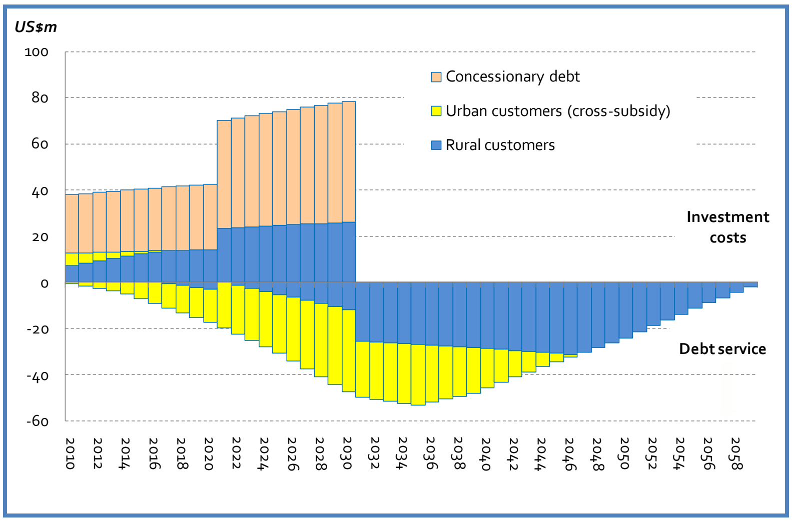
For the purposes of these projections, the affordable tariff level is set at USc 15/kWh. The ongoing costs of supply are assumed to be USc 12.6/kWh comprising a cost for bulk supplies at the exit from the HV system of USc 11/kWh plus subtransmission and distribution losses and operating costs. The bulk supply cost is an average of an assumed import price of USc 8/kWh and supply from existing oil-fired IPPs at a price averaging USc 14.7/kWh. In future, bulk supply costs may fall as the share of supply from imports and new hydro and coal-fired IPPs in Cambodia rises. However, these reductions will be offset by the future application of VAT to electricity sales[34] and expected increases in import prices following the forthcoming renegotiation of the existing contract with Vietnam.

Rural household customers connected to the grid are thus assumed to contribute USc 2.4/kWh on average towards the capital costs of the electrification programme, plus paying their direct connection costs. This is equivalent to an annual contribution of around US$ 14. The difference between revenues from rural customers and the capital costs of the electrification programme to be funded by customers (comprising 20% of the initial investment cost and servicing of donor loans) is assumed to be met by cross-subsidies from urban customers.

4.4.3 Funding Breakdown

Of the initial grid investment cost, of US$ 589 per household, donor loans are assumed to finance US$ 393 (80% of the subtransmission and distribution investment cost), rural households fund US$ 112 representing the direct connection cost and a contribution of US$ 14 to subtransmission and distribution investment costs and urban customers the remaining US$ 84 in investment costs. Donor loans are repaid over time from rural and urban customer tariff revenues. Over the lifetime of the electrification programme, rural customers pay 63% of the total costs with the remainder being paid by urban customers[35]. Of the investment costs, around 30% are funded by rural customers and 65% from donor loans with urban customers funding the remaining part. The funding of the grid component of the electrification programme over the entire period until final repayment of all associated loans is shown in Figure 20.

Figure 20 - Grid Electrification Programme Funding



[34] In 2009, VAT was applied to electricity sales by EDC. Currently, EDC is required to pay VAT but cannot recover this from retail tariffs. This situation is unsustainable and it is expected that VAT will be added to retail tariffs in the near-future.

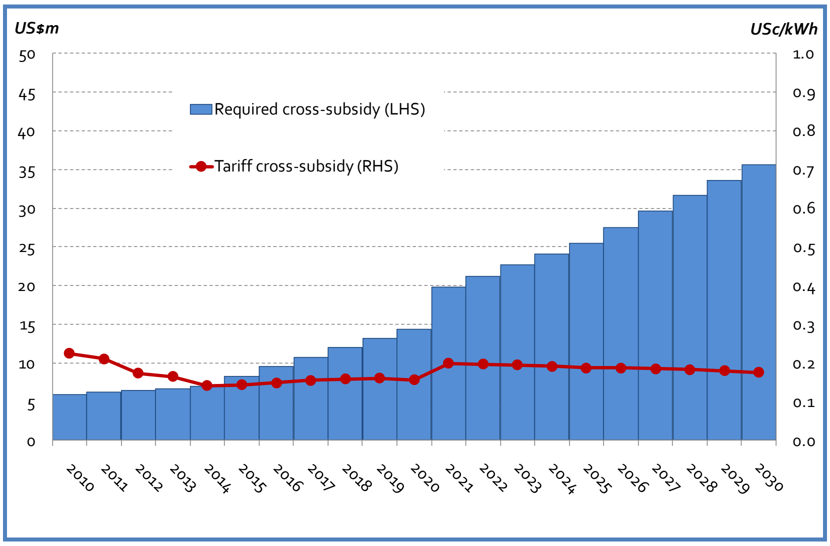
[35] Total costs are calculated as the present value of investment costs financed by customers plus debt service on donor loans. The funding split shown is undiscounted. Applying a discount rate reduces the share of the programme paid for by rural customers as contributions from urban customers are highest in earlier years.

4.4.4 Cross-Subsidy Requirements

The estimated cross-subsidy required from urban customers is around USc 0.15-0.2/kWh, or 1-2% of average urban tariffs. This relatively small amount is partly due to the assumption that concessionary funding is available for the majority of capital investments but, primarily, due to the large differences in projected urban and rural electricity sales. Despite rapid growth in the numbers of electrified households, the low consumption of rural customers means that rural grid sales are less than 5% of total national grid-connected sales. As a result, a large volume of urban demand is cross-subsidising a much small volume of rural demand.

Our projections of cross-subsidy requirements are shown in Figure 21.

Figure 21 - Cross-Subsidies for Rural Electrification



4.5 Donor Funding Options

The foregoing projections assume donor funding of 80% of investment requirements over the electrification programme's life. The available funds may be less than this, which would imply either reducing the scale of the programme or placing greater reliance on customer funding - principally by increasing cross-subsidies from urban customers - and so reducing the share of funding met from donor loans. However, whatever the actual outcome, it is expected that the majority of capital expenditures under the programme will be funded by donors. This subsection considers how to provide these funds in a way which ensures rural customers benefit from them.

It should be noted that donor support may not be specifically directed to electrification. It is also possible that donor funding for other RGC activities may allow redirection of RGC revenues to electrification and away from these activities, if the benefits to Cambodia justify this. For convenience, however, this section refers to „donor funding' throughout.

The discussion in this section focuses on donor funding provided for the purposes of meeting the RGC's electrification targets, recommending on how this funding can be most effectively used for this purpose. It does not discuss other possible funding sources. Notably among these are the various fund and facilities targeted at the expansion of renewable energy sources and reduction of carbon emissions such as the Clean Technology Fund, the Global Environment Facility and the various Carbon Funds administered by the World Bank. These may provide additional funds, with particular relevance to mini-grid projects based around renewable energy sources and for solar systems. As expected, renewable energy sources to play a relatively small role in the electrification programme given the constraints on their deployment (see earlier sections), potential specific funding of these is of less significance in the overall strategy. However, it should be noted that the strategy as a whole can be expected to have beneficial effects in terms of reducing carbon emissions as it will help replace existing use of charcoal, kerosene and diesel generators in rural areas with grid electricity which is increasingly generated from hydro and, through imports, gas-fired sources.

4.5.1 Subtransmission Funding

Donor funding for subtransmission investments can be delivered in the form of capital subsidies provided by RGC (using donor funds) to EDC. As EDC will be the owner and operator of the subtransmission network, these concessionary funds will reduce its funding costs and directly feed through into reductions in grid tariffs and final customer tariffs. If the benefits of donor funding in terms of affordable rural tariffs and limited cross-subsidies from urban customers, then this onlending needs to be on terms equivalent to those under which donors provide funds to RGC. Increases in interest costs or reductions in payment periods will lead to higher funding costs for EDC and directly impact on customer tariffs.

As with capital subsidies to REEs (see below), the optimal funding mix for EDC is likely to be through a mixture of grants (providing the subsidy element) and loans provided on commercial or near-commercial terms (providing the incentives to ensure that investments are financially viable and to ensure effective maintenance and collections). An example of such a funding mix is provided by the most recent World Bank support to Lao PDR for electrification. The loan from the World Bank to the Government of Lao PDR is provided on IDA terms with the funds being provided by the Government to Electricité du Laos as a mix of 80% grant funding and 20% as a loan with terms comparable to those offered by IBRD (understood to be an interest rate of 6% and a loan term of 15 years including a 5-year grace period).

However donor funding of capital subsidies is provided to EDC, it is critical that tariffs are set to allow EDC to recover its full costs including the repayment of any loans.

4.5.2 Distribution Funding

Donor funding of subtransmission investments is unlikely to be enough, in itself, to reduce rural electrification costs to levels that are affordable. Even if donor funding covered the entirety of the required subtransmission investments, this would represent less than 50% of the estimated average household connection cost.

Donor funding will, therefore, also be required to fund part of distribution investment costs. There are two main alternative routes through which this could be provided:

- Donor funds are provided to EDC which uses these to partly finance the costs of construction of distribution networks. Following completion, EDC would then lease these networks to REEs to operate
- Donor funds are provided to both REEs and EDC to finance distribution investments. Where EDC constructs distribution networks then it would subsequently lease these to REEs as under the first option.

The first option of limiting donor funding for distribution investments to EDC alone has the advantage of simplicity. However, it is not appropriate at this time in Cambodia:

- Limiting access to donor funds to EDC implicitly assumes that REEs should not construct new distribution networks. This is likely to deter some potential REEs who might wish to develop their own networks and may be seen as signalling that REEs are no longer wanted, at least in their current form. It also increases the calls on EDC's resources and risks delays in programme implementation
- Unless EDC also funds the construction of network expansion for both EDC and REE-owned networks, limiting donor funds to EDC alone will favour households in new service areas over those in existing REE service areas. Expansion of networks in the latter areas would need to be funded by the REEs using commercial funding while the construction of new networks by EDC would use lower-cost donor funding
- If proposals on medium-term tariff policy are not accepted, then restricting access to donor funds to EDC will increase tariffs for customers of REEs, who are forced to rely on more expensive commercial borrowing to fund their investments[36]. This may lead to tariffs in some areas which are above the affordable level and will lead to households preferring to wait for electrification rather than be connected by a REE at higher tariffs than would be charged for an EDC-funded network.

[36] Under the proposed tariff policy, rural retail tariffs would be uniform. The impacts of different financing costs for distribution networks, depending on whether they are developed by EDC or REEs, would be captured through differences in the grid tariff applied. Under the current tariff policy, retail tariffs differ by REE depending on the REE's individual costs and so REEs with higher financing costs would have higher retail tariffs.

It is therefore proposed to adopt the second option, with REEs and EDC provided donor funding for distribution investments. Funding for EDC would come as part of the electrification subsidies provided by RGC to EDC as discussed above. Funding for REEs would be channelled through the REF. The proposed mechanism is discussed below.

The use of different funding routes will require decisions on the proportions of available funding for electrification to be provided to EDC and to REEs. The split should be determined based on the expected share of REEs in new connections and the share of LV distribution costs in total capital costs. For example, if LV distribution represents around 50% of the costs of subtransmission and distribution investments and REEs are expected to connect around 55% of new rural customers then 27.5% of available electrification subsidies would be directed to REEs through the REF with the remainder being directed to EDC[37]. The proportion of connections to be made by REEs is obviously uncertain, depending on many factors, and may well reduce over time as electrification expands to less commercially attractive areas. Therefore, flexibility as to the split of funding should be retained with the proportions being adjusted over time.

4.5.3 Mini-Grid Funding

While the costs of mini-grids are high, customers can be expected to have a high ability to pay for these given the generally small amounts of electricity used. Donor funding is not, therefore, required to ensure affordability unlike the funding of grid electrification although it may be a concern in a few cases. And, by not providing donor funding to mini-grids, funds can be freed for the grid electrification programme.

The argument for donor funding of mini-grid investments is primarily one of equity. Restricting large-scale donor funding to grid electrification discriminates between those customers connected to the grid, who may also be the wealthier households, and those supplied through mini-grids and solar systems. The inequality between the two groups in terms of cost of supply would be exacerbated if only grid-connected customers benefit from donor funding of investments.

In future, many mini-grids can be expected to be connected to grid supplies. This will further worsen inequalities between customers in the absence of donor funding for mini-grids. Customers who were originally supplied through a mini-grid may find they have paid the full costs of their distribution network while customers who were always connected to the grid have only paid a part of the associated distribution network's costs. The possibility of future grid connection also requires that mini-grids are constructed to the same technical standards as the main grid. This will further increase the costs of mini-grids and, therefore, the costs of supply to their customers in the absence of donor funding.

Donor funding may also be necessary to overcome limitations on the current access of REEs to debt financing. At present, REEs have little or no ability to borrow commercially. A 2008 study[38] estimated that, of a typical REE expansion project costing US$ 90-100,000, around 25% would be financed from grants by the Rural Electrification Fund (REF). The remainder is financed from equity (family, friends and sale of assets such as land).

ACLEDA has been the biggest lender to REEs. The same study reported that loans were typically:

- Short-term (12-24 months)
- High interest rates (20-25% annual equivalent)
- Required substantial collateral.

If REE investment in mini-grids is to be scaled-up to the levels required to meet electrification targets then more sources of financing will be needed. The current limits on commercial borrowing mean that donor funding is probably the only source of such funds that can be mobilised in sufficient scale in the short to medium-term.

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[37] Under the rural electrification component of the RETP, EDC is expected to connect around 50,000 rural households and REEs around 45,000 households through grid connections, 12,000 through SHS and additional households through mini-hydro grids for a total of around 60,000 connections by REE.

[38] Mason, Clive. August 2008. *SMEs in Decentralised Energy Services Program: Access to Finance*. Final Report.

Overall, it is appropriate to provide donor financing for capital investments for mini-grids in a similar proportion to that for main grid connections (i.e., up to 80% of the investment cost). However, it is recognised that policy decisions are required as to whether to favour equitable treatment of mini-grid customers over the higher electrification levels that could be achieved if all available donor funds are directed to grid expansion. This funding would be provided on a similar basis to that proposed for grid electrification by REEs.

There may, in any case, be a need for limited donor funding to help address market failures in mini-grid electrification. The most significant market failure probably relates to the difficulty in developing mini-hydro grids. Unlike mini-grids based on diesel and biomass / biogas generating technologies, the design of a mini-hydro grid requires an extended period of analysis of sites and technical options. The design process itself is costly, requires specialist knowledge and is time-consuming. While mini-hydro grids may be optimal in the long-run, offering lower costs than diesel mini-grids, these up-front costs may well prevent REEs developing them in the absence of suitable funding mechanisms. Specific funding such as this may be an effective use of funds targeted at the promotion of renewable energy sources and reduction of carbon emissions.

It is expected that donor funding for mini-grids would be channelled through the REF.

4.5.4 Solar Systems Funding

Similar arguments to those regarding donor funding of mini-grids apply to the funding of solar systems. Again, affordability does not appear to be a significant concern and, instead, policy decisions are needed on the balance to be struck between equitable treatment of all households and increased electrification rates.

In the case of solar systems, the balance probably lies more towards not providing donor funding as part of the electrification programme. This does not, of course, prevent donor support for solar systems outside the main electrification programme:

- Electrification through solar home systems should not count towards the achievement of the RGC's targets, given that these are based on the delivery of grid-equivalent supplies. Allocating donor funding to solar systems would, therefore, actually reduce progress towards these targets by diverting resources from technologies that do deliver grid-equivalent supplies
- The provision of solar systems is a competitive activity which is generally commercially viable in its own right. The introduction of donor funding may actually undermine the competitive nature of the market as this will tend to be directed towards a small number of suppliers (although these would be selected through a competitive process) who may also have some degree of exclusivity. Other solar systems companies will find it very hard to compete with such preferred suppliers
- Solar systems are modular by nature - a key difference from mini-grid and grid supplies. This further reduces affordability concerns, although these are not a major consideration for off-grid technologies, as households can select the system size that best meets their willingness and ability-to-pay.

It is recognised that this may make it more difficult for solar systems to compete with mini-grids, which benefit from donor funding on concessionary terms. However, such competition is probably limited in practice. Solar systems will generally be viewed as either an interim solution, pending the development of a mini-grid or arrival of the main grid, or a long-term solution where mini-grids and main grid extension are not feasible. The use of solar systems as an interim solution is assisted by their portability. Even where competitive on the basis of a comparison of levellised costs, solar systems are also generally not able to offer the same capacity or reliability as good quality mini-grid and main grid supplies[39].

4.6 Connection Loans

Connection costs are defined as the costs of the service drop, meter and internal house wiring. Requiring customers to pay these costs will reduce the investment costs borne by EDC and REEs, freeing up funds for other purposes.

[39] The discussion in this section is limited to the extent that solar systems can contribute to the achievement of the RGC's electrification targets. There may be other reasons to promote the use of solar power - in particular as a means of reducing reliance on fossil fuels and carbon emissions. However, these benefits do not contribute to the objective of increasing electrification rates.

It is recognised that there is a risk that poorer households, in particular, will not be able to pay these connection costs. Often, the barrier to connection is the need to make a (relatively) large one-off payment for the connection. As part of the electrification strategy, it is proposed that poorer households will have access, through the REF, to interest-free loans to help pay connection costs. The terms of these loans and eligibility for them would be established by EAC. Administration of the connection loan programme would be by the REF.

Preliminary proposals have been developed on a possible mechanism for providing connection loans and the terms of these loans. These proposals are based on the successful „Power for the Poor' programme operating in Lao PDR. Some modifications have been proposed, primarily due to the fact that in Cambodia there will be multiple suppliers to rural customers whereas, in Lao PDR, there is only one supplier in the form of Electricité du Laos (EDL).

A summary of the proposed connection loan mechanism and a comparison with the Power for the Poor Programme is provided in Table 16.

Table 16 - Connection Loan Programmes in Cambodia (Proposed) and Lao PDR

Lao PDR - Power to the Poor programme	Cambodia - proposed programme
Eligibility	
Poorer households are identified by the village head, village committee and Lao Women's Union	Poorer households are identified by the village head[40]
Households must live in a permanent structure located no more than 30 metres from the existing grid	Eligibility criteria are similar to the „Power to the Poor' programme
Households must show their ability to meet loan repayments	Eligibility is confirmed by the supplier (REE or EDC) who applies to REF for a loan on behalf of the households
Eligibility is confirmed by EDL and the electrical contractor responsible for the works	REF conducts audits at intervals to confirm suppliers have correctly identified eligible households
Loan disbursement	
The electrical contractor provides a quote for the connection and wiring	REF provides a loan of US$ 80 per eligible household to the supplier
EDL provides a loan of US$ 80 to the household in the form of a voucher	The supplier onlends this to the household in the form of a voucher
The households pays the electrical contractor for the works, using the voucher as part-payment	The households pays the electrical contractor for the works, using the voucher as part-payment
The electrical contractor redeems the voucher with EDL	The electrical contractor redeems the voucher with the supplier
Loan repayment	
Repayment of the loan is made over three years and is interest-free. Monthly charges are approximately US$ 2.30	Repayment of the loan is made over five years and is interest-free. Monthly charges are approximately US$ 1.30 (equivalent to USc 2.7/kWh)
Repayments are made to EDL and included in electricity bills	Repayments are made to the supplier and included in electricity bills
	The supplier repays their loan to REF on the same terms as the repayments by households. Suppliers are liable for loan repayments to REF even where households do not make their repayments

In the medium to long-term, connection loans should be largely financing on a revolving fund basis. However, there will be a need for initial working capital until repayments come to broadly equal disbursements - a situation that should be achieved after five years when the sum of repayments is broadly equal to new annual lending. This working capital will probably need to be provided from donor funding - ideally in the form of a grant given that connection loans will be interest-free. Assuming that an average of 65,000 households are connected annually to the grid up to 2020 and that, of this total, one-third[41] are

[40] The alternative of providing loans to the smallest connection size was considered but rejected. The use of elected village officials to identify eligible households is consistent with both the Lao programme and Cambodian practice in other sectors (eg, provincial water supply projects).

[41] IED under the CAP-REDEO project assume that 34% of rural households in Kampong Cham province fall into the lowest-income class. IED. November 2008. *Supply Options Report: Final Report.* CAP-REDEO Project.

eligible for connection loans of US$ 80 per household then annual connection loans total US$ 1.7 million. Over four years, the total loans which would need to be made from the initial working capital provided by donors come to US$ 7 million. A further injection of working capital would be needed after 2020 when the rate of electrification is expected to increase.

It is still possible that some customers will have difficulties repaying such loans. This can be partly addressed through promoting income-generating activities for households resulting from electrification. Support for training in and funding of such income-generating activities should form part of an overall rural electrification and development programme.

4.7 REF Funding Mechanisms

Under the proposed electrification programme, the REF would be responsible for providing concessionary funding to licensees for investments in grid-connected distribution networks and mini-grids and for onlending to eligible customers as connection loans. This section focuses on the mechanisms for funding licensees for investment purposes.

4.7.1 Coverage of Funding

It is proposed that REF funding is limited to REEs. Funding for EDC, for both subtransmission and distribution investments, would be provided directly from the Ministry of Economy and Finance (MEF). As the split of distribution investments between EDC and REEs is not known in advance, as It is proposed that EDC would only invest where REEs are unwilling to do so, this may require some adjustments to loan volumes over time. If more REEs than expected are willing to invest in new distribution networks then loan volumes to EDC can be reduced and those provided to REEs through the REF increased. If less REEs than expected are willing to invest, then loan volumes to EDC would instead be increased to fund the additional distribution investments.

4.7.2 Types of Funding

At least part of the funding provided to REEs should be in the form of loans in order to creates an incentive for REEs to ensure the commercial viability of their investments (taking account of available subsidies) and the ongoing sustainability of their business given the need to repay the initial loans. As with funding to EDC, It is proposed that funding to REEs is provided through a mix of grants, providing the capital subsidy component and loans on market or near-market terms, providing the commercial incentives. A further advantage of such a split is that part or all of the grant funding can be made on an output-based aid (OBA) basis creating further incentives on REEs to efficiently and rapidly undertake electrification activities.

Currently, commercial loans to REEs are at extremely high rates with very short terms. REEs should not be expected to fund any significant part of their capital investments under such terms given the high up-front costs this would create, with consequent cashflow problems for REEs, as well as the limited benefit in terms of commercial incentives (as loans would be rapidly repaid). Instead it is proposed that efforts should be made to offer loans at lower interest rates and longer terms by providing some form of partial guarantee to commercial lenders. With AusAID support, the REF is currently developing a guarantee mechanism of this type and it is recommended that this continue.

The appropriate mix of grants and commercial loans will depend on the terms of these loans and the scale of the subsidy component that REEs should receive[42]. There is also the question of whether the financing terms available to REEs should be similar to those available to EDC. More expensive financing would not, under the proposed methodology for setting rural tariffs, lead to customers of REEs paying more than customers of EDC. However, it would increase the cost allowance for REEs and, therefore, reduce EDC's grid tariff which set be deducting the allowed REE cost from the uniform rural tariff and thereby increase the need for cross-subsidies from EDC's urban customers.

[42] As an example, of the changing grant component, if REEs were to be offered financial support with a similar present value to that provided to EDC under the RETP (2% interest rate, 25-year loan term and 5-year grace period) for rural electrification then, under existing commercial lending terms (20% interest rate and 2-year loan term) the grant component would need to be around 70% of total financial support.

Potential difficulties arise where the licence terms of REEs are shorter than the duration of REF loans. This may or may not be the case depending on the extent to which guarantees allow for longer loan terms - as of 2007 the average term of consolidated licences issued for REEs operating mini-grids was under five years.

One solution is to extend licence terms to match expected loan terms. However, this may work against other objectives such as the consolidation of REEs over time. It would be consistent with EAC's current approach of using licence extensions as an incentive to REEs to invest in improving their network. REEs who borrow to invest in expanding services would be eligible for long-term licences which, in turn, would allow their licence term to match loan terms.

Another solution, which could work alongside longer licence terms, would be for the REE to retain liability for the loans, even if its licence expires and is not renewed. The REE would then become responsible for servicing the loans out of revenues derived from its assets even where it no longer operates them. If the REE sells the assets to a new licensee then the proceeds can be used to repay the original loan. Alternatively, the REE could lease its assets to the new licensee and use the lease payments to service the loans. This may be preferable as it avoids the need for new licensees to make a large up-front payment to purchase the assets.

A further problem with lending donor funds, rather than providing these as grants, is the small size of many REEs, some of which are individuals or families. Such REEs may have difficulties in committing to a long-term loan given uncertainties over future incomes, health and outside opportunities. Restricting access of the smallest REEs to loans could be used, of course, as a means of providing incentives for their consolidation but this would be at the risk of deterring REE interest.

4.7.3 Eligibility and Disbursements

The general principles followed in developing the proposed funding mechanism are:

- REF funding should, in general, be licensee and technology-neutral
- Grant funding should generally be provided on an output-based aid basis, where financing constraints allow.

Consistent with this, it is proposed that the REF provides a standard grant payment for each household electrified by a REE - whether through a grid connection or through a mini-grid. The grant payment would be set so as to cover a standard proportion (around 70% or so) of expected average grid connection costs. This leaves REEs to select the optimal technology and treats grid-connected customers and those served from mini-grids equitably[43]. An initial payment would be made on submission of a suitable electrification plan showing proposed investments and expected numbers of connections. Further payments would be made on completion of the investments for each actual connection made and after a suitable period, such as six months to one year, for those connections continuing to operate.

REEs are generally severely cash-constrained meaning they will need to receive a large part of the total investment costs up-front. Part of this will be covered by loans. However, it is expected that the grant component of funding to REEs will need to be 70% or more of total costs meaning that, in addition, a large proportion of the grant funding will also need to be made prior to investments commencing. It is suggested that around half the grant funding would be provided as an initial payment implying the total up-front funds (loans and grants) would be around 65% of total investment costs.. Making such a large share of payments up-front does emphasise the need for the electrification plan's viability to be verified and for suitable monitoring and security arrangements to be put in place.

The payments would be made for each household connected and would not seek to target poorer households. This is partly based on previous experience in Cambodia - the provincial water supply project, for example, which linked subsidies to the number of poor households connected found that licensees limited their connections to poor households in order to receive the subsidy and ignored richer households. Overall coverage rates achieved were lower than more conventional projects which paid for the construction of a

[43] The use of a standard grant payment does mean that REEs using mini-grids, where these have a higher connection cost per household than the average grid connection, would need to borrow more and, therefore, would have a higher financing cost and tariff compared to grid connections. Higher tariffs for mini-grids are considered to be acceptable, as is demonstrated by current practice in Cambodia and elsewhere.

planned network. A separate mechanism is also proposed, in the form of connection loans, to assist poorer households in being connected to electricity supplies.

Both new REEs and existing REEs extending their services would be eligible for funding.

4.7.4 Other REF Support

In addition to funding for new connections, the REF might provide support to REEs to upgrade their networks to reach the standards required for grid connection. The REF should also continue to implement the current programme to support mini-hydro grids by covering the costs of feasibility studies for these. The technical skills required for such studies, the time taken and the uncertainty over the viability of mini-hydro schemes in many cases means that REEs will generally be reluctant to fund such feasibility studies themselves and will prefer to use simpler technology options, such as diesel generation, even if this is higher-cost in the long-run.

4.7.5 REF Capacity

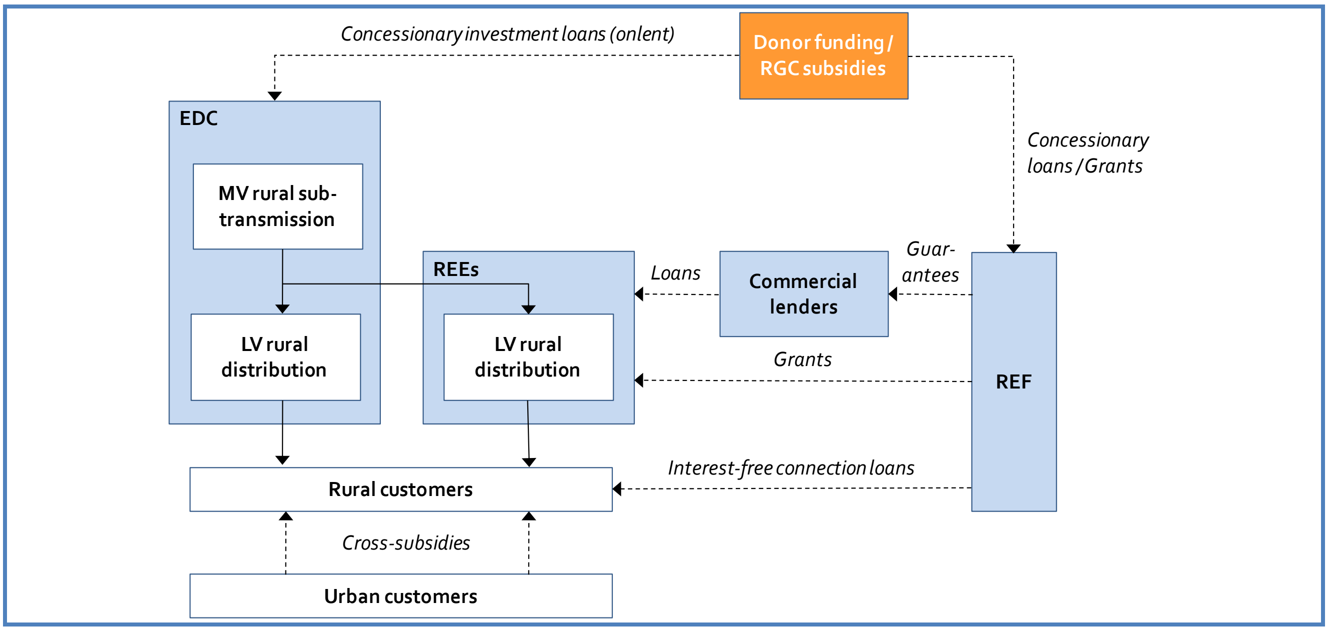
Under the proposed electrification programme, the REF could find itself administering funding for up to 70,000 new connections annually with total annual funding of around US$ 33 million. This assumes REEs are responsible for investing in distribution for two-thirds of new grid connections and all mini-grid connections. To this volume of work needs to be added the requirement to also administer connection loans of a value of around US$ 1.7 million annually as well as other smaller funding activities such as feasibility studies for mini-hydro grids and the possible commercial loan guarantee scheme.

As a comparison, under the current grant programme to REEs operated by the REF under the RETP, around US$ 10 million has been disbursed for 50,000 new connections over a two to three year period. The proposed electrification programme, therefore, represents an increase in the REF's workload of around three times. While this is achievable, a substantial capacity-building exercise will be required to ensure the REF is ready to take on its proposed role.

4.8 Summary of Subsidy Mechanisms

A summary of the proposed subsidy mechanisms is provided in Figure 22.

Figure 22 - Grid electrification funding



AECOM

5.0 Implementation Plan

In this concluding section, a five-year plan is set out for the implementation of the rural electrification strategy. The plan comprises a set of policy decisions and follow up implementing actions for consideration by the responsible institutions. Alongside this, the expected targets and estimated costs are set out for connections to be achieved under the first five-year period of the electrification programme.

5.1 Policy Decisions

The implementation plan is divided into immediate policy decisions, that must be taken before the strategy can be implemented, and follow up actions that will support the strategy's implementation.

Policy Decisions

- EDC will take the lead role in rural grid electrification
- Rural electrification rates will be one of the indicators used to assess EDC's performance
- REEs will continue to develop LV distribution networks and mini-grids, as a complement to EDC's efforts. EAC will be responsible for coordinating the activities of REEs with EDC through the licensing process in order to avoid duplication of effort
- In the longer-term, government policy is to encourage consolidation of REEs into EDC or larger regional companies. Such consolidation is to be voluntary and REEs are to receive fair compensation for assets transferred
- Capital subsidies to EDC will be provided through onlending and grants and to REEs through a combination of grants from the REF and the provision of REF partial guarantees to commercial lenders. Poorer customers will be eligible for connection loans provided from REF
- EDC's tariffs are to be set at a level that recovers its full costs of supply and EDC is not required to incur losses as a result of its rural electrification programme
- Rural household tariffs for grid-connected customers will be based on affordable tariffs, subject to requirements that they will always cover ongoing costs at a minimum and are not below equivalent urban tariffs. A uniform tariff will apply for all rural household customers
- In the medium-term, grid or bulk supply tariffs charged by EDC to REEs will be set by deducting a standard cost allowance, determined by EAC, from the uniform rural retail tariffs.

5.2 Implementing Actions

The implementation plan for the strategy identifies the main actions required. Actions are grouped with regard to principle responsibility. These actions follow once the key policy decisions have been made. Many of the actions are likely to require support in the form of Technical Assistance projects. These are identified by a (TA) in parentheses below.

<u>MEF / MIME</u>

- Convene a donor conference to establish availability of funds over a 5-10 year period to support electrification activities
- Update electrification programme targets based on funding availability (TA)
- Establish initial allocation of funds between EDC and REF (TA).

<u>MIME / EAC</u>

- Commission full study of EDC's costs and required tariffs (TA)
- Commission study of affordability of rural electricity supplies (TA).

<u>EAC</u>

- Define rules for allocation of new distribution areas, including provision for allocation to EDC where REEs fail to express willingness to develop areas in a timely fashion
- Amend rules as required to facilitate future consolidation of licensees and leasing of assets

- Develop and enforce rules for approval of REE plans for ensuring full coverage of licensed areas[44]
- Develop rules for setting rural grid-connected tariffs and, in the medium-term, grid / bulk supply tariffs. Following completion of the tariff study and affordability study, prepare and issue new tariffs (TA).

EDC

- Implement the MV planning TA under the RETP and begin provincial planning activities (TA)
- Assess capacity-building requirements for implementation of expanded rural electrification role and undertake capacity-building programme (TA)
- Establish a separate REO to lead rural electrification activities (TA)
- Identify REE MV assets required for use as part of the subtransmission network and negotiate to lease these.

REF

- Finalise partial guarantee mechanism for commercial lending to REEs, based on ongoing AusAID work (TA)
- Update existing grant mechanism for REE distribution network extensions to include new REEs (TA)
- Review success of revised support mechanisms for micro-hydro and SHS and develop appropriate future mechanisms for these and for other mini-grid technologies based on OBA grants and commercial lending (TA)
- Develop customer connection loan scheme (TA).

World Bank and other donors / international financing institutions

- Provide necessary financing commitments
- Support RGC in investigating access to additional sources of finance (e.g. CDM / Carbon Fund)
- Support implementation of the strategy through identified TA activities:

5.3 Five-year Investment Programme

Table 17 summarises the connection targets and investment requirements under the first five years of the proposed electrification programme. These represent the rates of connections needed to achieve the RGC's target of 70% grid-equivalent electrification of rural households by 2030 and an interim target of 45% grid-equivalent electrification by 2020.

Targets for solar systems are shown in Table 17, but do not contribute to the achievement of the electrification targets. As discussed earlier in this report, solar systems cannot offer grid-equivalent supplies which is the definition of electrification adopted by RGC.

Table 17 - Proposed Initial Five-Year Investment Programme

	Connections		Capital costs (US$m)	
	Total	Annual average	Total	Donor-funded
Electrification programme				
Grid extension	322,814	64,563	195.0	156.0
Mini-grid (all technologies)	130,933	26,187	70.3	56.2
Sub-total	**453,747**	**90,749**	**265.3**	**212.2**
Solar systems	30,000	6,000	11.1	0.0
Total	**483,747**	**96,749**	**276.4**	**212.2**

Estimated donor funding for the investment programme is based on the assumption that 80% of the capital costs of grid electrification and mini-grids are financed from donor sources. Funding constraints may lead to this financing share being dropped or may lead to RGC determining that the limited available resources are best concentrated on grid expansion rather than investments in mini-grids.

[44] This is already a licence obligation but does not appear to be enforced in practice.

The absence of donor funding for solar systems reflects the assumption that these do not contribute to meeting electrification targets and, therefore, that donor funding for the electrification programme is better directed to grid extension and mini-grid investments. This does not, of course, mean that donor funding should never be provided for solar systems - there may be various reasons why donors will be willing to support solar systems outside the electrification programme.

The estimated donor funding requirements of US$ 212 million substantially exceed the known current commitments, totalling US$ 130 million (see Section 2.4.4). This implies that reaching the proposed connection rates for the initial five years of the electrification programme, and which will need to be achieved and maintained if the RGC's targets are to be met, requires the rapid mobilisation of an additional US$ 80 million in donor funding.

Appendix 1 List of Persons Met

H.E. Suy Sem	Minister	MIME
H.E. Dr. Sat Samy	Secretary of State	MIME
H.E. Ke Ky	Under Secretary of State	MIME
H.E. Tun Lean	Director General, Chairman of EDC's Board	MIME
Mr Heng Kunleang	Director of Energy Development Dept	MIME
Mr Nou Sovandara	Deputy Director of EDD	MIME
Mr Pan Narith	Deputy Chief Office	MIME
Mr Sok Chandareth	Official of General Dept of Energy	MIME
Mr Nip Nearem	Chief Planning Office	MIME
Mr Victor Jona	Deputy General Director	MIME
Mr Clive Hughes	Adviser	MIME
Dr. Chulasa Praing	Corporate Planning & Projects Dept	EDC
Mr Kong Puthy	Head of Project Management Office No 2	EDC
Mr Plong Titia Phalkun	Deputy Director of Transmission	EDC
Mr Piseth Chun	Chief of SA & GIS	EDC
Mr Thach Sovannreasey	Deputy Chief of SA & GIS	EDC
Mr Randy Vang	Chief of GIS Division	EDC
H.E. Dr. Ty Norin	Chairman, Secretary of State	EAC
Mr Hul Kunvuth	Executive Director	EAC
Mr B.P. Rekhani	WB-Advisor to EAC	WB-Cons
Mr Loeung Keosela	Executive Director	REF
Mr Anousak Phongsavath	Director, Rural Electrification Division	MEM Laos
Mr Gnanhkham Doungsavanh	Project Manager RE Programme	EdL Laos
Mr Veasna Bun	Infrastructure Operations Officer	WB
Ms Chhun China	Programme Assistant	WB
Ms Pajnapa Peamsilpakulchorn	Infrastructure Analyst	WB
Mr Alfredo Bano Leal	Infrastructure Analyst	WB
Ms Chanin Manopiniwes	Infrastructure Economist	WB
Mr Jason Steele	WB-Consultant	WB-Cons
Mr Monyrath Nuth	Senior Programme Manager (Governance)	AusAID
Mr Nida Ouk	Senior Project Implementation Officer	ADB
Mr Shinoda Takanobu	Representative Electric Sector	JICA
Mr Slipiseth Heng	Programme Officer Infrastructure Division	JICA
Mr Van Kiet	Infrastructure Officer	KfW
Mr They Kheam	Director of Demographic Statistics	NIS
Dr Khun Sokha	Deputy Director Public Works Research	MPWT
Mr Nop Narin	Deputy Director Land Management	MLMUPC
Mr Ro Narith	Deputy Chief of GIS Office	MLMUPC
Mr Rogier van Mansvelt	Sustainable Forestry Consultant	Cons
Mr Kunthap Hing	Adviser Khmer Solar	KS
Mr Tony Knowles	Executive Director	SME
Mr Arjen Luxwolda	Managing Director	Kamworks
Mr Eav Orr	WB-Consultant	R&N
Mr Sophon Rath	WB-Consultant	R&N
Mr William Derbyshire	WB-Consultant	ECA
Mr Conrad Holland	WB-Consultant	AECOM NZ
Mr Michael Breckon	WB-Consultant	AECOM NZ

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Appendix 2 Workshop Agenda and Participant List

Cambodia Rural Electrification Strategy and Implementation Plan
Workshop

Himawari Hotel, Phnom Penh, Cambodia
Friday 4th December 2009

Agenda

Time	Item	Speaker
9:00 - 9:10	Opening Remarks	MIME H.E. Ke Ky Under Secretary of State
9:10 - 9:15	Project Summary	AECOM NZ Conrad Holland Team Leader
9:15 - 9:30	Strategy Overview	AECOM NZ Conrad Holland Team Leader
9:30 - 9:45	Electrification Targets and Resource Requirements	AECOM NZ Michael Breckon Power Engineer
9:45 - 10:30	Electrification Strategy Part I: Planning, Licensing and Technology Selection	AECOM NZ Conrad Holland Team Leader
10:30 - 10:45	Coffee Break	
10:45 - 11:45	Electrification Strategy Part II: Institutional, Pricing and Subsidies	ECA William Derbyshire Economist
11:45 - 12:00	Implementation Plan	AECOM NZ Michael Breckon Power Engineer
12:00 - 13:30	Lunch	
13:30 - 15:00	Open Discussion	All
15:00 - 15:15	Consultant Team Responses; Summary of Proceedings	AECOM NZ Conrad Holland Team Leader
15:15 - 15:30	Closing Remarks	MIME H.E. Suy Sem Minister

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December 4, 2009

No.	Name នាម និង គោត្តនាម	Position មុខងារ	Institution ក្រសួង/ស្ថាប័ន	Telephone ទូរស័ព្ទ	Email	Signature ហត្ថលេខា
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8	Jeroen Verschelling	director	KAMWORKS	099872220	Jeroen@kamworks.com	
9	Ty Norin	Chairman	EAC		norin@eac.gov.kh	
10	Ke Ky	Under Secretary,	MIME			
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15	PRAING CHULASA	Director	EDC	012444968	chulasa@online.com.kh	
16	ORR, EAN		REF	012 568 238		
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25	Vang Randy	chief of GIS Section	—	011 976867		
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33	C HUGHES	Consultant				

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36	Keo Rottanak	EDC				
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40	Tan Peng Seng	PA	WB		ptang@worldbank	
41	Pam Narith	MIME			pamnarith@yahoo.com	
42	Bun Vichet	Mime			Staff	
43	THAY PISETH	MIME				
44	Jie Tang	Sr Energy Specialist	WB		jtang@worldbank	

Final Workshop – Rural Electrification Strategy and Implementation Plan
Participants List
December 4, 2009

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46	Tum Lean		MIME			[signature]
47	SHINODA TAKANOBU		JICA			[signature]
48	HENG SALPISETH		JICA			[signature]
49	~~BUN VEASNA~~		~~WB~~			
50	SANN RATHA		WB			Yes
51	You Mab		MoC			[signature]
52	Veena Arn		WB			[signature]
53	Sok Mary.	reporter	P.Penh Press			[signature]
54	W DERBYSHIRE	Consultant	ECA			[signature]
55	C. Holland	Consultant	AECOM			[signature]

Appendix 3 Final Workshop Meeting Notes

1. Questions and Comments

Questions and comments are shown in normal font. Where applicable, Consultant team responses are shown in *italic* font.

Mr Jeroen Verschelling, Kamworks
Is energy conservation included in the demand forecasts?
Not as far as we can tell.

The cost estimates should be revised to take account of the recent falls in SHS prices and the suspension of import duty on SHS components.
Noted.

The following written questions were subsequently received in the afternoon:

Is there a risk that the REF will focus on specific licensees and technologies and squeeze out smaller suppliers and SHS?
The success of the solar component of the REF has been mixed. To a certain extent this is probably due to the fact that the REF is still developing as an institution. We would welcome any suggestions that you may have to improve the REF offering in solar, biomass gasification and other renewable generation technologies.

Is it consistent with other policies for the World Bank to be supporting fossil fuel expansion in rural electrification in preference to renewable technologies?
It is not intended to specifically support any generation technology, including fossil fuel based generation, through the rural electrification strategy.

Should higher electricity prices be welcomed, as a means of promoting energy conservation?
Rural people do pay very high tariffs but, implicitly, this greatly limits access to electricity and means that even those able to afford it can only consume very small amounts and are unable to take advantage of the full benefits it can offer. We do not wish to encourage inefficient electricity use but do want to ensure rural households have access to affordable electricity supplies. There is a more general issue as to whether the current energy policies sufficiently promote energy conservation, particularly among larger customers. Unfortunately, this is outside the scope of this project.

Mr B P Rekhani, EAC Regulatory Expert
There may be instances where REEs want to invest in MV lines (e.g., as spur lines to supply their licence areas). Does a policy of making EDC the developer of MV infrastructure prevent this?
No. REEs should be able to invest in spur lines. EDC will be responsible for the backbone network. Recommendations will be needed on whether REEs investing in MV spur lines should receive some credit for this and on whether and how REE-owned MV lines should be incorporated into EDC's backbone network if this subsequently becomes necessary.

To date eight subtransmission licences have been issued but only two are operational. The existing licences should not be withdrawn but EAC could refuse to issue new ones.
A time limit might also be applied, so that if existing licensees have not constructed their networks within a given period then EAC will withdraw their licence.

Some changes are required to the estimation of costs and cross-subsidy requirements. VAT is now applied to electricity sales (at a rate of 10%). Imports from Vietnam are currently limited to 80 MW. Tariffs are being increased now to raise funds for future transmission investments. The analysis also assumes that current tariffs are cost-reflective, which may not be the case.
Noted.

Determining affordable tariffs will place a lot of responsibility on EAC. Technical assistance and capacity-building will be required.

A comprehensive willingness-to-pay study is likely to be needed for this purpose. Certainly, EAC should not be expected to set an affordable tariff limit without supporting evidence on affordability limits.

HE Keo Rottanak, EDC Managing Director
Four issues will affect EDC's viability to move forward; implementation capacity, fiscal conditions, ability to recover its costs and financing capabilities. Currently, GoC taxation policies and fiscal arrangements do not recognise the needs of the electricity industry. VAT has been imposed on electricity sales but EDC is not allowed to include this in tariffs.

Donor financing is available but current procurement arrangements are too cumbersome, restrictive and inefficient. EDC is reluctant to accept donor funds until more efficient procurement arrangements are in place.

Mr Jie Tang, World Bank Senior Energy Specialist
REEs should be able to build LV networks in areas where EDC has no objections to this, given EDC's limited resources. Such networks must be built to the same technical standards as apply to EDC. Subsidies from the REF can be used to balance costs and revenues of REEs under a uniform retail tariff. Main messages are that:

Tariffs must be set to allow EDC to recover its costs, including a reasonable profit
Rural tariffs should be affordable
EDC should initially focus on expansion to the areas with the highest ability to pay.

Mr Arun Sanghvi, World Bank Energy Sector Adviser
There are some basic principles for any successful rural electrification programme:

The programme must be approached from a programmatic perspective, looking at the totality of financing needs over time, rather than on a project-by-project basis
The programme needs to emphasise the development perspective. For example, targets can be set for connection of social institutions such as schools
No country has successfully implemented a rural electrification programme without a national utility driving the process. The only possible exception is Latin America where concessions have been used to complete electrification - but this is in the context of a well-developed and long-established concessioning and regulatory framework for infrastructure
No country has succeeded in a rural electrification programme without subsidies.
The implementing national utility must be commercially viable
Sustainable and viable financing platform is essential.

The next steps in Cambodia are to define the roles of EDC and REEs and establish accountability for reaching rural electrification targets. Need to look for "win-win" outcomes. EDC will have to take the lead role and the bulk of the MV and LV system will be EDC-owned.

A sustainable financing plan must be in place (e.g. Rwanda uses a 5-year rolling plan). The plan needs to provide for full cost-recovery and affordability and explain how the gaps will be filled. Investment subsidies are preferred. The Government will need to co-operate and co-ordinate with donors to finance the programme.

Mr Jie Tang, World Bank Senior Energy Specialist
Donor funds for rural electrification should be onlent to EDC at the same terms as these are provided to the Ministry of Economy and Finance. In Lao PDR, 80% of WB funds are provided as a grant and 20% as a loan with a 25-year grace period. Industrial and commercial customers are used to cross-subsidise household customers and a uniform national tariff is applied with lifeline blocks for households. VAT should be treated as a recoverable cost of EDC.

Concessional financing should be delivered through the simplest route, which is direct to EDC. The administrative capacity of REF is very small and it will not be able to manage these funds.

HE Ty Norin, Chairman-Secretary of State of EAC
The 40 km PAGE limit shouldn't be seen as a hard limit. Larger radii might be needed in some cases and could be achieved using higher voltage subtransmission lines. Prioritisation for electrification should be

based on population density, which may not correspond with distance from provincial capitals and with the importance of road connections.

The main question is how to speed up investment. MEF is a potential obstacle. The strategy should not scare off REEs from making new investments, as these will still be needed.

REEs will need to be able to build their own MV distribution lines and may use these to supply other REEs as well. EDC should not duplicate existing REE-owned MV lines.

Representative of AusAID
OzAid has recently joined the sector; they are concerned that their grant is being used as a loan. It is important that MEF agrees to the recommended onlending approach. How will Government „ownership' of the strategy be ensured?

Mr Rogier van Mansvelt, National Climate Change Office Consultant
What is the breakdown of the rural electricity demand projections?
The rural electrification demand projections were based on a) The Power Development Master Plan projections prepared by Kepco and b) MIME demand projections

Does the analysis take account of the price risk of fossil fuels and the recent changes in SHS prices? Have the opportunities for decentralised generation (e.g. biomass generators in rice mills feeding to the grid at night) been considered?
The cost of generation used is based on the figures arrived at in the "Master Plan Study on Rural Electrification by Renewable Energy in the Kingdom of Cambodia" June 2006, Nippon Koei & KRI International. This study also reviews in detail the opportunities for biomass gasification generation in Cambodia. We note your comments on the recent changes in SHS prices and will review these based on secondary sources

The Consultants may want to refer to the electrification master plan prepared by IED for Kampong Chan which is available online.

2. World Bank Slide Presentation

The notes here only cover additional comments made during the presentation and not included in the slides.

REEs do not have the technical and financial capacity to develop LV networks to take advantage of the expansion of the MV grid. To avoid delays, it is preferable that EDC build LV networks alongside the MV grid.

The role of REEs should be complementary to that of EDC. They should provide O&M and billing services for grid-connected LV networks and develop off-grid networks.

The REF would provide subsidies to REEs for off-grid networks. These would cover part of capital costs and be provided on an output-based aid model.

The REF would also fund feasibility studies for mini-hydro to reduce the risks to REEs of developing this.

Current donor commitments (not all firm) for future rural electrification funding are:

ADB - $30 million
AusAID - $10 million (on and off-grid)
China EXIM - $50 million
World Bank - $40 million

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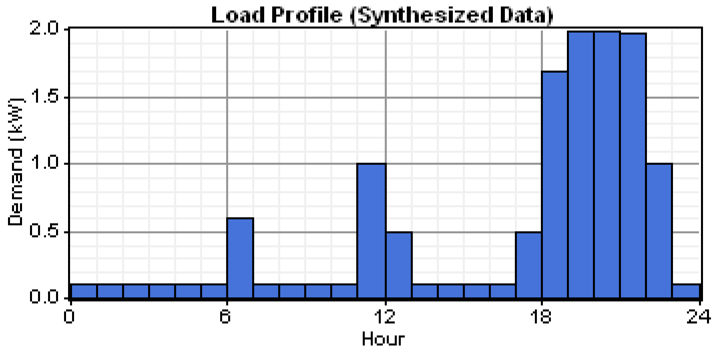
Appendix 4 SHS Levellised Cost of Energy

A. HOMER Input Summary

File name:	Solar SHS Cambodia 3 kWh month demand.hmr
File version:	2.68 beta
Author:	AECOM NZ Ltd. CWH December 09
Notes:	This model analyses a PV SHS vs grid connection for supplying an off-grid house in Cambodia with a household level non grid equivalent electricity supply defined as being 3 kWh per month with a maximum annual capacity shortage of 5%. AECOM NZ considered a range of PV array sizes and battery sizes. 98.6 Wh/day is equivalent to 3 kWh per month. The graph of the levellised cost of energy shows that at a load size of 98.6 Wh per day, the cost per kWh is $0.397. The break even grid distance is 9 metres for 98.6 Wh per day. Equipment Costs: The latest cost (CIF Sihanoukville December 2009) of PV panels, based on advice from Kamworks, is 1.75 USD/ Wp. To allow for battery cabinets, charge controllers, mounting frames, local transport and installation a total cost of $2.00 USD/Wp installed has been used The battery is a Vision 12N24 12 volt 26 Ah Storage battery with an estimated price of $30 USD. The cost of the solar panel, steel mounting frame, charge controller and labour are totalled and included in the cost of the Homer PV input. Low voltage grid costs are assumed at $12,200/km from EDC figures. A discount rate of 4% is assumed and a grid power price of 16.5 c/kWh which includes the costs of generation, transmission, MV distribution and LV service drops.

a) DC Load: Primary Load

Data source:	Synthetic
Daily noise:	10%
Hourly noise:	10%
Scaled annual average:	0.0986 kWh/d
Scaled peak load:	0.0224 kW
Load factor:	0.183



b) PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
1.000	2,000	2,000	2

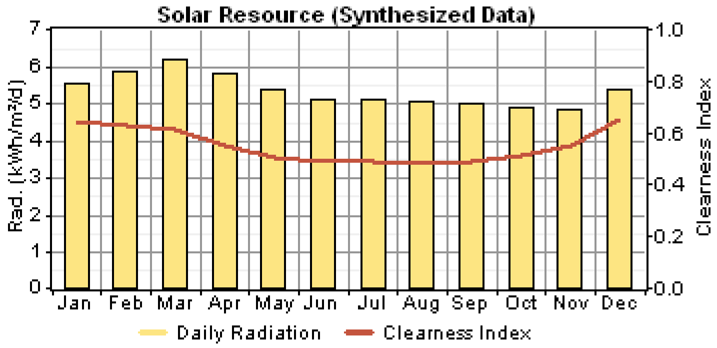
Sizes to consider:	0.00, 0.02, 0.03, 0.04, 0.05, 0.06 kW
Lifetime:	25 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	12.5 deg
Azimuth:	0 deg
Ground reflectance:	20%

c) Solar Resource

Latitude: 12 degrees 30 minutes North
Longitude: 104 degrees 30 minutes East
Time zone: GMT +8:00
Data source: Synthetic

Month	Clearness Index	Average Radiation (kWh/m²/day)
Jan	0.647	5.535
Feb	0.628	5.848
Mar	0.612	6.183
Apr	0.551	5.808
May	0.507	5.362
Jun	0.485	5.082
Jul	0.485	5.079
Aug	0.482	5.055
Sep	0.492	5.018
Oct	0.511	4.860
Nov	0.554	4.816
Dec	0.649	5.376

Scaled annual average: 5.33 kWh/m²/d



d) Battery: Vision CP12240D

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	30	30	0.50

Quantities to consider: 0, 1, 2, 3
Voltage: 12 V
Nominal capacity: 24 Ah
Lifetime throughput: 103 kWh

e) Grid Extension

Capital cost: $ 12,200/km
O&M cost: $ 122/yr/km
Power price: $ 0.165/kWh

f) Economics

Annual real interest rate: 4%
Project lifetime: 25 yr
Capacity shortage penalty: $ 0/kWh
System fixed capital cost: $ 0
System fixed O&M cost: $ 0/yr

g) Generator control

Check load following: No
Check cycle charging: Yes
Setpoint state of charge: 50%

Allow systems with multiple generators: Yes
Allow multiple generators to operate simultaneously: Yes
Allow systems with generator capacity less than peak load: Yes

h) Emissions

Carbon dioxide penalty: $ 0/t
Carbon monoxide penalty: $ 0/t
Unburned hydrocarbons penalty: $ 0/t
Particulate matter penalty: $ 0/t
Sulphur dioxide penalty: $ 0/t
Nitrogen oxides penalty: $ 0/t

i) Constraints

Maximum annual capacity shortage: 0, 3, 4, 5%
Minimum renewable fraction: 0%

Operating reserve as percentage of hourly load: 0%
Operating reserve as percentage of peak load: 0%
Operating reserve as percentage of solar power output: 25%
Operating reserve as percentage of wind power output: 50%

B. System Report - Solar SHS Cambodia 3 kWh month demand

a) Sensitivity case

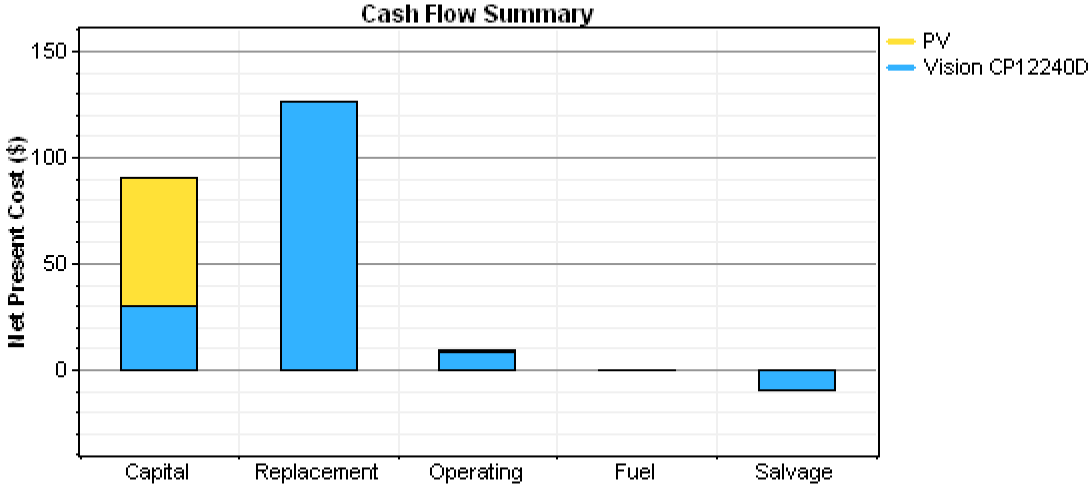
Maximum Annual Capacity Shortage: 5 %

b) System architecture

PV Array	0.03 kW
Battery	1 Vision CP12240D

c) Cost summary

Total net present cost	$ 215
Levellised cost of energy	$ 0.397/kWh
Operating cost	$ 8.02/yr

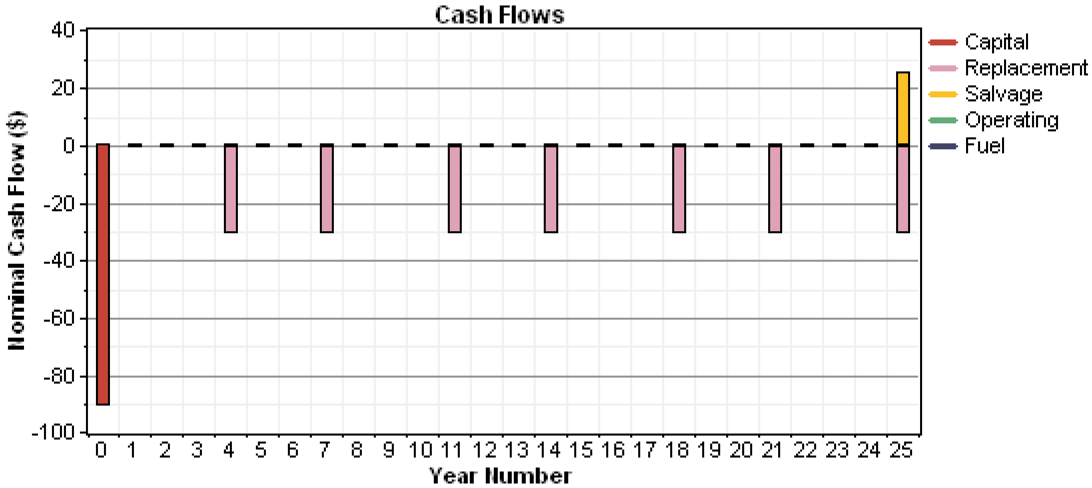


d) Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	60	0	1	0	0	61
Vision CP12240D	30	126	8	0	-9	154
System	90	126	9	0	-9	215

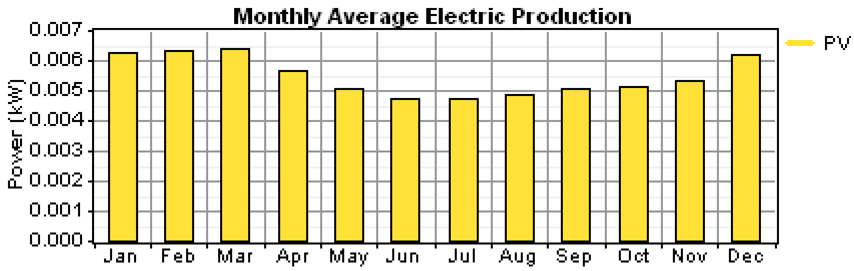
e) Annualised Costs

Component	Capital ($/yr)	Replacement ($/yr)	O&M ($/yr)	Fuel ($/yr)	Salvage ($/yr)	Total ($/yr)
PV	4	0	0	0	0	4
Vision CP12240D	2	8	1	0	-1	10
System	6	8	1	0	-1	14



f) Electrical

Component	Production (kWh/yr)	Fraction
PV array	48	100%
Total	48	100%



Load	Consumption (kWh/yr)	Fraction
DC primary load	35	100%
Total	35	100%

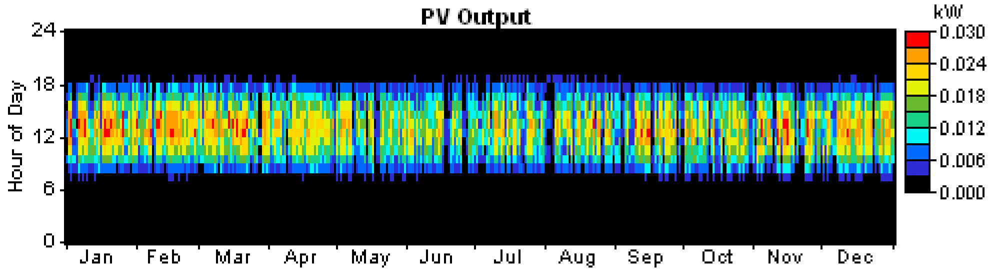
Quantity	Value	Units
Excess electricity	6.82	kWh/yr
Unmet load	1.31	kWh/yr
Capacity shortage	1.31	kWh/yr
Renewable fraction	1.000	

g) PV

Quantity	Value	Units
Rated capacity	0.0300	kW
Mean output	0.00548	kW
Mean output	0.131	kWh/d
Capacity factor	18.3	%
Total production	48.0	kWh/yr

Quantity	Value	Units
Minimum output	0.00	kW

Maximum output	0.0294	kW
PV penetration	133	%
Hours of operation	4,333	hr/yr
Levellised cost	0.0813	$/kWh

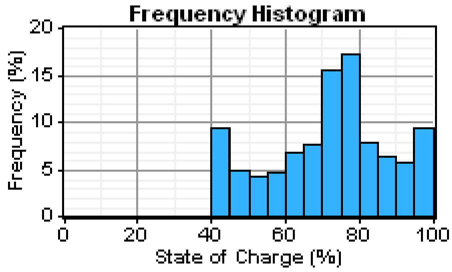


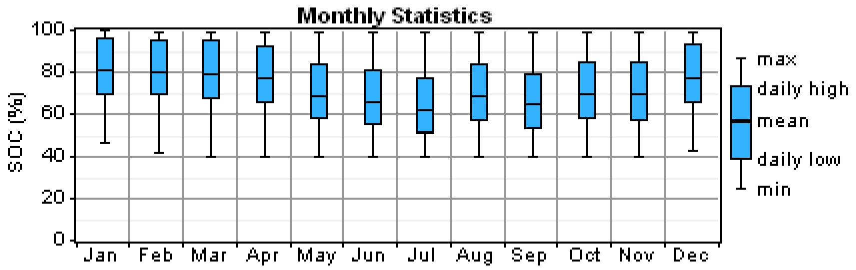
h) Battery

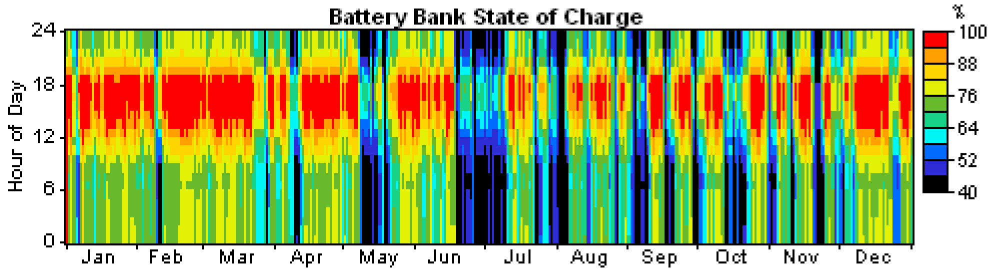
Quantity	Value
String size	1
Strings in parallel	1
Batteries	1
Bus voltage (V)	12

Quantity	Value	Units
Nominal capacity	0.288	kWh
Usable nominal capacity	0.173	kWh
Autonomy	42.1	hr
Lifetime throughput	103	kWh
Battery wear cost	0.325	$/kWh
Average energy cost	0.000	$/kWh

Quantity	Value	Units
Energy in	32.9	kWh/yr
Energy out	26.4	kWh/yr
Storage depletion	0.0902	kWh/yr
Losses	6.40	kWh/yr
Annual throughput	30	kWh/yr
Expected life	3.49	yr

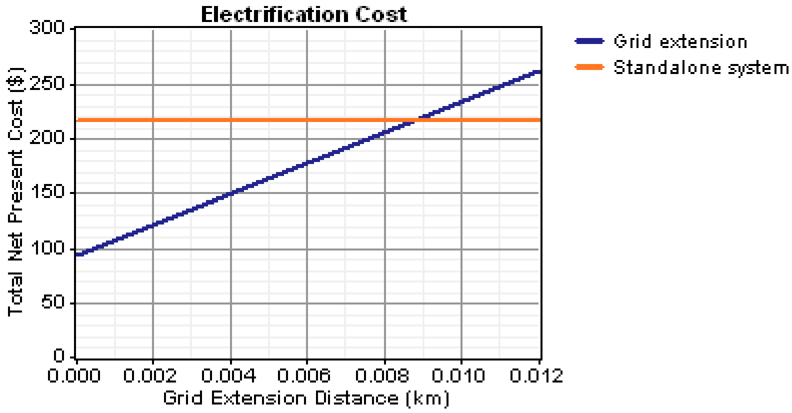






i) Grid Extension

Breakeven grid extension distance: 0.00869 km



j) Emissions

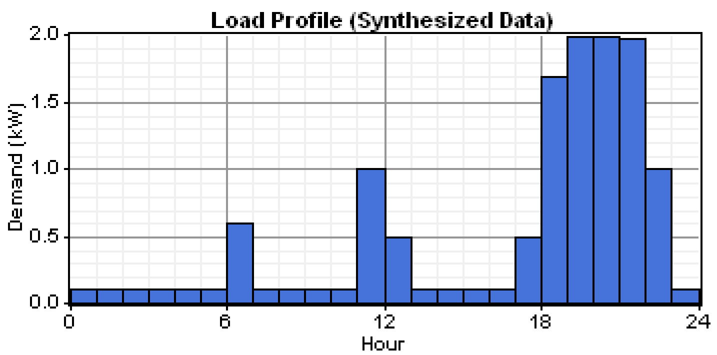
Pollutant	Emissions (kg/yr)
Carbon dioxide	0
Carbon monoxide	0
Unburned hydocarbons	0
Particulate matter	0
Sulphur dioxide	0
Nitrogen oxides	0

C. HOMER Input Summary

File name:	Solar SHS Cambodia 20 kWh month demand.hmr
File version:	2.68 beta
Author:	AECOM NZ Ltd. CWH December 09
Notes:	This model analyses a PV SHS vs grid connection for supplying an off-grid house in Cambodia with a grid equivalent electricity supply defined as being 20 kWh per month with a maximum annual capacity shortage of 5%. This model is for 20 kWh per household per month AECOM NZ considered a load size of 0.66 kWh/day and a range of PV array sizes and battery sizes. 0.66 kWh/day is equivalent to 20 kWh per month. The graph of the levellised cost of energy shows that at a load size of 0.66 kWh per day, the cost per kWh is $0.39. The break even grid distance is 56 metres for 0.66kWh per day. Equipment Costs: The latest cost (CIF Sihanoukville December 2009) of PV panels, based on advice from Kamworks, is 1.75 USD/ Wp. To allow for battery cabinets, charge controllers, mounting frames, local transport and installation a total cost of $2.00 USD/Wp installed has been used The battery is a Vision 12N24 12 volt 26 Ah Storage battery with an estimated price of $30 USD. The cost of the solar panel, steel mounting frame, charge controller and labour are totalled and included in the cost of the Homer PV input. Low voltage grid costs are assumed at $12,200/km from EDC figures. A discount rate of 4% is assumed and a grid power price of 16.5 c/kWh which includes the costs of generation, transmission, MV distribution and LV service drops.

a) DC Load: Primary Load

Data source:	Synthetic
Daily noise:	10%
Hourly noise:	10%
Scaled annual average:	0.658 kWh/d
Scaled peak load:	0.150 kW
Load factor:	0.183



b) PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
1.000	2,000	2,000	2

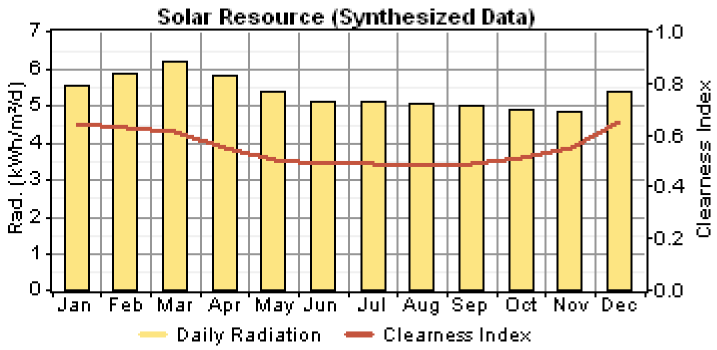
Sizes to consider:	0.00, 0.17, 0.18, 0.19, 0.20, 0.21, 0.22, 0.23, 0.24, 0.25, 0.26, 0.27, 0.28 kW
Lifetime:	25 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	12.5 deg
Azimuth:	0 deg
Ground reflectance:	20%

c) Solar Resource

Latitude: 12 degrees 30 minutes North
Longitude: 104 degrees 30 minutes East
Time zone: GMT +8:00
Data source: Synthetic

Month	Clearness Index	Average Radiation
		(kWh/m^2/day)
Jan	0.647	5.535
Feb	0.628	5.848
Mar	0.612	6.183
Apr	0.551	5.808
May	0.507	5.362
Jun	0.485	5.082
Jul	0.485	5.079
Aug	0.482	5.055
Sep	0.492	5.018
Oct	0.511	4.860
Nov	0.554	4.816
Dec	0.649	5.376

Scaled annual average: 5.33 kWh/m²/d



d) Battery: Vision CP12240D

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	30	30	0.50

Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8
Voltage: 12 V
Nominal capacity: 24 Ah
Lifetime throughput: 103 kWh

e) Grid Extension

Capital cost: $ 12,200/km
O&M cost: $ 122/yr/km
Power price: $ 0.165/kWh

f) Economics

Annual real interest rate: 4%
Project lifetime: 25 yr
Capacity shortage penalty: $ 0/kWh
System fixed capital cost: $ 0
System fixed O&M cost: $ 0/yr

g) Generator control

Check load following: No
Check cycle charging: Yes
Setpoint state of charge: 50%

Allow systems with multiple generators: Yes
Allow multiple generators to operate simultaneously: Yes
Allow systems with generator capacity less than peak load: Yes

h) Emissions

Carbon dioxide penalty: $ 0/t
Carbon monoxide penalty: $ 0/t
Unburned hydrocarbons penalty: $ 0/t
Particulate matter penalty: $ 0/t
Sulphur dioxide penalty: $ 0/t
Nitrogen oxides penalty: $ 0/t

i) Constraints

Maximum annual capacity shortage: 0, 3, 4, 5%
Minimum renewable fraction: 0%

Operating reserve as percentage of hourly load: 0%
Operating reserve as percentage of peak load: 0%
Operating reserve as percentage of solar power output: 25%
Operating reserve as percentage of wind power output: 50%

D. System Report - Solar SHS Cambodia 20 kWh month demand

a) Sensitivity case

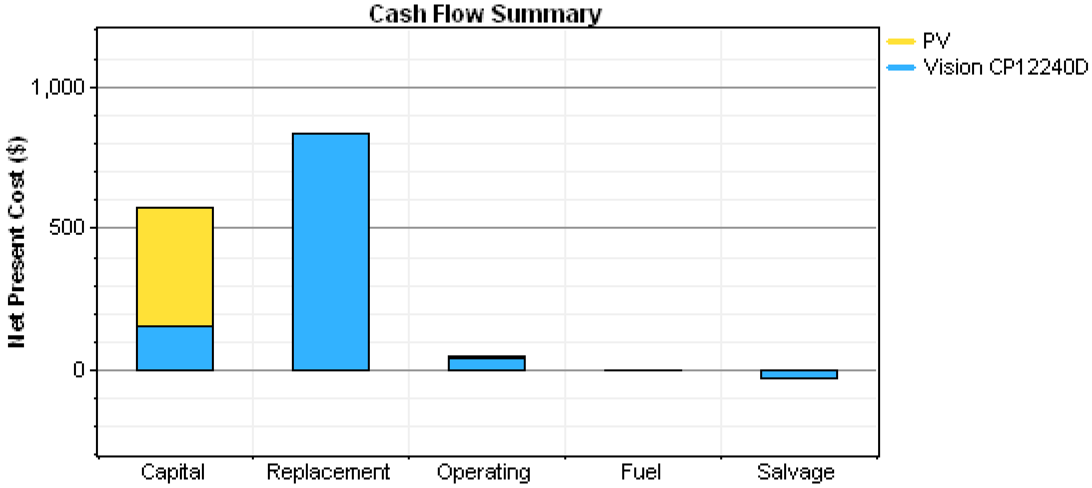
Maximum Annual Capacity Shortage: 5 %

b) System architecture

PV Array	0.21 kW
Battery	5 Vision CP12240D

c) Cost summary

Total net present cost	$ 1,413
Levellised cost of energy	$ 0.395/kWh
Operating cost	$ 54/yr

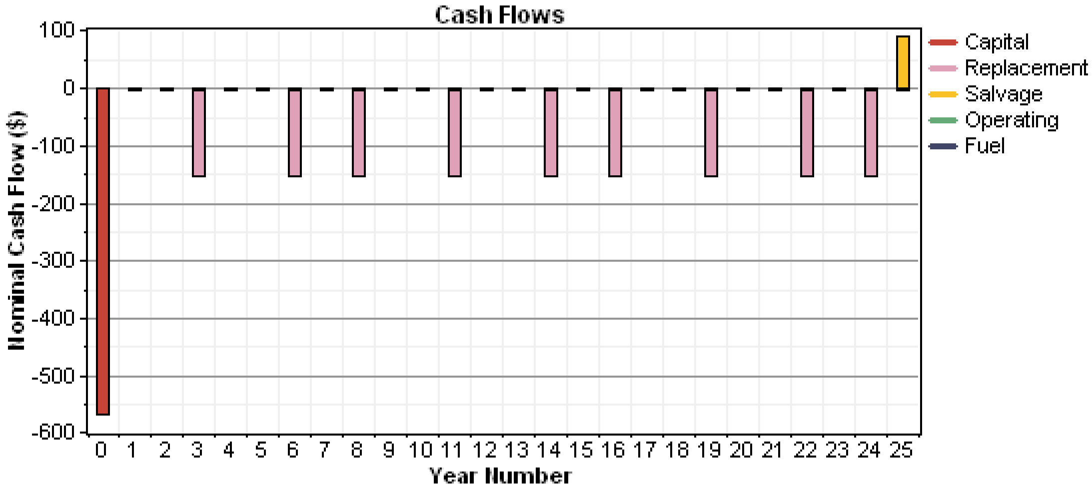


d) Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	420	0	7	0	0	427
Vision CP12240D	150	831	39	0	-34	986
System	570	831	46	0	-34	1,413

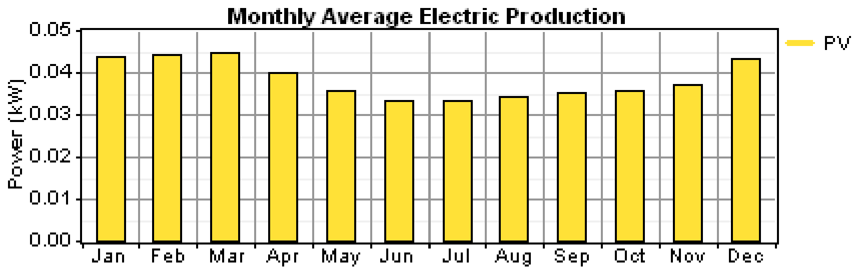
e) Annualised Costs

Component	Capital ($/yr)	Replacement ($/yr)	O&M ($/yr)	Fuel ($/yr)	Salvage ($/yr)	Total ($/yr)
PV	27	0	0	0	0	27
Vision CP12240D	10	53	3	0	-2	63
System	36	53	3	0	-2	90



f) Electrical

Component	Production	Fraction
	(kWh/yr)	
PV array	336	100%
Total	336	100%



Load	Consumption	Fraction
	(kWh/yr)	
DC primary load	229	100%
Total	229	100%

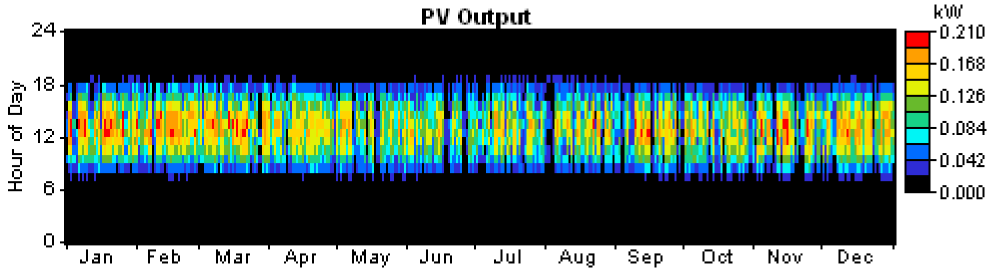
Quantity	Value	Units
Excess electricity	64.3	kWh/yr
Unmet load	10.9	kWh/yr
Capacity shortage	11.0	kWh/yr
Renewable fraction	1.000	

g) PV

Quantity	Value	Units
Rated capacity	0.210	kW
Mean output	0.0384	kW
Mean output	0.920	kWh/d
Capacity factor	18.3	%
Total production	336	kWh/yr

Quantity	Value	Units
Minimum output	0.00	kW

Maximum output	0.206	kW
PV penetration	140	%
Hours of operation	4,333	hr/yr
Levellised cost	0.0813	$/kWh

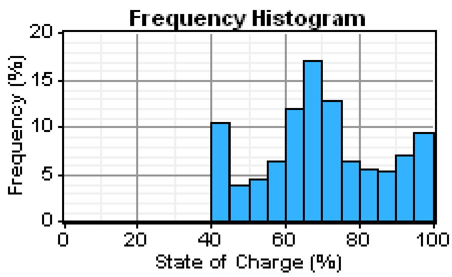


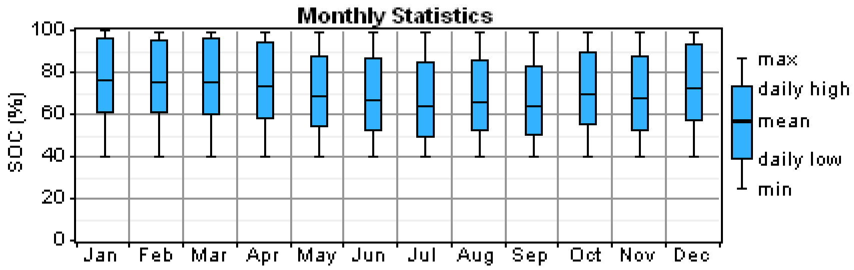
h) Battery

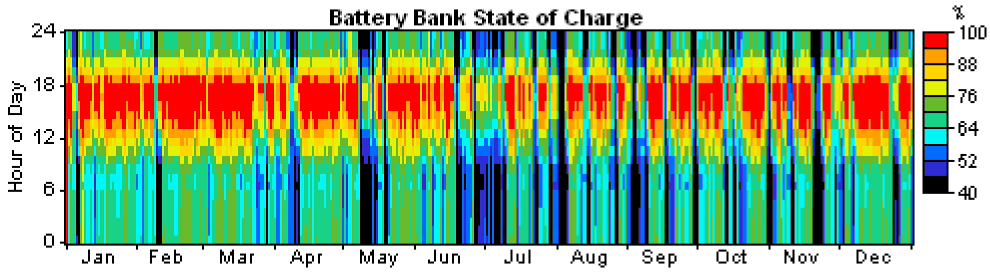
Quantity	Value
String size	1
Strings in parallel	5
Batteries	5
Bus voltage (V)	12

Quantity	Value	Units
Nominal capacity	1.44	kWh
Usable nominal capacity	0.864	kWh
Autonomy	31.5	hr
Lifetime throughput	516	kWh
Battery wear cost	0.325	$/kWh
Average energy cost	0.000	$/kWh

Quantity	Value	Units
Energy in	216	kWh/yr
Energy out	173	kWh/yr
Storage depletion	0.561	kWh/yr
Losses	42.1	kWh/yr
Annual throughput	194	kWh/yr
Expected life	2.66	yr

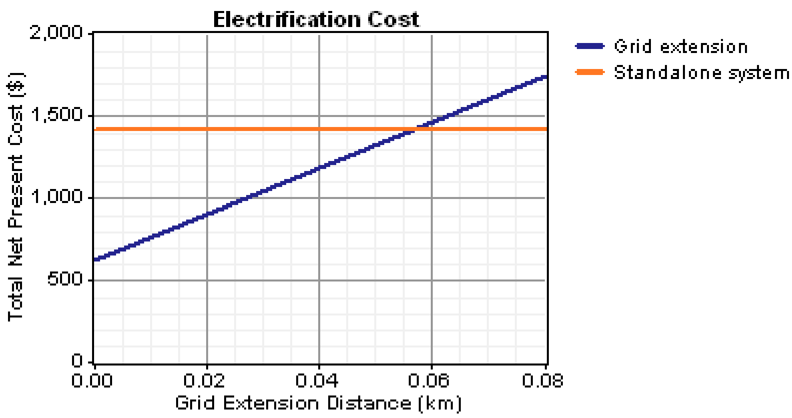






i) Grid Extension

Breakeven grid extension distance: 0.0563 km



j) Emissions

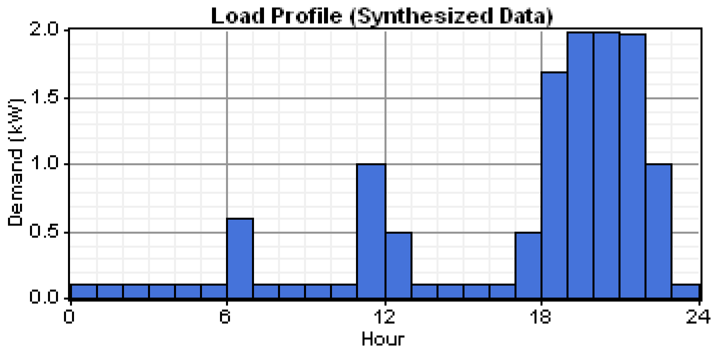
Pollutant	Emissions (kg/yr)
Carbon dioxide	0
Carbon monoxide	0
Unburned hydocarbons	0
Particulate matter	0
Sulphur dioxide	0
Nitrogen oxides	0

E. HOMER Input Summary

File name:	Solar SHS Cambodia 50 kWh month demand.hmr
File version:	2.68 beta
Author:	AECOM NZ Ltd. CWH December 09
Notes:	This model analyses a PV SHS vs grid connection for supplying an off-grid house in Cambodia with a grid equivalent electricity supply defined as being 50 kWh per month with a maximum annual capacity shortage of 5%. This model is for a demand of 50 kWh per household per month. AECOM NZ considered a load size of 1.64 kWh/day, and a range of PV array sizes and battery sizes. 1.64 kWh/day is equivalent to 50 kWh per month. The graph of the levellised cost of energy shows that at a load size of 1.64 kWh per day, the cost per kWh is $0.39. The break even grid distance is 139 metres for 1.64 kWh per day. Equipment Costs: The latest cost (CIF Sihanoukville December 2009) of PV panels, based on advice from Kamworks, is 1.75 USD/ Wp. To allow for battery cabinets, charge controllers, mounting frames, local transport and installation a total cost of $2.00 USD/Wp installed has been used The battery is a Vision 12N24 12 volt 26 Ah Storage battery with an estimated price of $30 USD. The cost of the solar panel, steel mounting frame, charge controller and labour are totalled and included in the cost of the Homer PV input. Low voltage grid costs are assumed at $12,200/km from EDC figures. A discount rate of 4% is assumed and a grid power price of 16.5 c/kWh which includes the costs of generation, transmission, MV distribution and LV service drops.

a) DC Load: Primary Load

Data source:	Synthetic
Daily noise:	10%
Hourly noise:	10%
Scaled annual average:	1.64 kWh/d
Scaled peak load:	0.374 kW
Load factor:	0.183



b) PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
1.000	2,000	2,000	2

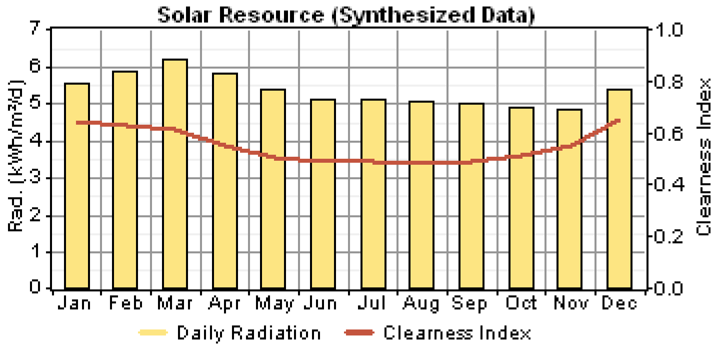
Sizes to consider:	0.00, 0.40, 0.41, 0.42, 0.43, 0.44, 0.45, 0.46, 0.47, 0.48, 0.49, 0.50, 0.51 kW
Lifetime:	25 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	12.5 deg
Azimuth:	0 deg
Ground reflectance:	20%

c) Solar Resource

Latitude: 12 degrees 30 minutes North
Longitude: 104 degrees 30 minutes East
Time zone: GMT +8:00
Data source: Synthetic

Month	Clearness Index	Average Radiation (kWh/m²/day)
Jan	0.647	5.535
Feb	0.628	5.848
Mar	0.612	6.183
Apr	0.551	5.808
May	0.507	5.362
Jun	0.485	5.082
Jul	0.485	5.079
Aug	0.482	5.055
Sep	0.492	5.018
Oct	0.511	4.860
Nov	0.554	4.816
Dec	0.649	5.376

Scaled annual average: 5.33 kWh/m²/d



d) Battery: Vision CP12240D

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	30	30	0.50

Quantities to consider: 0, 11, 12, 13, 14, 15, 16, 17
Voltage: 12 V
Nominal capacity: 24 Ah
Lifetime throughput: 103 kWh

e) Grid Extension

Capital cost: $ 12,200/km
O&M cost: $ 122/yr/km
Power price: $ 0.165/kWh

f) Economics

Annual real interest rate: 4%

Project lifetime: 25 yr
Capacity shortage penalty: $ 0/kWh
System fixed capital cost: $ 0
System fixed O&M cost: $ 0/yr

g) Generator control

Check load following: No
Check cycle charging: Yes
Setpoint state of charge: 50%

Allow systems with multiple generators: Yes
Allow multiple generators to operate simultaneously: Yes
Allow systems with generator capacity less than peak load: Yes

h) Emissions

Carbon dioxide penalty: $ 0/t
Carbon monoxide penalty: $ 0/t
Unburned hydrocarbons penalty: $ 0/t
Particulate matter penalty: $ 0/t
Sulphur dioxide penalty: $ 0/t
Nitrogen oxides penalty: $ 0/t

i) Constraints

Maximum annual capacity shortage: 0, 3, 4, 5%
Minimum renewable fraction: 0%

Operating reserve as percentage of hourly load: 0%
Operating reserve as percentage of peak load: 0%
Operating reserve as percentage of solar power output: 25%
Operating reserve as percentage of wind power output: 50%

F. System Report - Solar SHS Cambodia 50 kWh month demand

a. Sensitivity case

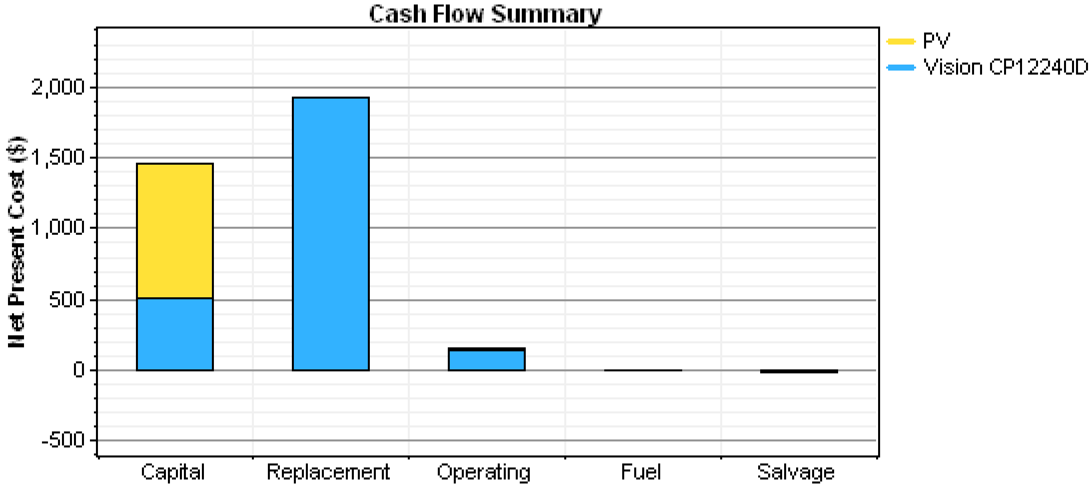
Maximum Annual Capacity Shortage: 5 %

b. System architecture

PV Array	0.47 kW
Battery	17 Vision CP12240D

c. Cost summary

Total net present cost	$ 3,502
Levellised cost of energy	$ 0.393/kWh
Operating cost	$ 131/yr

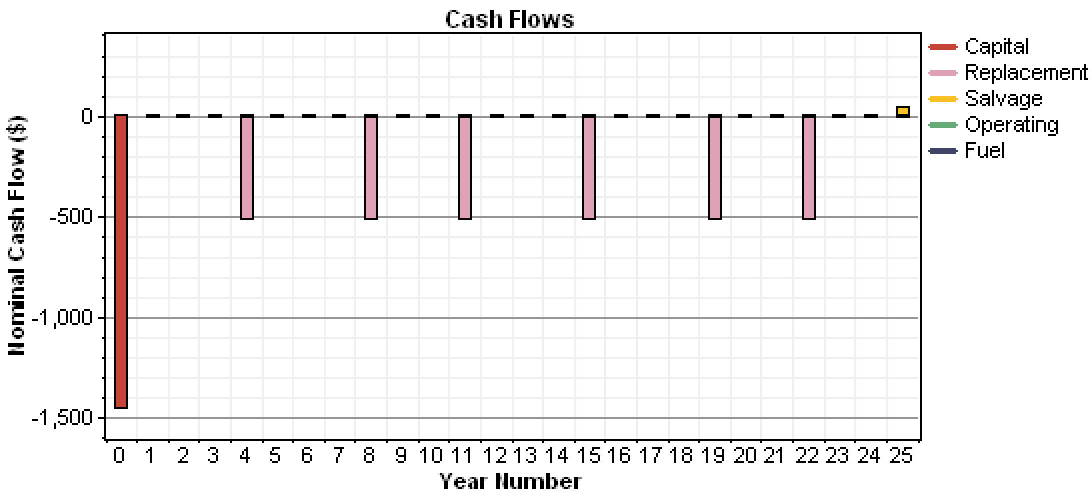


d. Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	940	0	15	0	0	955
Vision CP12240D	510	1,919	133	0	-14	2,548
System	1,450	1,919	147	0	-14	3,502

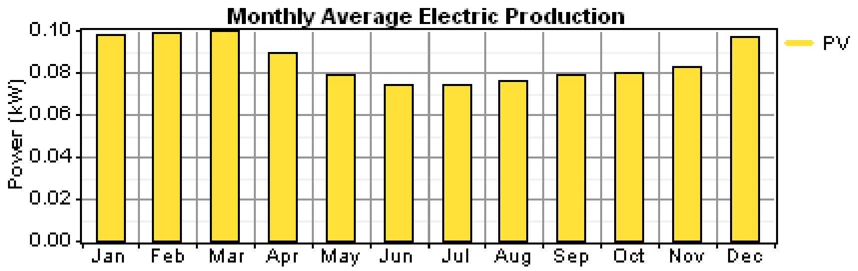
e. Annualised Costs

Component	Capital ($/yr)	Replacement ($/yr)	O&M ($/yr)	Fuel ($/yr)	Salvage ($/yr)	Total ($/yr)
PV	60	0	1	0	0	61
Vision CP12240D	33	123	9	0	-1	163
System	93	123	9	0	-1	224



f. Electrical

Component	Production (kWh/yr)	Fraction
PV array	752	100%
Total	752	100%



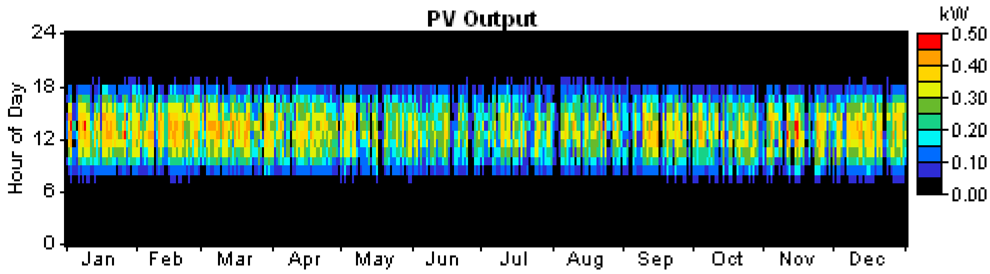
Load	Consumption (kWh/yr)	Fraction
DC primary load	571	100%
Total	571	100%

Quantity	Value	Units
Excess electricity	74.5	kWh/yr
Unmet load	29.1	kWh/yr
Capacity shortage	29.3	kWh/yr
Renewable fraction	1.000	

g. PV

Quantity	Value	Units
Rated capacity	0.470	kW
Mean output	0.0858	kW
Mean output	2.06	kWh/d
Capacity factor	18.3	%
Total production	752	kWh/yr

Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	0.461	kW
PV penetration	125	%
Hours of operation	4,333	hr/yr
Levellised cost	0.0813	$/kWh

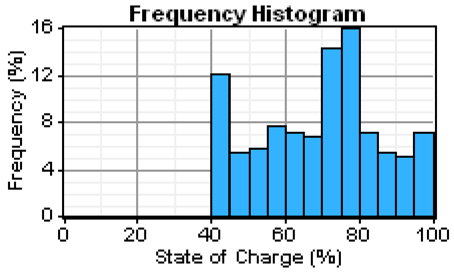


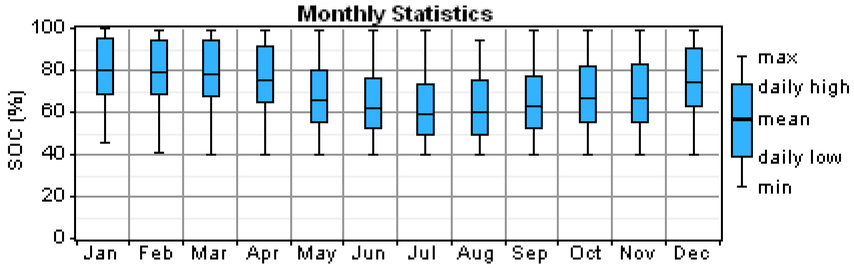
h. Battery

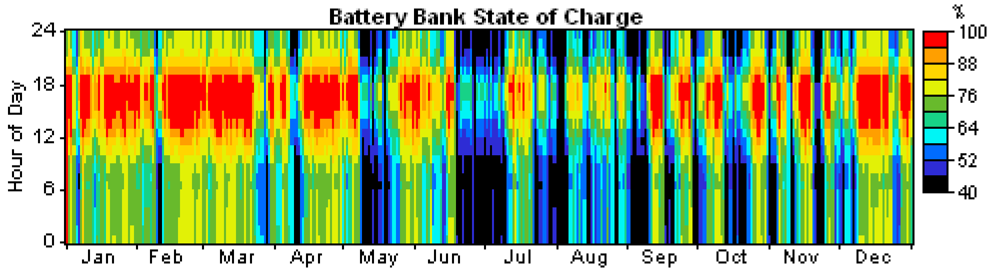
Quantity	Value
String size	1
Strings in parallel	17
Batteries	17
Bus voltage (V)	12

Quantity	Value	Units
Nominal capacity	4.90	kWh
Usable nominal capacity	2.94	kWh
Autonomy	42.9	hr
Lifetime throughput	1,753	kWh
Battery wear cost	0.325	$/kWh
Average energy cost	0.000	$/kWh

Quantity	Value	Units
Energy in	541	kWh/yr
Energy out	434	kWh/yr
Storage depletion	1.64	kWh/yr
Losses	105	kWh/yr
Annual throughput	486	kWh/yr
Expected life	3.61	yr

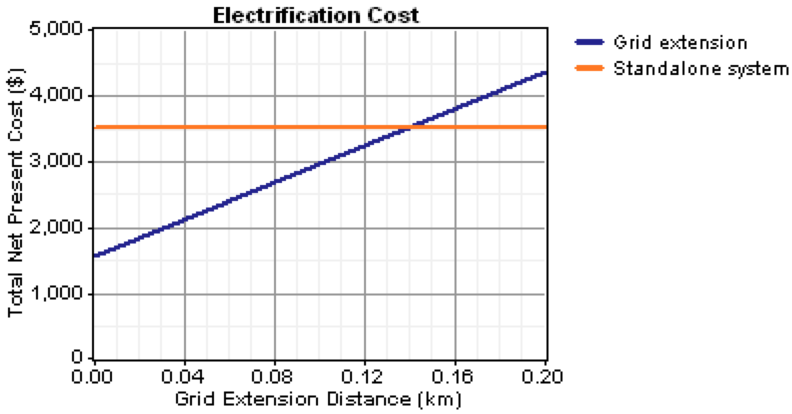






i. Grid Extension

Breakeven grid extension distance: 0.139 km



j. Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	0
Carbon monoxide	0
Unburned hydrocarbons	0
Particulate matter	0
Sulphur dioxide	0
Nitrogen oxides	0

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Appendix 5 Use of GIS in Power System Planning

AECOM NZ located the available GIS “layers” of data that are required for power system planning. The layers include data for the roads, the country boundaries, the province boundaries, the village locations, the existing and planned HV and MV etc. These layers are built up using GIS software to render geographic information that that can be used for grid and Off-Grid planning as outlined in **Figure 12** and **Figure 13**.

The principle GIS layers available to EDC as identified in the inception phase include the following:

Administration

- Boundary Country
- Boundary Province
- Boundary District
- Boundary Commune
- Sea Areas

Village

- Province Centre
- District Centre
- Commune Centre
- Village Centre

Electrical

- Hydropower planned
- 230 kV Transmission Lines Under Construction
- 230 kV Transmission Lines Planned
- 115 kV Transmission Lines Planned
- 115 kV Transmission Lines Under Construction
- 115 kV Transmission Lines Existing
- 22 kV Distribution Lines Existing
- 22 kV Distribution Lines Cross Border Supplies

Contour Lines

- None

Land Use

- Protected Areas
- Land Use Vegetation

Rivers

- Main Rivers
- Smaller Rivers

Roads and Transport

- Main Roads
- Railways
- Bridges

Unexploded Ordinance (UXO)

- Big Cluster Areas
- Buffer of Still Dangerous Areas

There does not appear to be a controlled GIS meta database either a) available for the GIS datasets (layers or shp files) used by MIME or EDC or b) available from a central organisation or industry grouping. Due to this it is not possible to comment at this stage whether the GIS data used by EDC is current. However for power system planning the most important layers are:

Village

- Village Location
- Village Name, Khmer and English
- Village Household Numbers, existing and projected
- Village Population Numbers, existing and projected

Licensing

- REE/Name Location
- REE/EDC Name and License Number
- REE/EDC buffer area existing
- REE/EDC buffer area future

Electrical Transmission and Distribution

- 22/0.4 kV transformers
- 22 kV Network Existing
- 22 kV Network Future By Year
- 115 kV Network Existing
- 115 kV Network Future By Year
- 230 kV Network Existing
- 230 kV Network Future By Year
- 500 kV Network Planned
- 500 kV Network Future By Year

Electrical Generation Grid

- Diesel or Heavy Fuel Oil Power Station Existing
- Diesel or Heavy Fuel Oil Power Station Future By Year
- Coal Fired Power Station Future By Year
- Gas Fired Power Station Future By Year
- Large Hydro Power Station Existing
- Large Hydro Power Station Future By Year

Electrical Generation Mini Grid

- Mini Hydro Power Station Existing
- Mini Hydro Power Station Future
- Biomass Power Station Existing
- Biomass Power Station Future

Electrical Generation Household Level Solutions

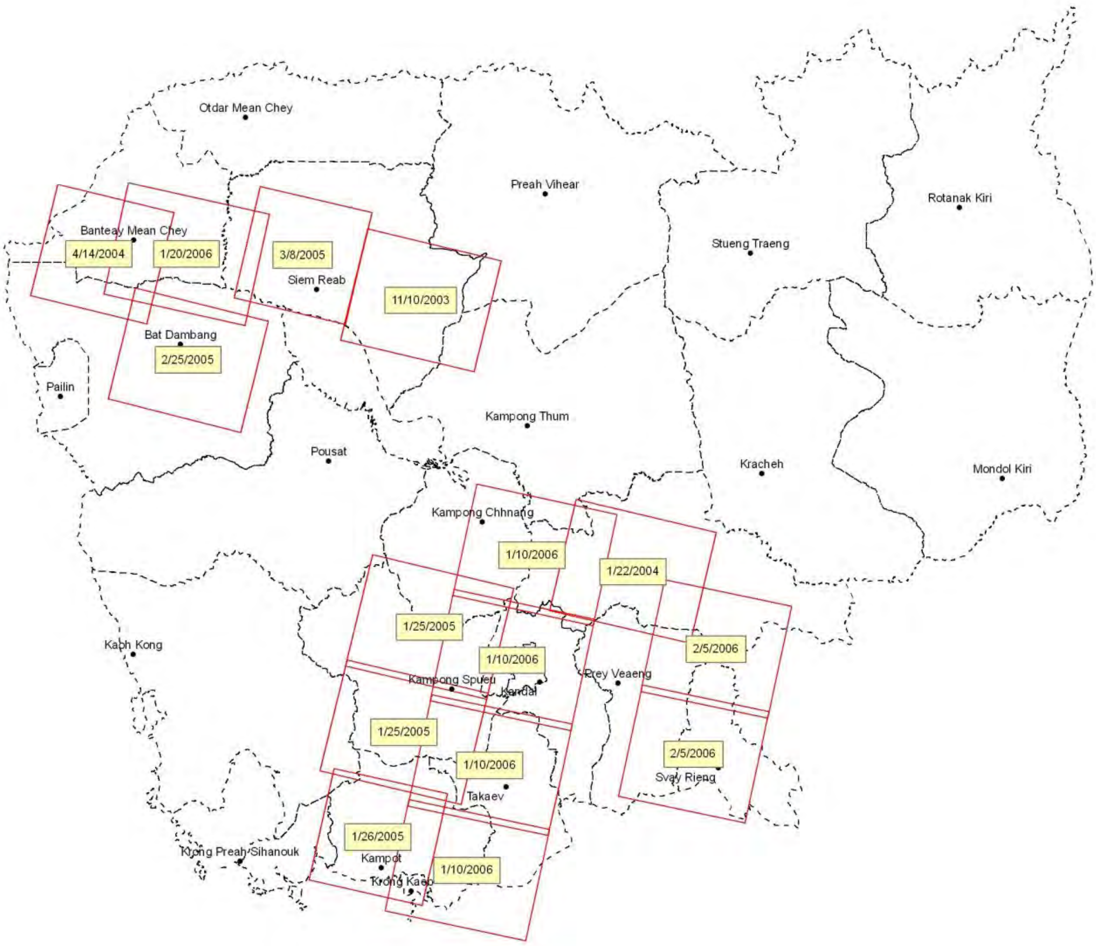
- Solar Existing
- Solar Future
- Battery Charging Station Existing
- Battery Charging Station Future

The other layers, e.g. administration, contours, land use, rivers and roads, do not change markedly over short time frames. These types of GIS layers are useful for power systems planning even if several years old, whereas some layers e.g. the electrical layers, village layers and licensing layers should be at most 2 years old.

The EDC planning for grid based rural electrification makes use the 2004 village/household numbers from the National Institute of Statistics (NIS). The village/household numbers are based on an extrapolation of the 1998 Census figures from a 2004 sample survey, the household numbers are further adjusted to 2008 by EDC. It would be more optimal if MIME and EDC planning made use of the more up to date information gathered for village location, village name and household numbers from the 2008 census. AECOM NZ contacted NIS with regards to the availability of the 2008 census data, they do not have this information publically available.

To expand the use of GIS for planning purposes and for day to day operations of EDC consideration should be given to further expanding the purchase of satellite remote sensing imagery at a resolution that clearly identifies households and villages. Figure 23 outlines the existing imagery purchased by EDC, it primarily covers the more heavily populated Provinces in Cambodia and some of the imagery will be out of date with regard to household locations.

Figure 23 - Satellite Imagery Purchased by EDC



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Appendix 6 Summary of Country Case Studies[45]

Principle	Cost Rica	Philippines	Bangladesh	Thailand	Mexico	Tunisia	Chile	China	Vietnam	Lao PDR
Institution of rural electrification and programme management	Support from U.S. based National Rural Electric Cooperative Association	National Electrification Administration (NEA)	Rural Electrification Board (REB)	Office of Rural Electrification in PEA (ORE)	Central support from National Utility	Implemented by STEG the national utility	Rural electrification programme (PER)	Multiple Central Agency TA to local county companies	Power Company No 1, 2 and 3 under central and regional direction(PC1, PC2 and PC3)	Central support from National Utility (EdL)
Political Interference	Planning used to avoid problems	Significant problems in different stages of the program	Planning used to avoid problems	Planning and programme support from the King assisted in avoiding problems	Planning and progressive decentralisation of social infrastructure funds helped avoid problems	Planning used to avoid problems	Transparent process of project selection by PER	Many regional problems	Significant problems in different stages of the programme due to electrification being driven by political priorities	Planning and GIS used to avoid problems, rapid roll out lessened interference
Nature of Subsidies	Initial loan with subsidies and grace period	Subsidised loans and grace periods for new capital cost construction and in some cases bulk power subsidies	Subsidised loans and grace periods for new capital cost construction and in some cases bulk power subsidies	Cross subsidies from regional consumers and bulk power subsidies some local contribution of social fund subsidies	Social Infrastructure to provide subsidies for capital construction costs of new service	Direct budget transfer of subsides from the government and presidential fund for political connections	Agency set up to award and provide capital cost subsidies to cooperatives and private electricity companies in ways that would not affect their tariffs	Government provided free technical assistance and subsidised loans for micro hydro electricity generation	Funding for capital investments from donors and government Cross-subsidy to rural customers	Subsidised loans and grace periods for new capital cost construction and cross subsidies from export power earnings
Pricing of electricity	Cooperative charges full price based on regulatory process	Cooperative charged full prices based on the regulatory process	Cooperative charges full price after subsidies based on REB regulation	National tariff based on cost recovery	Regional tariffs subsidised from central government budget	National tariffs based on cost recovery after subsidies	Cooperative and private utility charged full prices based on the regulatory process	Regional electricity companies use cost recovery based on state guidelines and self regulation	Formerly, tariffs set locally subject to overall national cap (which provincial governments could give approval to breach). Since 2009, uniform household tariff (rising block) applies with subsidies provided through reduced bulk sale price to rural distributors	National tariffs based on cost recovery after subsidies, universal life line tariff for initial block of energy

[45] Based on Table 12-1 page 314 "*The Challenge of Rural Electrification, Strategies for Developing Countries*", D. F. Barnes, Editor with additional columns for Lao PDR and Vietnam by Aecom NZ.

Principle	Cost Rica	Philippines	Bangladesh	Thailand	Mexico	Tunisia	Chile	China	Vietnam	Lao PDR
Lowering barriers to obtaining supply	Connection fees based on connection costs for the whole community in the initial phase loans for house wiring and appliances	Low connection fees partially subsidised through existing price	Low connection fees partially subsidised through existing price	Low connection fees and house wiring loans in initial programme	Low connection fees partially subsidised through existing price	Low connection fees partially subsidised through existing price	Low connection fees partially subsidised through existing price	Low connection fees with significant variation among counties	Low connection fees partially subsidised, very low cost standard connection arrangements	Low connection fees partially subsidised, low cost standard connection arrangements
Reducing construction and operating costs	U.S. based single- phase	U.S. based single- phase	U.S. based single- phase modified to local conditions	Three phase but reduced costs	U S based single phase for residential and thee phase for irrigation	Single-phase and single wire earth return modified to local grid system	Low cost system design but due to subsidy and adverse mountainous terrain initial programme costs were high	Initially many different low-cost techniques that were later standardised	Multiple initial standards moving towards three phase and single phase supplies similar to French and Thai standards. Most equipment made locally	Three phase and single phase supply but reduced cost technical standards following Thai standards. Locally made poles
Community involvement	Ratepayers are owners of the cooperative	Ratepayers are owners of the cooperative	Ratepayers are owners of the cooperative	Extensive community consultation	Regional boards require community contribution through social Infrastructure funds	Extensive community consultation	Community expresses need for service and may contribute financing as necessary but utility takes over after initial request	Decentralised distribution and generating companies based on counties quite varied community involvement	Community expresses need for service and may contribute financing as necessary. Initially most rural distributors run by local governments Utility now increasingly taking over due to concerns over inefficiency and poor sustainability	Reasonable autonomy granted to Provincial EdL branches to determine priorities. Rapid roll out minimised community friction
Planning for rural expansion	Estimated cost and expected revenue based on expansion plans taking least expensive and highest revenue potential	Estimated cost and expected revenue based on expansion plans taking least expensive and highest revenue potential	Estimated cost and expected revenue based on expansion plans taking least expensive and highest revenue potential	Estimated cost and expected revenue based on expansion plans taking least expensive and highest revenue potential	Cost based on expansion plans from communities requests and support from infrastructure funds	Estimated cost and expected revenue bated on expansion plans based on subsidy received for expansion	PER evaluates subsidy contribution based on costs, benefits and regional price and awards grants for new area expansion	Early planning had many difficult as, with mix of cost based and politically based priorities	Early planning had many difficulties, with mix of cost based and politically based priorities.	Estimated cost and expected revenue based on expansion plans taking least expensive and highest revenue potential broadly following the main road network