

Solar-diesel Hybrid Options for the Peruvian Amazon

Lessons Learned from Padre Cocha



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ESMAP
c/o Energy and Water Department
The World Bank Group
1818 H Street, NW
Washington, D.C. 20433, U.S.A.
Tel.: 202.458.2321
Fax: 202.522.3018

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Task Manager:

Ms. Xiaodong Wang

Financial and Institutional Evaluation:

Mr. Xavier Vallvé, Lead Consultant
Mr. Santiago González and Mr. Pol.
Arranz, Consultants

Technical and Economic Evaluation:

Mr. Ismael Aragón Castro, Lead Consultant
Mr. Eduardo H. Zolezzi, Senior Advisor

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Units of Measure

AC	Alternating Current
Ah	Ampere Hour
km	Kilometer
kV	Kilo Volt
kVA	Kilo Volt Ampere
kW	Kilo Watt (s)
kWh	Kilo Watt (s) Per Hour
kWp	Kilo Watt (s) Peak
LV	Low Voltage
MWp	Mega Watt (s) Peak
V	Volts
W	Watt
Wh	Watt Hour
Wp	Watt Peak

Currency Equivalents

1US\$ = 3.4 S (Perú nuevo sol)

Acronyms and Abbreviations

AGI	Association of Ghana Industries
CFC	Common Fund for Commodities
DEP-MEM	Executive Directorate of Projects-Ministry of Energy and Mines
EOSA	Electro Oriente S.A.
ERPACO	Electro RAPS of Padre Cocha
FOSE	Compensation Fund for Electricity Service (Fondo de Compensación Social Eléctrico)
GOREL	Loreto Regional Government
ILZRO	International Lead and Zinc Research Organization
INEI	National Institute for Statistics and Information Technologies (Instituto Nacional de Estadística e Informática)
IRP	ILZRO RAPS Perú
M&O&M	Management, Operation and Maintenance
O&M	Operation and Maintenance
OSINERG	Supervisory Agency for Energy Investment (Organismo Supervisor de Inversión en Energía)
PV	Photovoltaic
RAPS	Remote Area Power Supply
RE	Renewable Energy
RESPAR	Renewable Energy Systems in the Peruvian Amazon Region
SEIA	Solar Energy Industry Association
SEIN	National Interconnected System (Sistema Eléctrico Interconectado)
WTP	Willingness-To-Pay

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1. Introduction

Today, seven million Peruvians – 23 percent of the country’s population – lack access to modern energy services. Most of these residents are located in the Peruvian Amazon, where 95 percent of people have no electricity supply. In the sparsely populated department of Loreto, Perú’s vast northernmost region, more than one-third of residents lack access to energy services which could generate income and foster economic activity.

In Loreto’s isolated rural communities, grid extension is not an economic option. Diesel fuel delivery is expensive, difficult and environmentally harmful. Padre Cocha is a typical village of the Amazon jungle, located 5 Kilometers (km) upstream from Loreto’s capital city of Iquitos. Padre Cocha’s present population is 2,500 inhabitants with 331 households.

In 1997, the International Lead and Zinc Research Organization (ILZRO) and Solar Energy Industry Association (SEIA), together with the Executive Directorate of Projects-Ministry of Energy and Mines (DEP-MEM), signed an agreement to promote development of Remote Area Power Supply (RAPS) hybrid system, consisting of solar Photovoltaic (PV), diesel generating sets and a distribution minigrid, in isolated zones of Perú. After performing studies, Padre Cocha was selected for installing the first diesel/PV system as a pilot demonstration to evaluate benefits and replicability of this technology. The Loreto Regional Government (GOREL) and the local municipality and the distribution company, Electro Oriente S.A. (EOSA), provided support. In June 2002, the RAPS system was installed in Padre Cocha. In July 2003, the RAPS system started operation, providing 24-hour of electricity services, where residents had no access to power services before the installation.

The ESMAP study aims to: (1) evaluate whether the RAPS system at Padre Cocha is technically, financially and institutionally sustainable and replicable; and

(2) recommend supply options of electricity services to villages like Padre Cocha, and measures to ensure financial and institutional sustainability of such systems. This study consists of two subreports: (1) technical and economic evaluation; and (2) financial and institutional evaluation. This summary report presents a consolidated synopsis of key conclusions from both subreports, and the financial and institutional evaluation subreport can be found in Annex 1.

2. Evaluation of the ILZRO/RAPS System in Padre Cocha

Demand Analysis

Demand Segment Analysis

At present, the system serves 240 consumers out of a potential total of 344 and public street lighting. Almost all consumers are residential. The daily total average energy consumption is near 220 Kilo Watt (s) Per Hour (kWh): 39 percent produced by the PV cells and the rest by the diesel generator. The maximum peak load is 22 Kilo Watt (kW), which occurs at night.

The consumer demand pattern is typical of villages in the region. While average household consumption is 20.6 kWh per month, 74 percent of households consume below this level. When public lighting is added, an average consumption was 22.9 kWh per month. Distribution loss is 12 percent of the total consumption. Table 2.1 shows demand segment analysis for Padre Cocha.

Table 2.1: Padre Cocha Demand Segmentation

Segments	Consumption Range		Contracts		Segment Demand		
	Wh/Day	kWh/Mo	Nb	%	kWh/Day	%	
Residential	Very Low Usage	0 to 275	0 to 8.5	97	40	12.5	5
	Low Usage	275 to 550	8.5 to 17	74	31	30.5	13
	Medium Usage	550 to 985	17 to 30	35	14	25.6	10
	High Usage	985 to 2200	30 to 67	18	7	26.1	11
	Very High Usage	2250 to 3300	67 to 100	8	3	22.0	9
	Subtotal Residential			232	95	116.7	48
Nonresidential	> 3300	> 100	10	5	46.8	19	
Subtotal Residential and Nonresidential				242	100	163.5	67
Public Lighting						19.2	8
RAPS Power Plant and Community Hall						12.4	5
Distribution Losses (Average 2 kW per hour)						48.0	20
Total Generation				242	100	243.1	100

Load Forecast

Because 24-hour electricity service is relatively recent in Padre Cocha, the village lacks sufficient historic information with which to make demand forecasts, using auto-regression techniques or time series. Data for evaluating demand is derived mainly from government agencies – National Institute for Statistics and Information Technologies (Instituto Nacional de Estadística e Informática), Supervisory Agency for Energy Investment (Organismo Supervisor de Inversión en Energía) (INEI, OSINERG and DEP-MEM), ILZRO RAPS Perú (IRP) and field surveys and technical evaluations. Based on similar projects in rural Perú, the study applied a method which closely follows the one used by DEP-MEM in its demand forecasts to estimate individual household-level consumption.

This study concluded that the RAPS system can meet Padre Cocha's demand beyond 2013, even in the high-demand-projection scenario considering increased demand resulting from productive use and ecotourism-related activities such as water pumping, new educational facilities and ecotourism services.

Financial Evaluation

Capital Costs of the RAPS System and Sources of Funding

The RAPS system consists of: (i) two RPS-150-type solar PV modules, each of 14 Kilo Watt Peak (kWp) and 150 kWh/day (totaling 300 kWh/day) capacity; and (ii) a single diesel generator of 128 kW. Each solar PV module includes 180 solar PV panels of 80 Watt Peak (Wp), 240 storage batteries of 375 Ampere Hour (Ah), rectifier systems, charger and 40 kW inverter. The diesel genset is a second-hand unit supplied by EOSA, caused by a lack of funding to purchase a new unit of 100 kW as required in the system design. The system delivers electricity to the distribution grid at 240 Volts (V) Alternating Current (AC). The total cost of the system was estimated to be US\$577,000 with the following breakdown, as shown in Table 2.2.

Table 2.2: Capital Costs of the Padre Cocha RAPS

Concept		Thousand Soles	Thousand US\$
Raps System	PV Modules	436.33	128.33
	Batteries	195.84	57.60
	Control and Power Conditioning	417.07	122.67
	Building and Materials	79.33	23.33
Project Design, Commissioning and Legalization		282.15	82.98
Subtotal RAPS Equipment, Materials and Execution		1,410.72	414.91
Distribution Grids		413.72	121.68
Generator Set		137.68	40.50
Total Initial Investment		1,962.12	577.09

Note: Change rate 3.4 soles/US\$

As of the end of 2004, IRP reports an expenditure of US\$2 million in administration, promotion, studies and equipment acquisition. Table 2.3 shows the sources of funding. This figure does not include the GOREL contributions in the amount of US\$130,000 for the purchase of PV panels and US\$120,000 for the cost of distribution grid, as well as EOSA's contribution of US\$40,000 for donation of the diesel genset.

Table 2.3: Sources of Funds US\$

Common Fund for Commodities (CFC)	540,000
Sandia Nat Lab (USDOE)	204,480
ILZRO & ILZRO RAPS Latin America	1,349,050
Total US\$	2,093,530

Operation & Maintenance Costs for the RAPS System

Operation and Maintenance (O&M) costs, including purchase of fuel and provision for battery replacement, are US\$37,704 per year as per the following breakdown, as shown in Table 2.4.

Table 2.4: Operation and Administration Costs

Expenditure	Cost			
	Monthly		Yearly	
	(S)	US\$	S	US\$
Fixed Costs (63%)				
Local Salaries ¹	2,550	750	30,600	9,000
Spare Parts and Maintenance	504	148	6,048	1,776
Administrative	150	44	1,800	528
Battery Replacement	2,686	790	32,232	9,480
IRP Technical Support	850	250	10,200	3,000
Subtotal	6,740	1,982	80,880	23,784
Variable Costs (37%)				
Fuel and Lubricant ²	3,728	1,097	44,736	13,164
Fuel and Transport ³	213	63	2,556	756
Subtotal	3,941	1,160	47,292	13,920
Total Cost	10,681	3,142	128,172	37,704

¹ Administrative and transaction duties associated with PV (primary energy source) (60 percent) and O&M duties related to running the diesel genset (secondary energy source) (40 percent).

² The September 2004 price of diesel in Iquitos was US\$1.82 per gallon; the cost of each lubricant change (three times per year) was about US\$ 103.18.

³ The total transport cost per gallon was about US\$0.0386 per gallon.

Tariff Structure and Revenues of the RAPS System

OSINERG applies special tariff-setting mechanisms for isolated systems which are not connected to the National Interconnected System (Sistema Eléctrico Interconectado) (SEIN). However, no special tariff scheme is established by OSINERG for installations like the Padre Cocha RAPS system. The generation systems of Padre Cocha and similar sites in the Peruvian Amazon are considered under tariff schemes of a Typical System I – diesel thermoelectric, with more than 50 percent of the electricity produced, derived from the diesel installation serving Electro Ucayali and EOSA distribution companies.

Perú's current administration has established (under Law No 27510) a tariff compensation system, known as Compensation Fund for Electricity Service (Fondo de Compensación Social Eléctrico) (FOSE), to support low-income sectors. Using this cross-subsidy mechanism,

consumers who use more than 100 kWh per month, subsidize those who consume less than 100 kWh per month and, in greater proportion, those who consume less than 30 kWh per month. Unfortunately, Padre Cocha cannot utilize the FOSE subsidy mechanism, which applies only to utility companies registered with OSINERG.

Since the RAPS system initiated 24-hour electricity service, two different tariff schemes have been applied, as shown below, but none can provide an adequate income to cover the O&M costs under the current demand pattern:

- From October 2003 to July 2004, a flat charge of 21.7 S (US\$6.38) per month was applied. This resulted in very high energy consumption per consumers and frequent complaints from small consumers. It was expected that revenue from this tariff would total 5,211 S (US\$1,533) monthly, only 49 percent of the O&M costs; and
- From August 2004 to date, an officially regulated tariff for rural areas was adopted. Although Padre Cocha is not part of any concession, it was decided to apply a regulated tariff (BTSB), the same which EOSA applies to its consumers in nearby Iquitos, with operation of diesel gensets. The fixed charge was reduced to 5 S (US\$1.47) per month, with an additional energy charge of 0.6976 S (US\$0.2052) per kWh. However, this new tariff did not increase revenue, it increased the number of connections. Expected revenue was 4,791 S (US\$1,409) per month, representing only 45 percent of the O&M costs. Unfortunately, the regulated tariff proved inadequate for scattered rural villages characterized by many low consumption users. In Padre Cocha, more than 74 percent of contracted users consume less than 20.6 kWh per month.

Annual projected revenues based on electricity bills between August 2004 and January 2005 is estimated at US\$14,654 per year, compared to the annual O&M costs of US\$37,704, as shown in Table 2.5. This generates a deficit of 61percent. Therefore, current tariff levels cannot recover the O&M cost, and the RAPS system is not financially viable.

Table 2.5: Revenues from the RAPS System

	<i>S./Month</i>	<i>US\$/Month</i>	<i>S./Year</i>	<i>US\$/Year</i>	<i>% of Total</i>
M&O&M Costs	10,681	3,142	128,172	37,704	100.0%
Average Income	4,152	1,221	49,824	14,654	38.9%

The tariff level should be increased to recover at least the O&M costs, within consumers' Willingness-To-Pay (WTP). In addition, the current tariff structure does not adequately reflect the ratio between fixed and variable costs (energy-dependent) and, thus, is not robust to demand changes. A higher fixed charge should be applied for Renewable Energy (RE) minigrids.

IRP management is considering a third tariff, to be proposed to Electro RAPS of Padre Cocha (ERPACO) and approved by the community, consisting on a binomial structure – a fixed charge of 5 S per month and an energy charge of 0.912 Perú nuevo sol per kWh. Although it will improve revenue, this new proposal still has a structural problem because the fixed charge, recovering the fixed O&M costs of the service, is low, therefore, it is unlikely to be robust to fluctuate the demand. With this new proposal, the expected revenue for the typical demand would be 5,896 S per month, still not sufficient to recover the O&M costs.

As a reference, the socioeconomic evaluation conducted in 1998 by the consultants of Energía Total, recommended a flat charge of 34 S (US\$10) per month for contracts up to 15 kWh per month, plus an energy charge of 1.8 S (US 0.53) per kWh for additional monthly consumption above 15 kWh. Expected revenue was 12,908 S (US\$3,796), enough to cover the O&M costs and repay a small portion of investment costs. Unfortunately, this recommendation was never implemented.

In sum, the current financial performance of the RAPS system is not sustainable. Considering the results of the different socioeconomic analysis available, it should be possible to establish a higher tariff within the user's WTP, which would collect sufficient revenue to pay at least for Management, Operation and Maintenance (M&O&M) cost. Therefore, a new tariff structure must be considered and applied. The paragraph under the heading "Proposed Tariff for the Padre Cocha RAPS System" in Chapter 3 – "Recommendation of Future Electricity Supply" recommends a cost recovery tariff structure for the RAPS system.

Levelized Cost of the RAPS System

Levelized cost of the Padre Cocha RAPS system is estimated at US\$1.00 per kWh, as shown in Table 2.6:

Table 2.6: Levelized Costs of RAPS System, Padre Cocha

<i>Component</i>	<i>Present Value (\$)</i>				<i>Levelized Cost</i>	
	<i>Investment</i>	<i>O&M</i>	<i>Replacement</i>	<i>Total</i>	<i>\$/kWh</i>	<i>%</i>
PV	128,333		0	128,333	0.152	15.1
Generator	40,495		15,613	56,108	0.066	6.6
Battery	57,600		22,207	79,807	0.094	9.4
Converter	122,667		18,315	140,982	0.167	16.7
O&M		107,735		107,735	0.127	12.7
Fuel		93,171		93,171	0.110	11.0
Other				106,317		
Total RAPS				712,452	0.842	84.2
Distribution Grid	116,202	19,607		135,809	0.161	16.1
Total	465,297	220,513	56,135	741,945	1.719	171.8

Technical Evaluation

Sizing

While the present load in Padre Cocha is 22 kW, or 220 kWh/day, the RAPS system was designed for a peak load of 80 kW and a production of 300 kWh/day, which resulted in oversized power supply components.

The distribution grid was also built for a total load of 250 Kilo Volt Ampere (kVA), oversized for the present load, which resulted in high transformer losses which initially surpassed 20 percent of the produced energy. After changing the transformer size, losses were reduced to 12 percent.

Distribution should be done with a Low Voltage (LV) grid, and losses limited to the voltage drop in the lines. Since the PV part of the generation plant is not noisy, it could be located within the village to keep distribution lines compact. The diesel generator could remain, as it is in common practice, in the outskirts.

Design and Installation

The RAPS system adopts modern technology with proper installation. The project technology design is fairly sound. However, some design and construction aspects which increase installation costs, and affect system performance, should be corrected in similar projects. Among these aspects, the following have been detected:

- To utilize properly sized (smaller) and efficient diesel generators;
- The rectification, charge and discharge of batteries sequence and the conversion to AC incur high losses and lower the overall efficiency. It should consider the configuration of directly connecting the genset to the AC distribution grid; a switch to connect the inverter when the genset is off; and the possibility of smaller parallel inverters to match demand and conversion efficiency;
- To install batteries in site constructions and not in factory containers; and
- To install batteries with higher unit capacity.

In addition, the use of variable angle PV panels should be evaluated to increase solar energy efficiency.

Operation and Waste Treatment

The present daily operation cycle is suitable, given the system size characteristics in regard to the load and configuration. In addition, the recycling plan for used lubricating oil and the disposal of used batteries are technically adequate.

Institutional Evaluation

Since its commissioning, a local community organization called Electro RAPS of Padre Cocha (ERPACO) has been responsible for the administration and operation of the RAPS system and the commercial service at Padre Cocha. The local community fully participated in this institutional structure, however, their technical and management capacity is somewhat limited. IRP provided the crucial technical and management support during this process. Unfortunately, since the revenues cannot recover the O&M costs, IRP continues to rely on ILZRO for funding.

The ERPACO organization, self-management based on the grounds of technical and administrative support provided by IRP, Perú, has provided positive results till date.

This institution, however, needs substantial capacity-building to demonstrate that it can be self-sustainable and succeed without that support.

The participation of the central government has been very limited, while the regional government has provided some infrastructure. Such a lack of effective involvement by these administrations can reduce the potential for successful replication of this initiative in other areas.

The following sections provide recommendations on how to ensure technical, economic, financial and institutional sustainability to supply electricity services to villages like Padre Cocha, and specific suggestions on how to improve the financial viability and institutional arrangement of the RAPS system.

3. Recommendations on Future Electricity Supply Options

Economic Comparison of Electricity Supply Alternatives

For a village like Padre Cocha, an economic analysis has been performed in order to determine the least-cost technology option.

Five technically feasible options have been evaluated:

- Diesel-only;
- Diesel-battery-hybrid;
- PV-diesel-battery-hybrid with four different PV array sizes;
- PV only; and
- PV-individual home systems.

For each option, except for solar home systems, the HOMER model is used, combined with the field experience of the consultants to design the size and configuration most economically suitable for the reference load at Padre Cocha.

After determining the size of each alternative option, the economic costs of different options were compared, which include capital investment costs, costs of equipment replacement, O&M costs, fuel costs and cost of distribution grid, over a 20-year period. The comparison parameter was the levelized cost per kWh generated (consumer plus public lighting), during all the evaluation period, considering an annual discount rate of 10 percent.

Optimum Sizing Results

Table 3.1 shows the optimum size of different system components for the nine technological options of minigrid and stand-alone systems to supply electricity services.

Table 3.1: Optimum Sizing Results

	PV Arrays kWp	Genset kW	Batteries kWh	Power Conditioning			
				Rectifier kW	Inverter kW		
Padre Cocha RAPS (Optimized) ¹	30	128			40		
1. Diesel-only	1a. Alternative One Stand-by Unit		1 x 36 kW	0	0		
	1b. Alternative Peak and Off-peak		2 x 18 kW	0	0		
2. Diesel-battery-hybrid		1 x 36 kW	310	20	10		
3. Diesel-PV-hybrid	3a. Solar PV 25%		25	36 kW	310	20	10
	3b. Solar PV 50%		50	36 kW	310	20	10
	3c. Solar PV 75%		75	36 kW	524	10	20
	3d. Solar PV 85%		93	36 kW	524	10	20
4. Solar PV 100%	140	0	765	0	25		

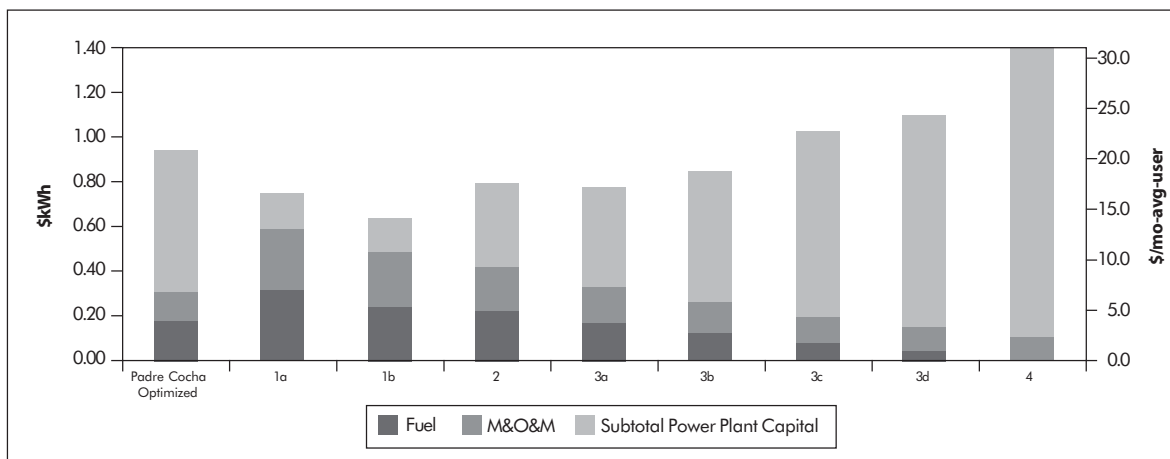
¹ Actual figures from Padre Cocha but with improvements to significantly reduce distribution losses.

Levelized Cost Comparison

Economic evaluation results are shown in the following Tables and Figure:

Table 3.2: Economic Cost Comparison

	Levelized Costs, Breakdown \$/kWh						
	PV	Genset	Battery	Power Conditioning	M&O&M	Fuel	Total
Padre Cocha Optimized	0.148	0.066	0.094	0.167	0.127	0.174	0.937
1a Genset Only (1 on + 1 Back-up Unit)	–	0.056	–	–	0.272	0.310	0.740
1b Genset Only (2 on at Peak and 1 on Off-peak)	–	0.054	–	–	0.240	0.237	0.633
2 Genset Battery-hybrid	–	0.025	0.198	0.056	0.186	0.225	0.791
3a PV-hybrid 25 kWp	0.146	0.020	0.122	0.056	0.155	0.170	0.772
3b PV-hybrid 50 kWp	0.293	0.016	0.122	0.056	0.142	0.116	0.846
3c PV-hybrid 75 kWp	0.439	0.013	0.206	0.076	0.110	0.074	1.019
3d PV-hybrid 95 kWp	0.556	0.013	0.206	0.076	0.105	0.043	1.100
4 PV-only 140 kWp	0.819	–	0.301	0.076	0.098	–	1.395

Figure 3.1: Comparison of Cost Breakdown for each Option**Table 3.3: Comparison between Levelized Energy Costs and Costs per Contract**

	Levelized Energy Costs (\$/average kWh)				Costs per Contract (\$/Contract Month)			
	Capital Initial and Replacement Cost	Fixed M&O&M	Fuel	Total	Capital Initial and Replacement Cost	Fixed M&O&M	Fuel	Total
Padre Cocha Optimized	0.636	0.127	0.174	0.937	13.98	2.80	3.84	20.62
1a Genset Only (1 on + 1 Back-up Unit)	0.158	0.272	0.310	0.740	3.47	5.98	6.82	16.28
1b Genset Only (2 on at Peak and 1 on Off-peak)	0.156	0.240	0.237	0.633	3.43	5.28	5.21	13.92
2 Genset Battery-hybrid	0.380	0.186	0.225	0.791	8.36	4.10	4.94	17.40
3a PV-hybrid 25 kWp	0.446	0.155	0.170	0.771	9.81	3.41	3.75	16.97
3b PV-hybrid 50 kWp	0.588	0.142	0.116	0.846	12.93	3.12	2.56	18.61
3c PV-hybrid 75 kWp	0.835	0.110	0.074	1.019	18.37	2.43	1.62	22.42
3d PV-hybrid 95 kWp	0.952	0.105	0.043	1.100	20.95	2.32	0.94	24.20
4 PV-only 140 kWp	1.297	0.098	–	1.395	28.54	2.15	–	30.69

As is shown in Table 3.1, the 2x18 kW diesel-only system is the least-cost option. PV-diesel-hybrid options have higher levelized costs, because the high initial investment costs cannot be offset by the fuel savings, at current fuel price. Figure 3.1 clearly shows that RE systems have high capital investment costs but very low M&O&M and fuel costs, whereas diesel generators have quite low capital investment costs but very high O&M and fuel costs.

Sensitivity Analysis

A sensitivity analysis was performed for the technological options with three parameters of oil price, population size and service hours to address the following issues:

- What is the price of fuel at which diesel stand-alone is not the least-cost option?
- What is the load for which the PV or diesel-PV systems become attractive?
- Which is the least-cost option – supply electricity for five hours or 24 hours?

Sensitivity to Fuel Price

The diesel price break-even point equals to US\$1.58/liter (US\$5.92/gallon) if compared to PV-diesel-hybrid systems, and US\$2.38/liter (US\$9.81/gallon) if compared to PV-only systems. In the first case, the break-even point results in 2.77 times the price used in the evaluation (US\$0.57/liter) and, in the second case, 4.2 times.

Sensitivity to Population Size

In regard to population size, the break-even point is calculated for a 25-consumers locality, with a total daily average consumption of 25 kWh/day, including public lighting.

Sensitivity to Service Hours

The reduction of service hours reduces total energy supplied to the users, which affects the level of sales of the distribution company. In Padre Cocha, most of the electricity used during the daytime are for refrigerators, freezers and fans. Therefore, only a portion of consumption can be shifted to night hours, as shown in the projected figures for the year 2009:

5 Hours Service	122 kWh/day	51%
8 Hours Service	145 kWh/day	60%
24 Hours Service	241 kWh/day	100%

As shown in Figure 3.2, without distribution grids, the levelized costs for 24-hour service are higher than that for five- or eight-hour service, particularly for diesel-battery and diesel-PV-hybrid systems.

Because the study concluded that the diesel stand-alone system is the least-cost supply option, levelized cost generation and distribution were calculated for five-, eight- and 24-hour diesel-only supply options, as shown in Figure 3.3. Given the same distribution grid, regardless of the number of hours of service provided, levelized cost with the distribution grid for five-hour daily service is higher than that for 24-hour service because of the lower amount of energy supplied. The study concluded that diesel-only generation with 24-hour service is the least levelized cost option because of distribution grid costs.

Figure 3.2: Levelized Cost Comparison Without Distribution Costs (US\$ per kWh)

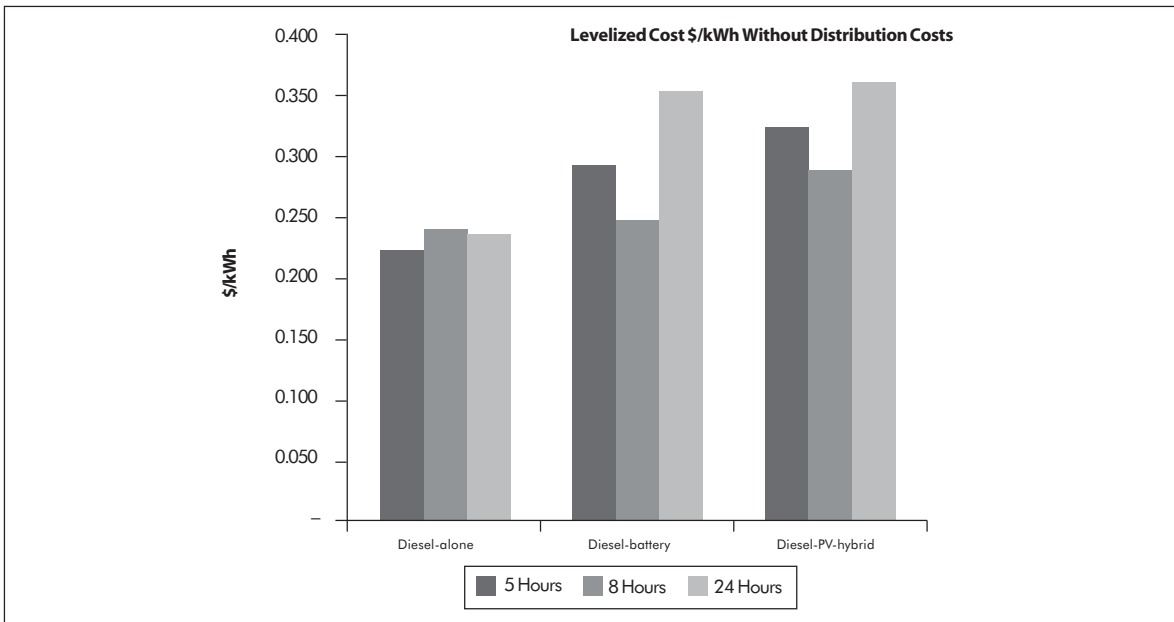
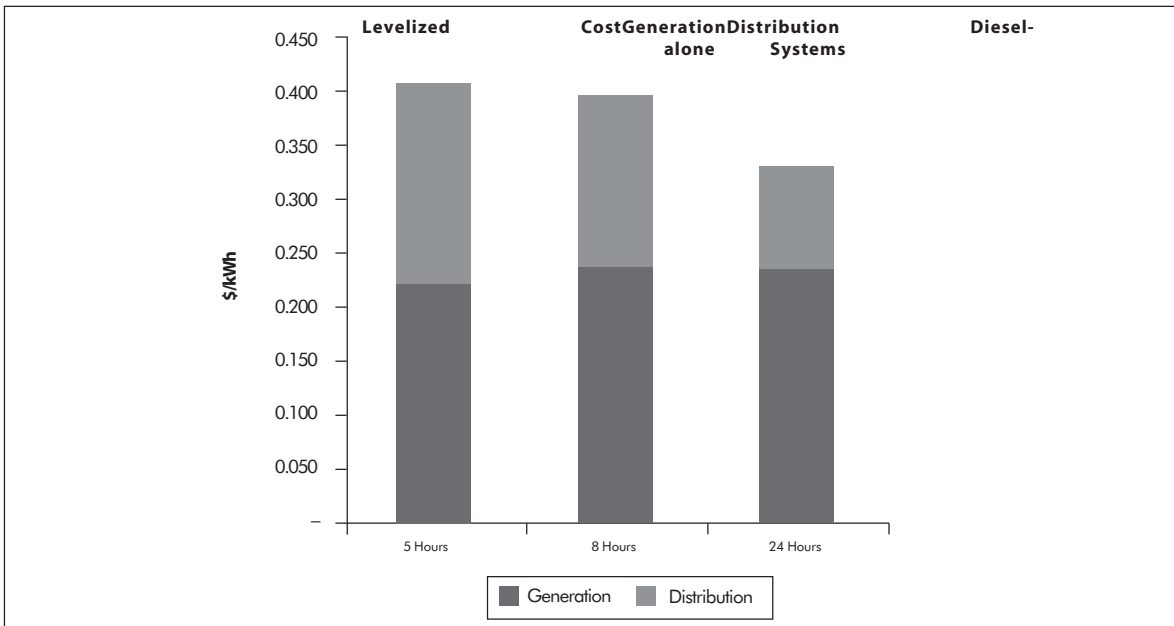


Figure 3.3: Levelized Cost Generation and Distribution: Diesel Stand-alone Options



Financial Sustainability – Tariff and Subsidy

Principle of Financial Sustainability for Renewable Energy Minigrids

Developing cost-recovery tariffs is probably the single most important factor determining the long-term commercial viability of minigrids and other rural electrification projects. However, in practice, it is usually unrealistic to expect full cost-recovery tariff given the low ability to pay in rural areas. It is important to keep a balance between ensuring commercial viability of the service providers and meeting rural consumers' ability to pay. When designing tariff structures for minigrid systems, a principle should be kept in mind that the tariff should at least recover M&O&M costs, replacement costs, preferably partial capital investment costs, while subsidies are applied to partial or total capital costs. Following the principle that tariffs should recover M&O&M costs, while subsidies should buy down initial investment costs, RE minigrids can become more attractive than diesel gensets, because they require lower tariffs compared to diesel generators, and are less exposed to fuel price volatility. Sometimes, in remote areas, where diesel price is quite high, the M&O&M costs for diesel generators can be higher than the local consumers' ability to pay.

An adequate tariff structure for RE-based minigrids should follow these principles:

- Enable to pay at least M&O&M and equipment replacement costs;
- Reflect the cost structure (that is, include a higher fixed charge than in typical tariff structures applied in larger grids); and
- Remain below users' WTP.

The fixed and variable costs is a major issue in financial evaluation of PV-hybrid minigrids in particular, and consequently ought to be carefully established and understood in order to define an adequate tariff structure. The costs associated with energy generation from renewable sources are essentially fixed (investment, salaries, monitoring and surveillance, spare parts and maintenance provision) regardless of the fact whether the energy is sold or not. In contrast, electricity generation from diesel gensets has some fixed costs, but a significant amount of variable costs, related to energy generated and consumed (fuel purchase and transport, lubricant, etc). However, studies of diesel genset operated in minigrids supplying low energy demand patterns have shown that diesel gensets usually operate below nominal power (that is, inefficient operation), which significantly increases the cost per energy unit generated. This effect ultimately sets a fixed cost, a "minimum" cost when the genset is operating.

Following this principle, a fixed monthly fee may be a more appropriate tariff scheme for RE minigrids, since it is more directly related to the cost structure of a RE system and it provides the operator with reduced transaction costs and a clearer financial forecast.

Consumers' Willingness-To-Pay

Based on recent study results in the Peruvian Amazon on users' WTP¹ any proposed tariff could at least have a monthly charge of 20 S, or about US\$6 for the very low consumption users, and about 30 S, or about US\$10 for the average consumption users.

Proposed Tariff for the Padre Cocha RAPS System

Given the high transaction costs and the large number of "very low" consumption contracts, the proposed monthly tariff to supply electricity services to villages like Padre Cocha is:

$$\begin{cases} T = 6 & \text{for contracts up to 8.5 kWh/month} \\ T = 6 + 0.25 \cdot (x - 8.5) & \text{for contracts above 8.5 kWh/month} \end{cases}$$

where T is the tariff (in \$/month) and x is consumption (kWh/month).

In the current case of Padre Cocha, this tariff would cover about 70 percent of M&O&M and replacement costs. To recover current M&O&M costs, the operator can consider the following two options:

Apply the proposed general tariff, but reduce distribution losses and cut administrative costs; or

Apply a higher tariff temporarily until improvements can be implemented, which should be no less than

$$\begin{cases} T = 8 & \text{for contracts up to 8.5 kWh/month} \\ T = 8 + 0.35 \cdot (x - 8.5)/\text{kWh} & \text{for contracts above 8.5 kWh/month} \end{cases}$$

In any case, it must try to get more consumers, especially in the very low consumption segment.

¹ *Energía Total (1998), NRECA International (1999), and IRP (2004).*

Proposed Tariff and Subsidy for Different Supply Alternatives

Tables 3.4 and 3.5 compares the minimum tariffs under different subsidy levels with consumers' WTP. As shown in Table 3.4, without any subsidies, the "full" tariffs (tariffs needed to recover the full costs including initial investment and M&O&M costs) of all the technological options would be above the users' WTP. Therefore, capital subsidy is required.

Table 3.4: Proposed Tariff Levels with 0%, 50% and 80% Capital Subsidies

Technological Options	% Subsidy on Initial Investment						
	80%			50%			0%
	Tariff for Average Consumption Contracts 22 kWh/Mo	Required Subsidy on Initial Investment		Tariff for Average Consumption Contracts 22 kWh/Mo	Required Subsidy on Initial Investment		Tariff for Average Consumption Contracts 22 kWh/Mo
		Total \$	Per Contract \$/Contract		Total \$	per Contract \$/Contract	
1a Genset Only (1 On + 1 Back-up Unit)	\$14.38	73,128	215	\$15.09	45,705	134	\$16.28
1b Genset Only (2 On at Peak and 1 on Off-peak)	\$12.09	70,428	207	\$12.78	44,017	129	\$13.92
2 Genset-battery-hybrid	\$13.30	157,598	464	\$14.84	98,499	290	\$17.40
3a PV-hybrid 25 kWp	\$10.48	256,588	755	\$12.90	160,368	472	\$16.97
3b PV-hybrid 50 kWp	\$ 9.60	355,579	1,046	\$12.83	222,237	654	\$18.61
3c PV-hybrid 75 kWp	\$ 9.57	507,657	1,493	\$14.17	317,286	933	\$22.42
3d PV-hybrid 95 kWp	\$ 9.35	586,849	1,726	\$14.66	366,781	1,079	\$24.20
4 PV Only 140 kWp	\$10.38	802,654	2,361	\$18.01	501,658	1,475	\$30.69

From Table 3.4, it is clear that a 50 percent subsidy level is not sufficient to enable affordable tariffs, regardless of the technological options considered. Even with 100 percent capital subsidy, Table 3.5 shows that the tariff levels for diesel gensets only and diesel-battery-hybrid systems (options 1a, 1b and 2) are higher than consumers' WTP. This implies that the diesel-based generation options would require subsidies for ongoing M&O&M costs to address affordability issues, which cannot ensure financial sustainability of the systems.

Diesel-PV-hybrid systems become attractive when capital subsidies are available. The study concluded that with an 80 percent initial capital subsidy (US\$755/connection), PV-hybrid option (option 3a) can offer an affordable tariff.

Table 3.5: The Lowest Hurdle Tariffs with 100% Capital Subsidy

Technological Options	B \$/kWh	A \$/Contract	C \$/kWh	Tariff (\$/Contract) $T = A + (B+C) \cdot x$ (x in kWh)	Tariff for Average Consumption Contracts 22 kWh/mo	Required Subsidy on Initial Investment	
						Total \$	per Contract \$/Contract
Padre Cocha Optimized	0.090	2.80	0.174	2.80 + 0.264•x	\$ 8.61	461,829	1,358
1a Genset Only (1 On + 1 Back-up Unit)	0.050	5.98	0.310	5.98 + 0.360•x	\$13.90	91,409	269
1b Genset only (2 on at Peak and 1 on Off-peak)	0.052	5.28	0.237	5.28 + 0.289•x	\$11.63	88,034	259
2 Genset-battery-hybrid	0.147	4.10	0.225	4.10 + 0.372•x	\$12.28	196,997	579
3a PV-hybrid 25 kWp	0.067	3.41	0.170	3.41 + 0.237•x	\$ 8.63	320,735	943
3b PV-hybrid 50 kWp	0.062	3.12	0.116	3.12 + 0.178•x	\$ 7.05	444,473	1,307
3c PV-hybrid 75 kWp	0.085	2.43	0.074	2.43 + 0.158•x	\$ 5.92	634,571	1,866
3d PV-hybrid 95 kWp	0.085	2.32	0.043	2.32 + 0.127•x	\$ 5.12	733,562	2,158
4 PV Only 140 kWp	0.111	2.15	-	2.15 + 0.111•x	\$ 4.60	1,003,317	2,951

Recommended Business Models

One of the key barriers to minigrid systems is the tragedy of common goods for scarce resources, that is the ownership and management of the system. Experience with minigrids demonstrated two business models – utility model and community-based organization model, under which utilities or community-based organizations own and maintain the infrastructure and provide service.

Table 3.6 contains a brief description of the two organizational schemes which have been found most feasible for the RAPS project to provide rural electricity services with decentralized RE-based minigrids:

Table 3.6: Typical Models for the Organization of a Rural Electricity Service

<i>Model</i>	<i>Funding</i>		<i>Responsible for Maintenance</i>
	<i>Initial Investment</i>	<i>M&O&M Costs</i>	
A. Utility Model	Users and public funds (municipalities and other governmental bodies)	Tariffs paid by users, with a cross-subsidy managed by a governmental body (for example, FOSE)	Utility (via a territorial concession)
B. Community Model	Principally, public funds (optionally, smaller contribution from users)	Tariffs paid by users. (possible subsidy from governmental bodies for equipment replacement costs)	Community organization, acting like an energy operator
<i>Model</i>	<i>Main Advantages</i>	<i>Main Disadvantages</i>	
A. Utility Model	<ul style="list-style-type: none"> • Protection of legal framework and official bodies • Technical expertise on M&O&M duties, monitoring, transaction, administration • Larger experience on managing electricity service provision • Availability of financial resources (better access to funds and financing mechanisms) • Centralized corrective maintenance service, stock of spare parts • Availability of service regulations and formal contracts 	<ul style="list-style-type: none"> • Usually not interested in minigrids in remote areas, and slow response when the systems run into problems • High M&O&M costs • Risk of distant perception by users, causing eventual rejection • Risk of financial failure in the event of neighbors rejection – refusal to pay tariffs in one community, which may affect the service in other communities • Current regulated tariffs need to recognize RE-based minigrids 	
B. Community Model	<ul style="list-style-type: none"> • Only organizational alternative in remote areas, where no utilities are operating • High sense of ownership • Social acceptance, neighbors collaboration and coresponsibility for the equipment ownership and conduction of basic maintenance duties • Creation of M&O&M jobs within the community • Increased community self-sufficiency, less bureaucracy needed to manage the service • Possibility to apply specifically designed tariff structures 	<ul style="list-style-type: none"> • Lack of management, administrative and technical capacity and resources • Need for specific training on M&O&M • Limited access to spare part stocks • Little or no access to financial resources (funds and financing mechanisms) • Risks associated with required revenue transactions 	

Given the limited technical and business skills of the community organization, the system is not operated on a financially viable basis. The distribution utility, on the other hand, is not interested in such a small system. A hybrid model is recommended as the first option for replication of RAPS systems. In the Padre Cocha community, EOSA could own the RE hybrid system and provide technical back-up, while ERPACO would be responsible for on-site basic maintenance and administrative duties. A major barrier to overcome for this model would be to improve the tariff structure so that the replication projects would have sound financial sustainability to attract EOSA investments.

With the experience of Padre Cocha, the partnership IRP-ERPACO should be encouraged. The study recommended that IRP-ERPACO should replicate the RAPS systems to provide electricity services to other neighboring villages, so that the M&O&M costs of such partnerships can be funded by a larger portfolio of villages sharing the same technical and management assistance.

Replication Potential

Based on available data from the department of Loreto, combined with information on the proposed demand segmentation and costs and user demand identified by the RAPS system in Padre Cocha, the replication potential of PV power for supplying residential and public lighting demand in Loreto was assessed. Two approaches were used: 1) sites which already had diesel gensets and distribution grids; and 2) the rural and isolated population in Loreto.²

Using the first approach, it was estimated that a total PV power of 4,191 kWp would serve 137 PV-hybrid microgrids to supply residential and public lighting electricity needs of 15,508 households in Loreto. The overall system cost would be about US\$56.6 million.³ Applying the second approach, it was found that 20.8 megawatt peak (MWp) would serve 2,149 PV-hybrid microgrids to supply residential and public lighting electricity needs of 77,131 households in Loreto, at a total estimated system cost of US\$281.4 million.⁴ Based on these methods, the replication potential of PV-hybrid systems could be evaluated for other regions in the Peruvian Amazon.

² Six provinces were assessed: Alto Amazonas, Loreto, Maynas, Ramón Castilla, Requena and Ucayali.

³ Urban sites supplied with large thermal power stations were excluded; the average family size of six was considered equivalent to one household user in terms of rural electrification.

⁴ Urban areas and sites with fewer than four households were excluded. It may be noted that the number of families considered, approximates the number of households without electricity (75,000), reported by INEI.

4. Conclusions

The Padre Cocha system evaluation offers useful lessons when considering electricity supply options for other similar isolated villages in the developing world.

Evaluation summary of the RAPS System: The RAPS system in Padre Cocha received 100 percent grant funding for its capital costs, and its current tariff level cannot recover the M&O&M costs. A primary reason for its high capital costs of US\$2,400/connection is that the RAPS system is oversized compared to the peak power demand, which also resulted in high distribution losses. The RAPS system also has a high M&O&M cost, which the revenue does not recover. Therefore, it is not considered to be financially sustainable and replicable, under the current condition of sizing, costs and tariff.

Least-cost Supply Options: In terms of levelized life cycle costs, diesel genset would be the least-cost option to supply electricity services in villages like Padre Cocha. The required technical configuration would be two properly sized units, one of them operating at off-peak hours and both of them in parallel at peak hours, directly connected to the distribution grid.

Proposed Tariff Structure and Subsidy Level: An adequate tariff structure should be applied. For RE minigrids, existing rural electrification tariffs may not be suitable, since they do not reflect the specific demand patterns and supply characteristics. An adequate tariff structure for RE minigrids should follow these principles: 1) to at least recover M&O&M costs; 2) to reflect cost structure – a high fixed charge (higher than typical tariff structures applied in large grid systems) to reflect fixed M&O&M costs, a variable charge to reflect fuel costs and a levelized capital cost charge to partially reflect capital investment costs; and 3) to remain below consumers' ability to pay. Following these principles, a fixed monthly fee may be a more appropriate tariff scheme for RE minigrids, since it is more directly related to the cost structure of a RE system, and it provides the operator with reduced transaction costs and a clearer financial forecast.

Given the low consumers' WTP, none of the supply options considered can offer a tariff level below users' WTP without any subsidies. Therefore, subsidies are required to cover partial capital investment.

Following these principles, however, diesel-genset-based schemes are neither affordable nor sustainable, even with 100 percent capital subsidies. On the other hand, diesel-PV- hybrid systems become more attractive, since they require lower tariffs compared to diesel-only options, and are less exposed to fuel price volatility. For a village similar to the load demand in Padre Cocha, the study concluded that a properly designed diesel-PV-hybrid system (option 3a.) can offer an affordable tariff level below consumers' WTP, with an 80 percent initial capital subsidy.

Proper Technical Design: System designs should be properly sized to meet the peak demand, efficient gensets should be adopted and distribution losses should be reduced. When possible, the use of local components should be prioritized.

Recommended Business Model: A hybrid of utility and community-based organization business model is recommended, since the utilities have the resources and technical capacity required to invest and provide technical back-up to such systems, while the community-based organization can provide day-to-day maintenance and administration to ensure community involvement. Regardless of the business model, it is important to clearly define the ownership and management issues of minigrid systems from the beginning to ensure technical and financial sustainability over the long term. Efficient management of the system can also reduce O&M costs.

Box 4.1 and Box 4.2 provide a strategic checklist for replication when designing tariffs for RE minigrids and selecting organizational arrangement respectively.

Box 4.1: Designing Tariffs: Strategic Checklist for Replication

Determine net-demand rates and characterize them according to consumption segments, separating residential, nonresidential (commercial and industrial) and communal (public lighting and buildings) demand. If this is not possible, use data from similar electrified sites in the region.

Identify and characterize users' WTP for electricity service, preferably by defined consumption segments (very low, low, medium, high and very high).

Assess funding availability for initial investment.

- *If funding is accessible, consider RE hybrid systems as a first option; next...*
 - Assess the RE system resource potential. If not significant, consider combustion genset generation. If significant, design RE system generation capacity to cover at least residential and communal demand;
 - Evaluate the legal framework for tariff structures in the region;
 - Design a tariff structure for financial sustainability (at least for the first five years);
 - Calculate the levelized cost of energy and cost per contract under various financial scenarios;
 - Separate capital costs from fixed M&O&M and variable O&M costs;
 - Define the tariff which covers at least all M&O&M and replacement costs and remains close to users' WTP; and
 - Consider a flat charge for residential contracts (at least for very low consumption contracts, typically below 8.5 kWh per month).

- *If funding is not accessible, consider combustion genset generation; next...*
 - Assess the resource potential of the fuel;
 - Complete steps IIIA-1, -2, -3a, and -3b;
 - Define the tariff which enables repayment of initial investment costs and remains close to users' WTP; and
 - Complete step IIIA-3d.

Box 4.2: Organization Arrangement: Strategic Checklist for Replication

- Define the roles and responsibilities of each key player;
- Identify candidate organizations to perform each role; and
- Assess the legal framework for electricity service provision in the region and the nature of the candidate service operator.
- Select the business model:
 - Concessionaire management is the most common option; and
 - If the legal framework does not define a concession system, or no candidate concessionaires can be found, follow a user management model.
- Assess the skills and resources (financial, infrastructure, references...) of each candidate organization. Emphasis must be put on the service operator, which should be competent for both financial management and technical O&M;
- Appoint specific organizations to perform each key role, by setting up formal agreements in compliance with applicable regulations. (Do not proceed without a formal appointment to perform each of the indispensable key roles); and
- Define the ownership.
- Develop service regulations, including:
 - Penalization and incentives (for example, reconnection fees);
 - Maintenance and basic conservation;
 - Spare parts provisioning;
 - Ongoing training for users and local technicians; and
 - Monitoring and evaluation.
- Set up service contracts between the operator and the users.



Annex 1

**Levelized Cost Comparison for
Different Technological Options**

Padre Cocha RAPs

SYSTEM CHARACTERISTICS

	2005	2011
PV Array	30	30
Diesel Generator	1 x 128	1 x 128
Battery Units (2 volts type)	480	480
Converter	80	80
Fuel	\$/liter	0.57

	Size/qty.	Capital Cost US\$	Replacement Cost US\$	Lifetime
PV (kW)	30	128,333	128,333	25
Diesel Generator	1 x 128	40,495	40,495	10
Battery (Units)	480	57,600	57,600	10
Converter (kW) & Others	80	122,667	122,667	15
Building and Materials		23,333	0	
Project Design, Commissioning and Legalization		82,984	0	
Distribution Grid Capital Costs		121,683		30
TOTAL		577,095		
Distribution Grid O&M		2303	US\$/yr	
Distribution Losses	Fix.kW/day	24	Variable	1%
Carbon Emissions Costs	0	US\$/ton		

CASH FLOW (US\$)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Energy Generated		99.3	101.0	102.8	104.7	106.6	108.5	110.4	112.5	114.5	116.6	116.6	116.6	116.6	116.6	116.6	116.6	116.6	116.6	116.6	116.6	116.6
Distribution Losses		9.7	9.7	9.7	9.7	9.7	9.7	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Energy Consumed		89.6	91.4	93.1	95.0	96.8	98.7	100.7	102.7	104.7	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8
Energy Generated/day		272.0	276.8	281.7	286.8	291.9	297.2	302.6	308.1	313.8	319.5	319.5	319.5	319.5	319.5	319.5	319.5	319.5	319.5	319.5	319.5	319.5
Distribution Losses		26.5	26.5	26.6	26.6	26.7	26.7	26.8	26.8	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9	26.9
Energy Consumed		245.5	250.3	255.2	260.2	265.3	270.5	275.8	281.3	286.9	292.6	292.6	292.6	292.6	292.6	292.6	292.6	292.6	292.6	292.6	292.6	292.6
PV Generation		80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Diesel Net Generation		29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Diesel Total (Net + Losses)		165.5	170.3	175.2	180.2	185.3	190.5	195.8	201.3	206.9	212.6	212.6	212.6	212.6	212.6	212.6	212.6	212.6	212.6	212.6	212.6	212.6
Diesel Total (Net + Losses)		60.4	62.2	63.9	65.8	67.6	69.5	71.5	73.5	75.5	77.6	77.6	77.6	77.6	77.6	77.6	77.6	77.6	77.6	77.6	77.6	77.6
Specific Fuel Usage		0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Annual Fuel Usage		26,182	26,936	27,708	28,497	29,304	30,130	30,975	31,840	32,724	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629

EQUIPMENT

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
PV		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Generator		1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128	1 x 128
Battery Units		480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480
Converter		80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Carbon Emissions		ton 0.0007217	18.9	19.4	20.0	20.6	21.2	21.7	22.4	23.0	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
Fuel Cons. liters		26,182	26,936	27,708	28,497	29,304	30,130	30,975	31,840	32,724	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629	33,629

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	2004	2005	2006	2007	2007	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
COSTS																						
Capital Costs and Replacement																						
PV Array	124,865	128,333	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-25,667
Replacement	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel Generator	40,495	40,495	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Replacement	15,613	-	-	-	-	-	-	-	-	-	40,495	-	-	-	-	-	-	-	-	-	-	-
Battery Units	57,600	57,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Replacement	22,207	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Converter	122,667	122,667	-	-	-	-	-	-	-	-	57,600	-	-	-	-	-	-	-	-	-	-	-
Replacement	18,315	-	-	-	-	-	-	-	-	-	-	-	-	-	-	122,667	-	-	-	-	-	-
Others	106,317	106,317	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution Grid	116,202	121,683	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OPERATION COSTS																						
Fuel Costs	147,520	14,924	15,354	15,793	16,243	16,703	17,174	17,656	18,149	18,653	19,169	19,169	19,169	19,169	19,169	19,169	19,169	19,169	19,169	19,169	19,169	19,169
O&M Costs	107,735	14,304	14,304	14,304	14,304	14,304	14,304	14,304	14,304	9,886	9,886	9,886	9,886	9,886	9,886	9,886	9,886	9,886	9,886	9,886	9,886	9,886
Carbon Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution Grid O&M	19,607	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303	2,303
TOTAL COSTS	899,143	577,095	31,961	32,400	32,850	33,310	33,781	34,263	34,756	30,842	129,453	31,358	31,358	31,358	31,358	154,025	31,358	31,358	31,358	31,358	31,358	31,358
PRESENT VALUE																						
Energy Consumed PV	10%	899,142																				
LEVELIZED COSTS																						
\$/kWh																						
S./kWh																						
LEVELIZED COSTS BY COMPONENTS																						
	Investment (\$)	O&M (\$)	Present Value (\$)	Replacement (\$)	Total (\$)	Consump	MWh	\$/kWh	Levelized Cost													
PV	124,865		0	124,865	846	846	0.148	13.9%														
Generator	40,495	15,613	22,207	79,807	846	846	0.066	6.2%														
Battery	57,600	18,315	18,315	140,982	846	846	0.167	15.7%														
Converter	122,667	107,735	147,520	106,317	0	846	0.127	12.0%														
O&M		147,520	106,317	0	0	846	0.174	16.4%														
Fuel		0	0	0	0	846	-	0.0%														
Others		0	0	0	0	846	0.776	73.1%														
Carbon Emission		0	0	0	0	846	0.161	15.1%														
Total RAPS		116,202	19,607	274,862	899,142	846	1.063	100.0%														
Distribution Grid		116,202	19,607	274,862	899,142	846	1.063	100.0%														
TOTAL	461,829	274,862	56,135	899,142	846	846	1.063	100.0%														
REVENUES																						
Fix Charge	0.561 \$ / User / Month	1.85 \$/User/Month																				
Energy Charge	0.211 \$/kWh	0.6976 \$/kWh																				

	2004	2005	2006	2007	2007	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Users Number	1.03		244	251	258	265	272	280	288	296	304	313	322	331	340	350	360	370	381	392	403	415
Energia Vendida	MWh/yr		89.6	91.4	93.1	95.0	96.8	98.7	100.7	102.7	104.7	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8
INGRESOS																						
Fix Charge	\$		1,641	1,689	1,736	1,783	1,830	1,884	1,937	1,991	2,045	2,106	2,166	2,227	2,287	2,355	2,422	2,489	2,563	2,637	2,711	2,792
Energy	\$		18,945	19,313	19,689	20,074	20,468	20,871	21,283	21,705	22,137	22,578	22,578	22,578	22,578	22,578	22,578	22,578	22,578	22,578	22,578	22,578
TOTAL INCOME	\$		20,586	21,002	21,425	21,857	22,298	22,755	23,220	23,696	24,182	24,684	24,744	24,805	24,865	24,933	25,000	25,067	25,141	25,215	25,289	25,370

PRESENT VALUE

	10%	195,730
Income PV	US\$	195,730
Subside		22%
Costs PV		703,412
		78%

	US\$	%
Income	195,730	22%
NPV Costs	899,142	
Difference	-703,412	-78%
Income	195,730	59%
Operation and Replacement	330,997	
Difference	-135,267	-41%

Diesel Stand-alone: 2 units x 36 kW

SYSTEM CHARACTERISTICS	2005	2014
PV Array	0	0
Diesel Generator	2 x 36	2 x 36
Battery Units	0	0

	Size/qty.	Capital Cost US\$	Replacement Cost US\$	Lifetime
PV (kW)	0	0	0	0
Diesel Generator (kW)	2 x 36	21,625	20,760	5
Battery (kWh)	0	0	0	10
Converter (kW)	0	0	0	15
Distribution Grid Capital Costs		73,076		30
Distribution Grid O&M		1,906	US\$/yr	
Distribution Losses	Fix.kWh/day	12	Variable	2%
Fuel	\$/liter	0.57		
Carbon Emissions Costs		5	US\$/ton	

CASH FLOW (US\$)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Energy Generated		95.92	97.69	99.51	101.37	103.27	105.22	107.21	109.24	111.32	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45
Energy Generated/Day		262.8	267.7	272.6	277.7	282.9	288.3	293.7	299.3	305.0	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8
Losses		17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
		6.3	6.3	6.4	6.4	6.4	6.5	6.5	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Energy Consumed		89.6	91.4	93.1	95.0	96.8	98.7	100.7	102.7	104.7	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8

EQUIPMENT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PV		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Generator		2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636
Battery Units		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Emissions		8.8	8.9	9.1	9.2	9.4	9.6	9.8	10.0	10.2	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Fuel Cons.		52,662	52,873	53,094	53,333	53,589	53,870	54,166	54,490	54,838	55,210	55,210	55,210	55,210	55,210	55,210	55,210	55,210	55,210	55,210	55,210	55,210
Specific Fuel Cons.		0.55	0.54	0.53	0.53	0.52	0.51	0.51	0.50	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49

COSTS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CAPITAL COSTS AND REPLACEMENT																						
PV Array		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Replacement		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel Generator		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Replacement		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Battery Units		-	-	-	-	20,760	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Replacement		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Converter		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Replacement		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution Grid		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-24,359

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
OPERATION COSTS																						
Fixed Service Operation	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200
Fuel Costs	30,017	30,138	30,138	30,264	30,400	30,546	30,706	30,875	31,059	31,258	31,470	31,470	31,470	31,470	31,470	31,470	31,470	31,470	31,470	31,470	31,470	31,470
Diesel Operators	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564	5,564
Technical O&M	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264	12,264
Carbon Emissions	44	45	45	45	46	47	48	49	50	51	52	52	52	52	52	52	52	52	52	52	52	52
Distribution Grid O&M	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906
INVESTMENT SUBSIDY																						
TOTAL COSTS	94,701	58,995	59,117	59,243	59,380	59,527	59,688	59,858	60,043	60,243	60,456	60,456	60,456	60,456	60,456	60,456	60,456	60,456	60,456	60,456	60,456	60,456
PRESENT VALUE	10%																					
Energy Consumed	846 MWh																					
LEVELIZED COSTS	\$/kWh																					
	\$/kWh																					
	\$/kWh																					

	Investment (\$)	Present Value (\$)			Levelized Cost	
		O&M (\$)	Replacement (\$)	Total (\$)	Consump MWh	\$/kWh
PV	0	0	0	0	846	-
Generator	21,625	25,864	47,489	0.056	846	0.056
Battery	0	0	0	0.0%	846	0.0%
Converter	0	0	0	0.0%	846	0.0%
O&M	230,101	846	230,101	0.272	846	36.7%
Fuel	262,270	846	262,270	0.310	846	41.9%
Carbon Emission	411	411	411	0.000	846	0.1%
Total RAPS	69,784	16,227	86,011	0.638	846	78.7%
Distribution Grid	91,409	509,009	626,282	0.102	846	13.7%
TOTAL			25,864	0.741	846	92.4%

REVENUES		0.561 \$/User/Month	1.85 \$./User/Month																				
	Energy Charge	0.000 \$/kWh	0 \$./kWh																				
Users Number	1.03	244	251	258	265	272	280	288	296	304	313	322	331	340	350	360	370	381	392	403	415		
Energy Vendida	MWh/yr	89.6	91.4	93.1	95.0	96.8	98.7	100.7	102.7	104.7	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8		
INGRESOS																							
Fix Charge	\$	1,641	1,689	1,736	1,783	1,830	1,884	1,937	1,991	2,045	2,106	2,166	2,227	2,287	2,355	2,422	2,489	2,563	2,637	2,711	2,792		
Energy	\$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
TOTAL INCOME	\$	1,641	1,689	1,736	1,783	1,830	1,884	1,937	1,991	2,045	2,106	2,166	2,227	2,287	2,355	2,422	2,489	2,563	2,637	2,711	2,792		

PRESENT VALUE		10%	16,924																				
		US\$																					
Income PV		3%	16,924																				
Subside		97%	609,359																				
Costs PV			626,282																				
Income		3%	16,924																				
Operation and Replacement			534,873																				
Difference			-517,949																				

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
OPERATION COSTS																							
Fixed Service Operation	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200
Fuel Costs	14,841	15,215	15,998	15,990	16,391	16,801	17,221	17,650	18,090	18,539	18,539	18,539	18,539	18,539	18,539	18,539	18,539	18,539	18,539	18,539	18,539	18,539	18,539
Diesel Operators	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855
Technical O&M	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332	4,332
Carbon Emissions	26	26	27	28	28	29	30	31	31	31	32	32	32	32	32	32	32	32	32	32	32	32	32
Distribution Grid O&M	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906
INVESTMENT SUBSIDY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL COSTS	#Value! 32,160	#Value! 32,594	#Value! 32,918	#Value! 33,311	#Value! 33,712	#Value! 34,123	#Value! 34,544	#Value! 34,974	#Value! 35,414	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864	#Value! 35,864

	10% #Value!	846 MWh	Replacement (\$)	Present Value (\$)	Total (\$)	Consump	\$/kWh	Levelized Cost	kWh	Amorty\$	\$/kWh
PRESENT VALUE											
Energy Consumed	846 MWh	846	6,400	17,213	17,213	846	0.020	#Value!	19,332	14,534	0.7495
LEVELIZED COSTS											
Investment (\$)	123,738	123,738	0	123,738	123,738	846	0.146	#Value!			
Generator	10,813	10,813	6,400	17,213	17,213	846	0.020	#Value!			
Battery	#Value!	#Value!	#Value!	#Value!	#Value!	846	#Value!	#Value!			
Converter	42,000	42,000	5,226	47,226	47,226	846	0.056	#Value!			
O&M	130,998	130,998		130,998	130,998	846	0.155	#Value!			
Fuel	144,179	144,179		144,179	144,179	846	0.170	#Value!			
Carbon Emission	250	250		250	250	846	0.000	#Value!			
Total RAPS	#Value!	#Value!	#Value!	#Value!	#Value!	846	#Value!	#Value!			
Distribution Grid	69,784	69,784	86,011	86,011	86,011	846	0.102	#Value!			
TOTAL	#Value!	#Value!	#Value!	#Value!	#Value!	846	#Value!	#Value!			

	Investment (\$)	O&M (\$)	Replacement (\$)	Present Value (\$)	Total (\$)	Consump	\$/kWh	Levelized Cost	kWh	Amorty\$	\$/kWh
REVENUES											
Fix Charge	0.561	\$/User/Month	1.85	\$/User/Month	1.85	272	280	288	313	322	331
Energy Charge	0.000	\$/kWh	0	\$/kWh	0	968	98.7	100.7	106.8	106.8	106.8
Users Number	1.03	MWh/yr	244	251	258	265	280	288	296	304	313
Energia Vendida			89.6	91.4	93.1	95.0	96.8	98.7	100.7	102.7	104.7
INGRESOS											
Fix Charge	\$	\$	1,641	1,689	1,736	1,783	1,830	1,884	1,937	1,991	2,045
Energy	\$	\$	-	-	-	-	-	-	-	-	-
TOTAL INCOME	\$	\$	1,641	1,689	1,736	1,783	1,830	1,884	1,937	1,991	2,045
PRESENT VALUE	10%	16,924									

	Income PV	Subside	Costs PV	Income	Operation and Replacements	Difference
Income PV	16,924	#Value!	#Value!	16,924	#Value!	#Value!
Subside		#Value!	#Value!			
Costs PV		#Value!	#Value!			
Income	16,924	#Value!	#Value!	16,924	#Value!	#Value!
Operation and Replacements						
Difference						

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
OPERATION COSTS																							
Fixed Service Operation	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200
Fuel Costs	9,452	9,827	10,210	10,602	11,003	11,413	11,833	12,262	12,701	13,151	13,151	13,151	13,151	13,151	13,151	13,151	13,151	13,151	13,151	13,151	13,151	13,151	13,151
Diesel Operators	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855	1,855
Technical O&M	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055	3,055
Carbon Emissions	16	17	18	18	19	20	20	21	22	22	23	23	23	23	23	23	23	23	23	23	23	23	23
Distribution Grid O&M	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906
INVESTMENT SUBSIDY																							
TOTAL COSTS	715,583	454,639	25,484	26,244	27,038	27,449	27,869	28,299	28,739	29,190	29,190	29,190	29,190	29,190	29,190	29,190	29,190	29,190	29,190	29,190	29,190	29,190	29,190

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
PRESENT VALUE																							
Energy Consumed	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846	846
LEVELIZED COSTS																							
\$/kWh	0.846																						
\$/kWh	2.79																						

	Present Value (\$)			Levelized Cost		
	Investment (\$)	O&M (\$)	Replacement (\$)	Total (\$)	Consump MWh	\$/kWh
PV	247,476	0	247,476	247,476	846	0.293
Generator	10,813	2,372	13,185	13,185	846	0.016
Battery	74,400	28,684	103,084	103,084	846	0.122
Converter	42,000	5,226	47,226	47,226	846	0.056
O&M		120,126	120,126	120,126	846	0.142
Fuel		98,303	98,303	98,303	846	0.116
Carbon Emission		170	170	170	846	0.000
Total RAPS		69,784	69,784	69,784	846	0.082
Distribution Grid		16,227	16,227	16,227	846	0.102
TOTAL	444,473	234,826	36,282	715,582	846	1.591

REVENUES		0.561 \$/user/month	1.85 \$/user/month	0.000 \$/kWh	0 \$/kWh
Fix Charge		244	244	244	244
Energy Charge		89.6	89.6	89.6	89.6
Users Number	1.03	244	244	244	244
Energia Vendida	MWh/yr	89.6	89.6	89.6	89.6
INGRESOS					
Fix Charge	\$	1,641	1,689	1,736	1,783
Energy	\$	—	—	—	—
TOTAL INCOME	\$	1,641	1,689	1,736	1,783

PRESENT VALUE		10%	16,924
Income PV	US\$		
Subside	16,924	2%	
Costs PV	698,659	98%	
Income	715,583	6%	
Operation and Replacement	\$ 271,109		
Difference	-254,186		

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
OPERATION COSTS																						
Fixed Service Operation		9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200
Fuel Costs		2,678	3,053	3,436	3,828	4,229	4,639	5,058	5,488	4,464	4,914	4,914	4,914	4,914	4,914	4,914	4,914	4,914	4,914	4,914	4,914	4,914
Diesel Operators		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Technical O&M		1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266	1,266
Carbon Emissions		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Distribution Grid O&M		1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906
INVESTMENT SUBSIDY																						
TOTAL COSTS	749,914	15,055	15,430	15,814	16,207	16,608	17,019	17,439	17,869	16,844	17,295	17,295	17,295	17,295	17,295	17,295	17,295	17,295	17,295	17,295	17,295	17,295
PRESENT VALUE	10%	930,514																				
Energy Consumed		846 MWh																				
LEVELIZED COSTS		1.100																				
		\$/kWh																				
		\$/kWh																				

	Present Value (\$)			Levelized Cost			
	Investment (\$)	O&M (\$)	Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh
PV	470,204		0	470,204	846	0.556	50.5%
Generator	10,813		0	10,813	846	0.013	1.2%
Battery	125,760		48,486	174,246	846	0.206	18.7%
Converter	57,000		7,092	64,092	846	0.076	6.9%
O&M		89,103		89,103	846	0.105	9.6%
Fuel		35,983		35,983	846	0.043	3.9%
Carbon Emission		62		62	846	0.000	0.0%
Total RAPS		844,503		844,503	846	0.999	90.8%
Distribution Grid	69,784		16,227	86,011	846	0.102	9.2%
TOTAL	733,561	141,375	55,578	930,514	846	1.101	100.0%

	kWh	Amunty\$	\$/kWh
	19,392	55,230	2.8481

	Investment (\$)	O&M (\$)	Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh
Fix Charge							
Energy Charge							
Users Number	1.03	244	251	258	272	280	288
Energia Vendida	MWh/yr	89.6	91.4	93.1	96.8	98.7	100.7
INGRESOS							
Fix Charge	\$	1,641	1,689	1,736	1,830	1,884	1,937
Energy	\$	-	-	-	-	-	-
TOTAL INCOME	\$	1,641	1,689	1,736	1,830	1,884	1,937
PRESENT VALUE	10%	16,924					

	0.561 \$/user/month	1.85 \$/user/month	0.000 \$/kWh	0. \$/kWh
Income PV				
Subside				
Costs PV				
Income				
Operation and Replacement				
Difference				

	US\$	2%	98%	9%	196,953	-180,029
Income PV	16,924					
Subside	913,591					
Costs PV	930,514					
Income	16,924					
Operation and Replacement	196,953					
Difference	-180,029					

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	2004	2005	2006	2007	2007	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
OPERATION COSTS																						
Fixed Service Operation	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200	9,200
Fuel Costs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diesel Operators	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Technical O&M	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Carbon Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distribution Grid O&M	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906
Investment Subsidy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL COSTS	1,180,003	1,025,856	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003	1,180,003
PRESENT VALUE	10%	1,180,003																				
Energy Consumed		846 MWh																				
LEVELIZED COSTS		\$/kWh	1.395																			
		\$/kWh	4.60																			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh	\$/kWh		
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh			
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh			
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh			
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh			
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh			
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh			
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

	Investment (\$)	O&M (\$)	Present Value (\$)		Levelized Costs					
			Replacement (\$)	Total (\$)	Consump MWh	\$/kWh	\$/kWh			
PV	692,933	0	0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0	0	0	0	846	-	0.0%			
Battery	183,600	70,786	70,786	254,386	846	0.301	21.6%			
Converter	57,000	7,092	7,092	64,092	846	0.076	5.4%			
O&M		82,582		82,582	846	0.098	7.0%			
Fuel		0		0	846	-	0.0%			
Carbon Emission		0		0	846	-	0.0%			
Total RAPS				1,093,992	5922	1.2934	92.7%			
Distribution Grid	69,784	16,227		86,011	846	0.102	7.3%			
TOTAL	1,003,317	84,209	77,878	1,180,004	6768	1.396	100.0%			

Annex 2

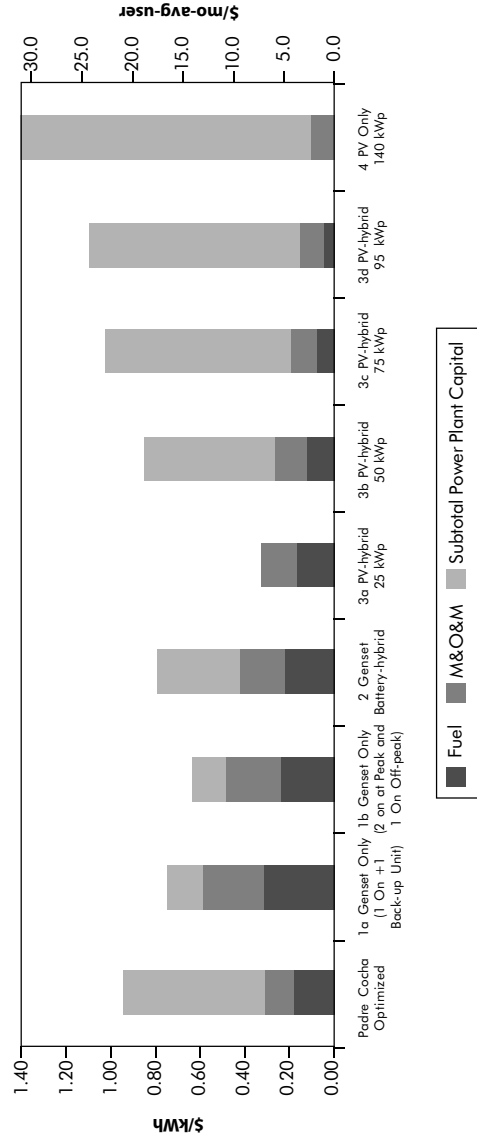
Levelized cost comparison
sustainability analysis for different
options, discount rates and
fuel prices

Levelized Cost Analysis of Sustainability of Different System Configurations

Condition1 0057:

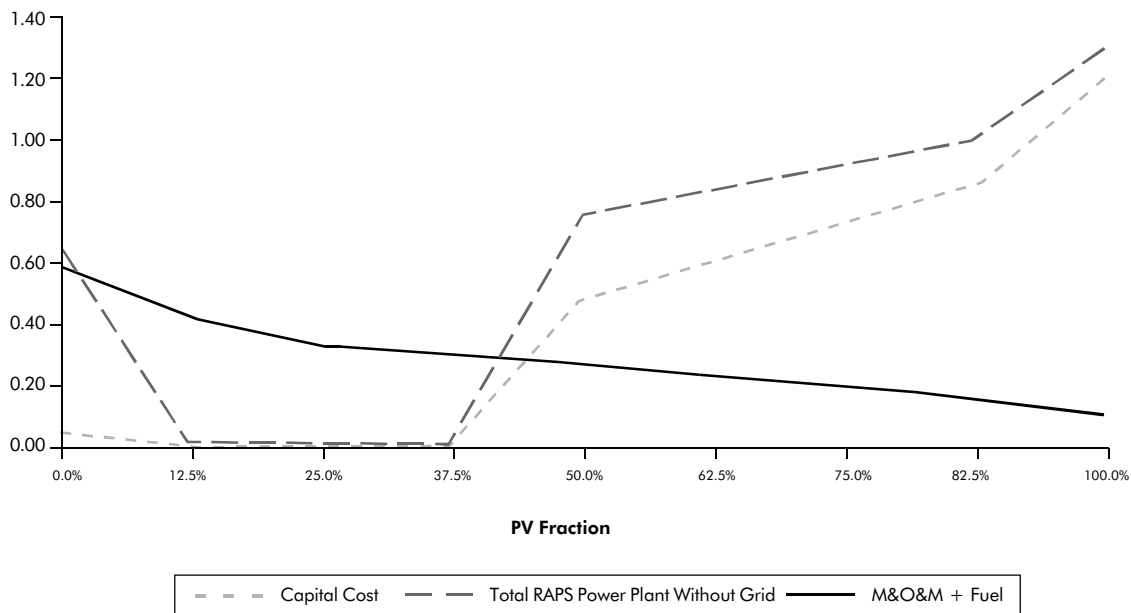
Discount Rate Idealized	\$/liter	0.57
Net Demand (kWh/day)	hp	4.00
10%		245

	PV Array kW	Genset kW	Battery kWh	Power Conditioning Inverter/Charger	Total Present Costs US\$	Levelized Costs, Breakdown \$/kWh							Total Capital Incl. Grid	Total			
						PV	Generator	Battery	Power Conditioning	M&O&M	Fuel	Carbon Emissions			Subtotal Power Plant Capital	Subtotal Power Plant	Distribution Grid Capital
Padre Cocha Optimized	30	1 x 128	360	80 / 80 kW	899,142	0.148	0.066	0.094	0.167	0.127	0.174	0.000	0.475	0.777	0.161	0.636	0.937
1a Genset Only (1 on + 1 Back-up Unit)		2 x 36 kW			626,282	-	0.056	-	-	0.272	0.310	0.000	0.056	0.639	0.102	0.158	0.740
1b Genset Only (2 On at Peak and 1 On Off-peak)		2 x 18 kW			535,544	-	0.054	-	-	0.240	0.237	0.000	0.054	0.531	0.102	0.156	0.633
2 Genset-battery-hybrid		1 x 36 kW	310	10/20 kW	669,287	-	0.025	0.198	0.056	0.186	0.225	0.000	0.278	0.690	0.102	0.380	0.791
3a PV-hybrid 25 kWp	25	1 x 36 kW	310	10/20 kW	652,699	0.146	0.020	0.122	0.056	0.155	0.170	0.000	0.670	0.344	0.102	0.446	0.772
3b PV-hybrid 50 kWp	50	1 x 36 kW	310	10/20 kW	715,583	0.293	0.016	0.122	0.056	0.142	0.116	0.000	0.486	0.744	0.102	0.588	0.846
3c PV-hybrid 75 kWp	75	1 x 36 kW	524	30/10 kW	862,196	0.439	0.013	0.206	0.076	0.110	0.074	0.000	0.733	0.918	0.102	0.835	1.019
3d PV-hybrid 95 kWp	95	1 x 36 kW	524	30/10 kW	930,514	0.556	0.013	0.206	0.076	0.105	0.043	0.000	0.850	0.998	0.102	0.952	1.100
4 PV Only 140 kWp	140		765	30 kW	1,180,003	0.819	-	0.301	0.076	0.098	-	-	1.196	1.293	0.102	1.297	1.395



	<i>PV Fraction</i>	<i>Capital Cost</i>	<i>M&O&M + Fuel</i>	<i>Total RAPS Power Plant Without Grid</i>
Genset Only	0.0%	0.056	0.582	0.638
	12.5%	0.236	0.412	0.648
PV 25 kWp	25.0%	0.344	0.325	0.670
	37.5%	0.415	0.292	0.707
PV 50 kWp	50.0%	0.486	0.258	0.744
	62.5%	0.610	0.221	0.831
PV 75 kWp	75.0%	0.733	0.184	0.917
PV 95 kWp	82.5%	0.850	0.148	0.998
PV Only	100.0%	1.196	0.098	1.294

Levelized Cost vs. PV Fraction

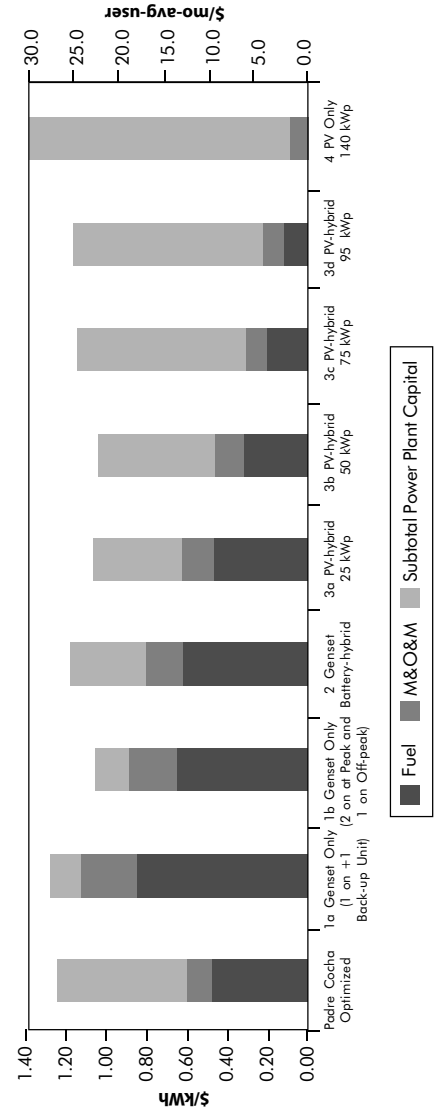


Levelized Cost Analysis of Sustainability of Different System Configurations

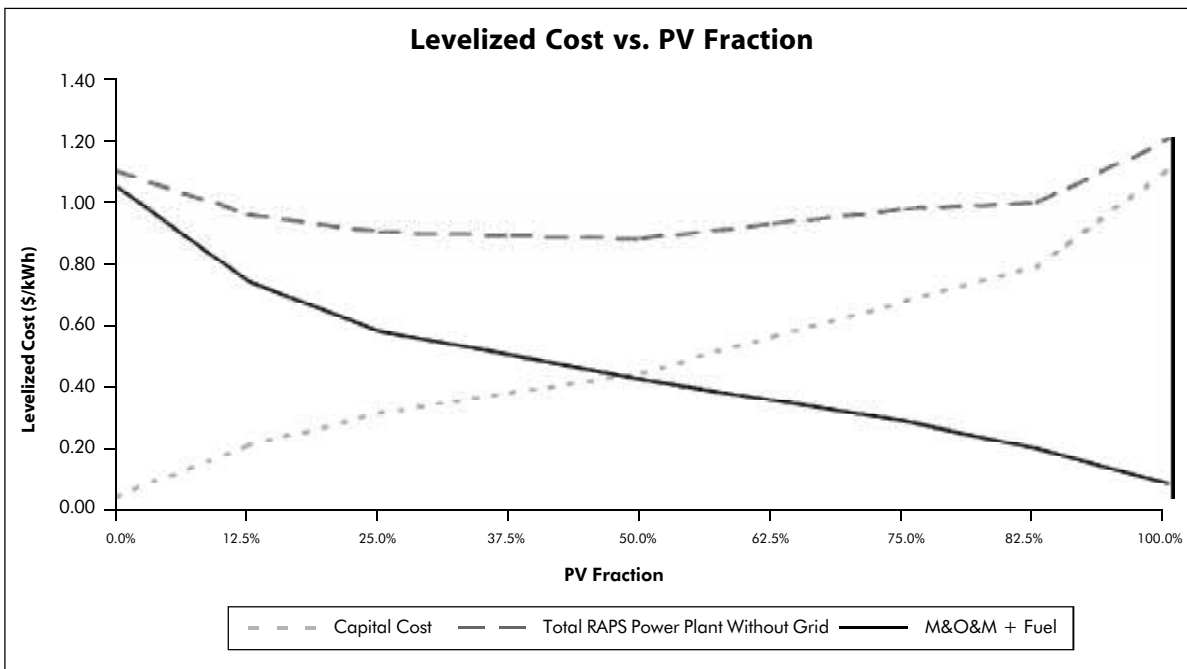
Condition 10158:

Discount Rate Idealized	\$/liter	1.58	Net Demand (kWh/day)	245	hp	4.00
		10%				

	PV Array kWp	Genset kW	Battery kWh	Power Conditioning Inverter/Charger	Total Present Costs US\$	Levelized Costs, Breakdown \$/kWh										Total Capital Incl. Grid	Total
						PV	Genset Plant	Battery	Power Conditioning	M&O&M	Fuel	Subtotal Power Plant Capital	Subtotal Power Plant	Distribution Grid Capital			
Padre Cocha Optimized	30	1 x 128	360	80/80 kW	1,159,692	0.148	0.066	0.094	0.167	0.127	0.482	0.475	1.085	0.161	1.245		
1a Genset Only (1 On + 1 Back-up Unit)	2 x 36 kW	2 x 36 kW			1,089,501	-	0.056	-	-	0.272	0.858	0.056	1.186	0.102	1.288		
1b Genset Only (2 On at Peak and 1 On Off-peak)	2 x 18 kW	2 x 18 kW			889,205	-	0.054	-	-	0.240	0.655	0.054	0.950	0.102	1.051		
2 Genset-battery-hybrid	1 x 36 kW	1 x 36 kW	310	10/20 kW	1,004,959	-	0.025	0.198	0.056	0.186	0.622	0.278	1.086	0.102	1.188		
3a PV/hybrid 25 kWp	25	1 x 36 kW	310	10/20 kW	907,346	0.146	0.020	0.122	0.056	0.155	0.472	0.344	0.971	0.102	1.073		
3b PV/hybrid 50 kWp	50	1 x 36 kW	310	10/20 kW	889,205	0.293	0.016	0.122	0.056	0.142	0.321	0.486	0.950	0.102	1.051		
3c PV/hybrid 75 kWp	75	1 x 36 kW	524	30/10 kW	972,156	0.439	0.013	0.206	0.076	0.110	0.204	0.733	1.048	0.102	1.149		
3d PV/hybrid 95 kWp	95	1 x 36 kW	524	30/10 kW	994,066	0.556	0.013	0.206	0.076	0.105	0.118	0.850	1.074	0.102	1.175		
4 PV Only 140 kWp	140		765	30 kW	1,180,003	0.819	-	0.301	0.076	0.098	-	1.196	1.293	0.102	1.395		



	<i>PV Fraction</i>	<i>Capital Cost</i>	<i>M&O&M + Fuel</i>	<i>Total RAPS Power Plant Without Grid</i>
Genset Only	0.0%	0.056	1.130	1.186
	12.5%	0.236	0.798	1.034
PV 25 kWp	25.0%	0.344	0.626	0.971
	37.5%	0.415	0.545	0.960
PV 50 kWp	50.0%	0.486	0.464	0.949
	62.5%	0.610	0.389	0.998
PV 75 kWp	75.0%	0.733	0.314	1.048
PV 95 kWp	82.5%	0.850	0.223	1.073
PV Only	100.0%	1.196	0.098	1.293

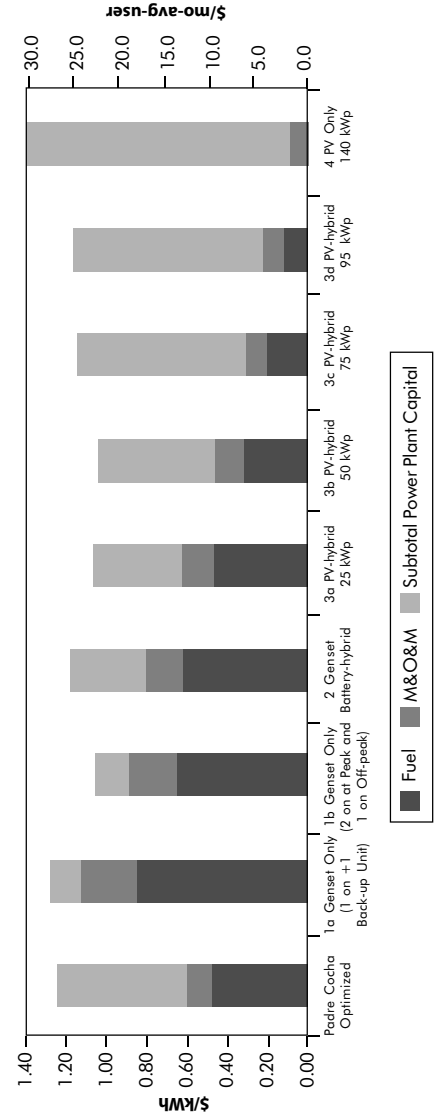


Levelized Cost Analysis of Sustainability of Different System Configurations

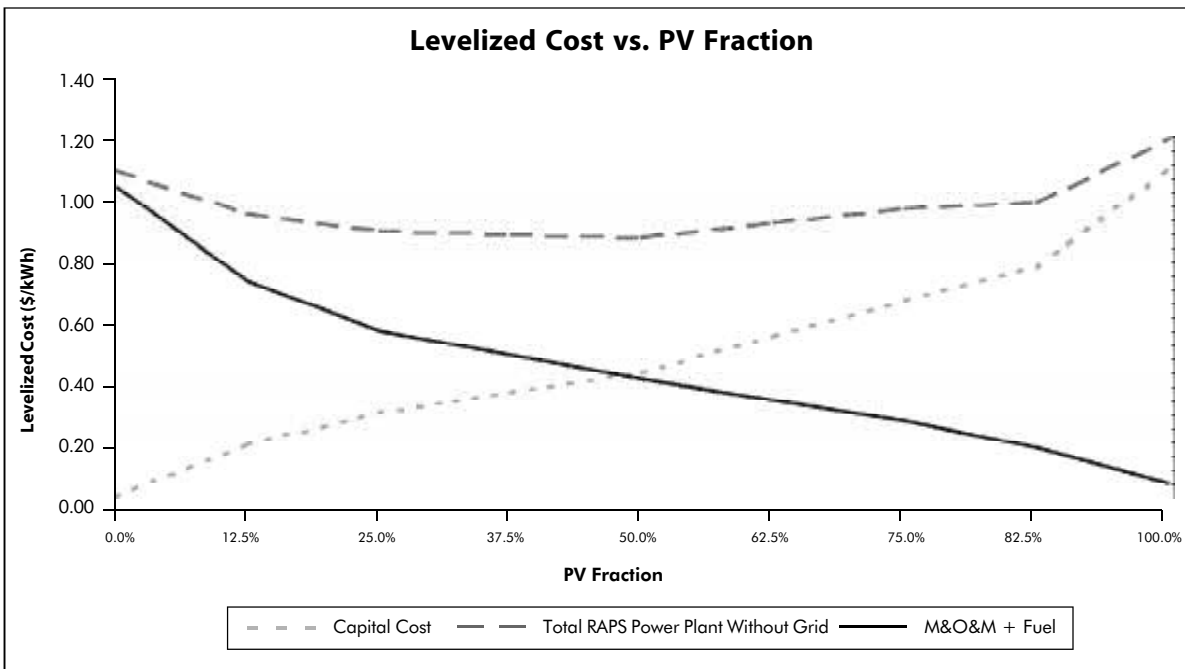
Condition10158:

Discount Rate Idealized	\$/liter	Net Demand (kWh/day)	hp
10%	1.58	245	4.00

	PV Array kWp	Genset kW	Battery kWh	Power Conditioning Inverter/Charger	Total Present Costs US\$	Levelized Costs, Breakdown \$/kWh										Total
						PV	Genset	Battery	Power Conditioning	M&O&M	Fuel	Subtotal Power Plant Capital	Subtotal Power Plant	Distribution Grid Capital	Total Capital Incl. Grid	
Padre Cocha Optimized	30	1 x 128	360	80/80 kW	1,159,692	0.148	0.066	0.094	0.167	0.127	0.482	0.475	1.085	0.161	0.636	1.245
1a Genset Only (1 On + 1 Back-up Unit)		2 x 36 kW			1,089,501	-	0.056	-	-	0.272	0.858	0.056	1.186	0.102	0.158	1.288
1b Genset Only (2 On at Peak and 1 On Off-peak)		2 x 18 kW			889,205	-	0.054	-	-	0.240	0.655	0.054	0.950	0.102	0.156	1.051
2 Genset-battery-hybrid		1 x 36 kW	310	10/20 kW	1,004,959	-	0.025	0.198	0.056	0.186	0.622	0.278	1.086	0.102	0.380	1.188
3a PV-hybrid 25 kWp	25	1 x 36 kW	310	10/20 kW	907,346	0.146	0.020	0.122	0.056	0.155	0.472	0.344	0.971	0.102	0.446	1.073
3b PV-hybrid 50 kWp	50	1 x 36 kW	310	10/20 kW	889,205	0.293	0.016	0.122	0.056	0.142	0.321	0.486	0.950	0.102	0.388	1.051
3c PV-hybrid 75 kWp	75	1 x 36 kW	524	30/10 kW	972,156	0.439	0.013	0.206	0.076	0.110	0.204	0.733	1.048	0.102	0.835	1.149
3d PV-hybrid 95 kWp	95	1 x 36 kW	524	30/10 kW	994,066	0.556	0.013	0.206	0.076	0.105	0.118	0.850	1.074	0.102	0.952	1.175
4 PV Only 140 kWp	140		765	30 kW	1,180,003	0.819	-	0.301	0.076	0.098	-	1.196	1.293	0.102	1.297	1.395



	<i>PV Fraction</i>	<i>Capital Cost</i>	<i>M&O&M + Fuel</i>	<i>Total RAPS Power Plant Without Grid</i>
Genset Only	0.0%	0.056	1.130	1.186
	12.5%	0.236	0.798	1.034
PV 25 kWp	25.0%	0.344	0.626	0.971
	37.5%	0.415	0.545	0.960
PV 50 kWp	50.0%	0.486	0.464	0.949
	62.5%	0.610	0.389	0.998
PV 75 kWp	75.0%	0.733	0.314	1.048
PV 95 kWp	82.5%	0.850	0.223	1.073
PV Only	100.0%	1.196	0.098	1.293

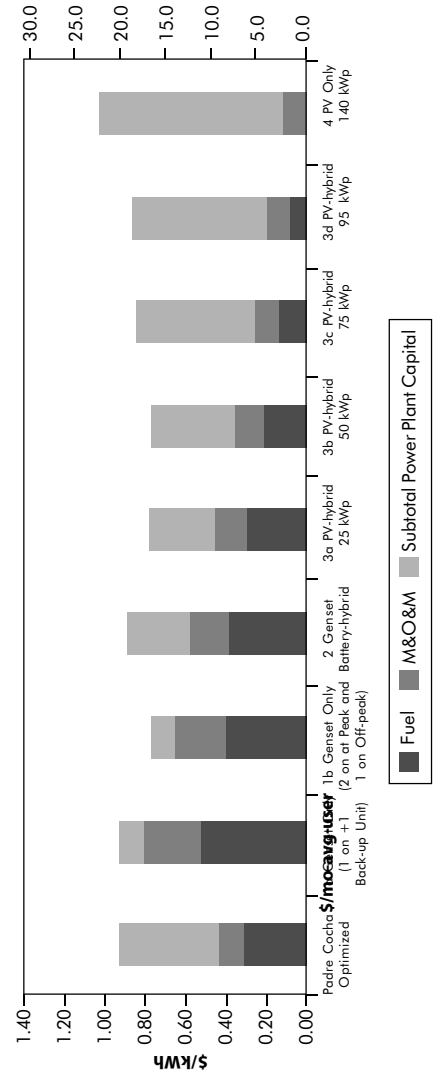


Levelized Cost Analysis of Sustainability of Different System Configurations

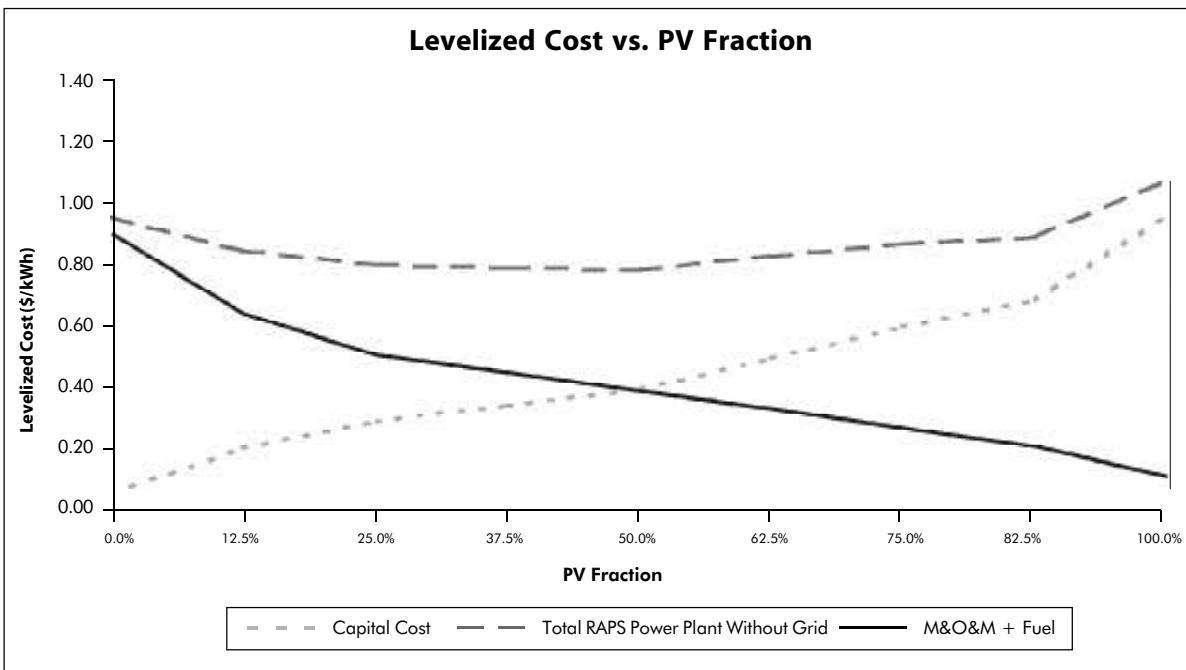
Condition 05092:

Discount Rate Idealized	\$/liter	0.925
Net Demand (kWh/day)	hp	4.00
5%		245

	Levelized Costs, Breakdown \$/kWh										Total				
	PV Array kW	Genset kW	Battery kWh	Power Conditioning Inverter/Charger	Total Present Costs US\$	PV	Generator	Battery Inverter/Charger	Power Conditioning	M&O&M		Fuel	Subtotal Power Plant Capital	Subtotal Power Plant	Distribution Grid Capital
Padre Cocha Optimized	30	1 x 128	360	80/80 kW	1,181,547	0.095	0.077	0.074	0.121	0.121	0.285	0.367	0.773	0.108	0.881
1a Genset Only (1 On + 1 Back-up unit)		2 x 36 kW			1,111,794	-	0.048	-	-	0.268	0.498	0.048	0.815	0.070	0.885
1b Genset Only (2 On at Peak and 1 On Off-peak)		2 x 18 kW			925,728	-	0.047	-	-	0.236	0.382	0.047	0.667	0.070	0.737
2 Genset-battery-hybrid		1 x 36 kW	310	10/20 kW	1,068,120	-	0.021	0.170	0.040	0.184	0.364	0.231	0.780	0.070	0.850
3a PV-hybrid 25 kWp	25	1 x 36 kW	310	10/20 kW	938,521	0.094	0.016	0.096	0.040	0.153	0.278	0.246	0.677	0.070	0.747
3b PV-hybrid 50 kWp	50	1 x 36 kW	310	10/20 kW	924,939	0.188	0.011	0.096	0.040	0.140	0.191	0.335	0.666	0.070	0.736
3c PV-hybrid 75 kWp	75	1 x 36 kW	524	30/10 kW	1,015,841	0.282	0.009	0.161	0.054	0.109	0.123	0.506	0.738	0.070	0.808
3d PV-hybrid 95 kWp	95	1 x 36 kW	524	30/10 kW	1,038,226	0.357	0.009	0.161	0.054	0.104	0.071	0.582	0.756	0.070	0.826
4 PV Only 140 kWp	140		765	30 kW	1,234,819	0.526	-	0.236	0.054	0.096	-	0.816	0.912	0.070	0.983



	<i>PV Fraction</i>	<i>Capital Cost</i>	<i>M&O&M + Fuel</i>	<i>Total RAPS Power Plant Without Grid</i>
Genset Only	0.0%	0.048	0.766	0.814
	12.5%	0.173	0.544	0.717
PV 25 kWp	25.0%	0.246	0.430	0.676
	37.5%	0.290	0.381	0.671
PV 50 kWp	50.0%	0.335	0.331	0.666
	62.5%	0.421	0.281	0.702
PV 75 kWp	75.0%	0.506	0.232	0.738
PV 95 kWp	82.5%	0.582	0.174	0.756
PV Only	100.0%	0.816	0.096	0.912



List of Technical Reports

Region/Country	Activity/Report Title	Date	Number
SUB-SAHARAN AFRICA (AFR)			
Africa	Power Trade in Nile Basin Initiative Phase II (CD Only): Part I: Minutes of the High-level Power Experts Meeting; and Part II: Minutes of the First Meeting of the Nile Basin Ministers Responsible for Electricity	04/05	067/05
	Introducing Low-cost Methods in Electricity Distribution Networks	10/06	104/06
Cameroon	Decentralized Rural Electrification Project in Cameroon	01/05	087/05
Chad	Revenue Management Seminar. Oslo, June 25-26, 2003. (CD Only)	06/05	075/05
Côte d'Ivoire	Workshop on Rural Energy and Sustainable Development, January 30-31, 2002. (<i>Atelier sur l'Énergie en régions rurales et le Développement durable 30-31, janvier 2002</i>)	04/05	068/05
Ethiopia	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Ethiopia - Action Plan	12/03	038/03
	Sub-Saharan Petroleum Products Transportation Corridor: Analysis and Case Studies	03/03	033/03
	Phase-Out of Leaded Gasoline in Sub-Saharan Africa	04/02	028/02
	Energy and Poverty: How can Modern Energy Services Contribute to Poverty Reduction	03/03	032/03
East Africa	Sub-Regional Conference on the Phase-out Leaded Gasoline in East Africa. June 5-7, 2002	11/03	044/03
Ghana	Poverty and Social Impact Analysis of Electricity Tariffs	12/05	088/05
	Women Enterprise Study: Developing a Model for Mainstreaming Gender into Modern Energy Service Delivery	03/06	096/06
	Sector Reform and the Poor: Energy Use and Supply in Ghana	03/06	097/06
Kenya	Field Performance Evaluation of Amorphous Silicon (a-Si) Photovoltaic Systems in Kenya: Methods and Measurement in Support of a Sustainable Commercial Solar Energy Industry	08/00	005/00
	The Kenya Portable Battery Pack Experience: Test Marketing an Alternative for Low-Income Rural Household Electrification	12/01	05/01
Malawi	Rural Energy and Institutional Development	04/05	069/05
Mali	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Mali - Action Plan (<i>Élimination progressive de l'essence au plomb dans les pays importateurs de pétrole en Afrique subsaharienne Le cas du Mali — Mali Plan d'action</i>)	12/03	041/03
Mauritania	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Mauritania - Action Plan (<i>Élimination progressive de l'essence au plomb dans les pays importateurs de pétrole en Afrique subsaharienne Le cas de la Mauritanie – Plan d'action.</i>)	12/03	040/03

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Nigeria	Phase-Out of Leaded Gasoline in Nigeria	11/02	029/02
	Nigerian LP Gas Sector Improvement Study	03/04	056/04
	Taxation and State Participation in Nigeria's Oil and Gas Sector	08/04	057/04
Regional	Second Steering Committee: The Road Ahead. Clean Air Initiative In Sub-Saharan African Cities. Paris, March 13-14, 2003	12/03	045/03
	Lead Elimination from Gasoline in Sub-Saharan Africa. Sub-regional Conference of the West-Africa group. Dakar, Senegal March 26-27, 2002 (<i>Deuxième comité directeur : La route à suivre - L'initiative sur l'assainissement de l'air. Paris, le 13-14 mars 2003</i>)	12/03	046/03
	1998-2002 Progress Report. The World Bank Clean Air Initiative in Sub-Saharan African Cities. Working Paper #10 (Clean Air Initiative/ESMAP)	02/02	048/04
	Landfill Gas Capture Opportunity in Sub Saharan Africa	06/05	074/05
	The Evolution of Enterprise Reform in Africa: From State-owned Enterprises to Private Participation in Infrastructure-and Back?	11/05	084/05
Senegal	Regional Conference on the Phase-Out of Leaded Gasoline in Sub-Saharan Africa (<i>Elimination du plomb dans l'essence en Afrique subsaharienne Conference sous regionales du Groupe Afrique de l'Ouest Dakar, Sénégal. March 26-27, 2002.</i>)	03/02	022/02
	Alleviating Fuel Adulteration Practices in the Downstream Oil Sector in Senegal	12/03	046/03
	<i>Maximisation des Retombées de l'Electricité en Zones Rurales, Application au Cas du Sénégal</i>	09/05	079/05
		03/07	
South Africa	South Africa Workshop: People's Power Workshop.	12/04	064/04
Swaziland	Solar Electrification Program 2001 2010: Phase 1: 2001 2002 (Solar Energy in the Pilot Area)	12/01	019/01
Tanzania	Mini Hydropower Development Case Studies on the Malagarasi, Muhuwesi, and Kikuletwa Rivers Volumes I, II, and III	04/02	024/02
	Phase-Out of Leaded Gasoline in Oil Importing Countries of Sub-Saharan Africa: The Case of Tanzania - Action Plan	12/03	039/03
Uganda	Report on the Uganda Power Sector Reform and Regulation Strategy Workshop	08/00	004/00
WEST AFRICA (AFR)			
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EAST ASIA AND PACIFIC (EAP)			
Cambodia	Efficiency Improvement for Commercialization of the Power Sector	10/02	031/02
	TA For Capacity Building of the Electricity Authority	09/05	076/05
China	Assessing Markets for Renewable Energy in Rural Areas of Northwestern China	08/00	003/00
	Technology Assessment of Clean Coal Technologies for China Volume I-Electric Power Production	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume II-Environmental and Energy Efficiency Improvements for Non-power Uses of Coal	05/01	011/01
	Technology Assessment of Clean Coal Technologies for China Volume III-Environmental Compliance in the Energy Sector: Methodological Approach and Least-Cost Strategies	12/01	011/01
	Policy Advice on Implementation of Clean Coal Technology	09/06	104/06
	Scoping Study for Voluntary Green Electricity Schemes in Beijing and Shanghai	09/06	105/06
Papua New Guinea	Energy Sector and Rural Electrification Background Note	03/06	102/06
Philippines	Rural Electrification Regulation Framework. (CD Only)	10/05	080/05
Thailand	DSM in Thailand: A Case Study	10/00	008/00
	Development of a Regional Power Market in the Greater Mekong Sub-Region (GMS)	12/01	015/01

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	Renewable Energy Action Plan	03/02	021/02
	Vietnam's Petroleum Sector: Technical Assistance for the Revision of the Existing Legal and Regulatory Framework	03/04	053/04
	Vietnam Policy Dialogue Seminar and New Mining Code	03/06	098/06
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	Integrating Gender in Energy Provision: The Case of Bangladesh	04/04	054/04
	Opportunities for Women in Renewable Energy Technology Use In Bangladesh, Phase I	04/04	055/04
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Macedonia	Elements of Energy and Environment Strategy in Macedonia	03/06	100/06
Poland	Poland (URE): Assistance for the Implementation of the New Tariff Regulatory System: Volume I, Economic Report, Volume II, Legal Report	03/06	101/06
	Russia Pipeline Oil Spill Study	03/03	034/03
Uzbekistan	Energy Efficiency in Urban Water Utilities in Central Asia	10/05	082/05
MIDDLE EASTERN AND NORTH AFRICA REGION (MENA)			
Turkey	Gas Sector Strategy	05/07	114/07
Regional	Roundtable on Opportunities and Challenges in the Water, Sanitation And Power Sectors in the Middle East and North Africa Region. Summary Proceedings, May 26-28, 2003. Beit Mary, Lebanon. (CD)	02/04	049/04
	Morocco	Amélioration de l'Efficacité Energie: Environnement de la Zone Industrielle de Sidi Bernoussi, Casablanca	12/05
LATIN AMERICA AND THE CARIBBEAN REGION (LCR)			
Brazil	Background Study for a National Rural Electrification Strategy: Aiming for Universal Access	03/05	066/05
	How do Peri-Urban Poor Meet their Energy Needs: A Case Study of Caju Shantytown, Rio de Janeiro	02/06	094/06
	Integration Strategy for the Southern Cone Gas Networks	05/07	113/07
Bolivia	Country Program Phase II: Rural Energy and Energy Efficiency Report on Operational Activities	05/05	072/05
	Bolivia: National Biomass Program. Report on Operational Activities	05/07	115/07
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	Technical Assistance for Long-Term Program for Renewable Energy Development	02/06	093/06
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	Sustainable Charcoal Production in the Chinandega Region	04/05	071/05
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	Estudio de Casos: Bolivia, Colombia, Ecuador y Perú	03/02	023/02
	Latin American and Caribbean Refinery Sector Development Report - Volumes I and II	08/02	026/02
	The Population, Energy and Environmental Program (EAP) (English and Spanish)	08/02	027/02
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	Mini-Grid Design Manual	09/00	007/00
	Photovoltaic Applications in Rural Areas of the Developing World	11/00	009/00
	Subsidies and Sustainable Rural Energy Services: Can we Create Incentives Without Distorting Markets?	12/00	010/00
	Sustainable Woodfuel Supplies from the Dry Tropical Woodlands	06/01	013/01
	Key Factors for Private Sector Investment in Power Distribution	08/01	014/01
	Cross-Border Oil and Gas Pipelines: Problems and Prospects	06/03	035/03
	Monitoring and Evaluation in Rural Electrification Projects: A Demand-Oriented Approach	07/03	037/03
	Household Energy Use in Developing Countries: A Multicountry Study	10/03	042/03
	Knowledge Exchange: Online Consultation and Project Profile from South Asia Practitioners Workshop. Colombo, Sri Lanka,	12/03	043/03

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	Petroleum Revenue Management Workshop	03/04	051/04
	Operating Utility DSM Programs in a Restructuring Electricity Sector	12/05	058/04
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	Gender in Sustainable Energy Regional Workshop Series: Mesoamerican Network on Gender in Sustainable Energy (GENES) Winrock and ESMAP	12/04	062/04
	Women in Mining Voices for a Change Conference (CD Only)	12/04	063/04
	Renewable Energy Potential in Selected Countries: Volume I: North Africa, Central Europe, and the Former Soviet Union, Volume II: Latin America	04/05	070/05
	Renewable Energy Toolkit Needs Assessment	08/05	077/05
	Portable Solar Photovoltaic Lanterns: Performance and Certification Specification and Type Approval	08/05	078/05
	Crude Oil Prices Differentials and Differences in Oil Qualities: A Statistical Analysis	10/05	081/05
	Operating Utility DSM Programs in a Restructuring Electricity Sector	12/05	086/05
	Sector Reform and the Poor: Energy Use and Supply in Four Countries: Botswana, Ghana, Honduras and Senegal	03/06	095/06



THE WORLD BANK



Energy Sector Management Assistance Program (ESMAP)
1818 H Street, NW
Washington, DC 20433 USA
Tel: 1.202.458.2321
Fax: 1.202.522.3018
Internet: www.esmap.org
E-mail: esmap@worldbank.org