ESMAP Technical Paper 111/07
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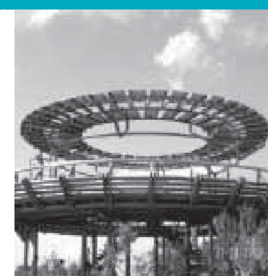
Solar-diesel Hybrid Options for the Peruvian Amazon

Lessons Learned from Padre Cocha



ESMAP

Energy Sector Management Assistance Program

Solar-diesel Hybrid Options for the Peruvian Amazon Lessons Learned from Padre Cocha

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Lessons Learned from Padre Cocha

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Energy Sector Management Assistance Program (ESMAP)

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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

Acknowledgments

This summary report was written by Ms. Xiaodong Wang, the Task Manager of the study, and Mr. Xavier Vallvé. It presents a consolidated synopsis of key conclusions of the two subreports: (1) Financial and Institutional Evaluation prepared by Mr. Xavier Vallvé, Mr. Santiago González and Mr. Pol Arranz; and (2) Technical and Economic Evaluation prepared by Mr. Ismael Aragón Castro and Mr. Eduardo H. Zolezzi.

We would like to thank Mr. Marcos Alegre from ILZRO/RAPS and Mr. Jerry Cole from ILZRO for providing valuable data and information on the ILZRO/RAPS system, Mr. Douglas Barnes for his advice and Ms. Norma Adams for her editorial support. Special thanks are due to Ms. Dominique Lallement for her support. Funding from Energy Sector Management Assistance Program (ESMAP), World Bank, is greatly appreciated. Last, special thanks to Ms. Ananda Swaroop and Ms. Marjorie K. Araya for editing, producing and disseminating the final report.

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*	*No*	*%*	*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

	S/./Month	*US$/Month*	*S/./Year*	*US$/Year*	*% of Total*
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

	Present Value ($)				*Levelized Cost*	
Component	*Investment*	*O&M*	*Replacement*	*Total*	*$/kWh*	*%*
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	0
	1b. Alternative Peak and Off-peak		2 x 18 kW	0	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

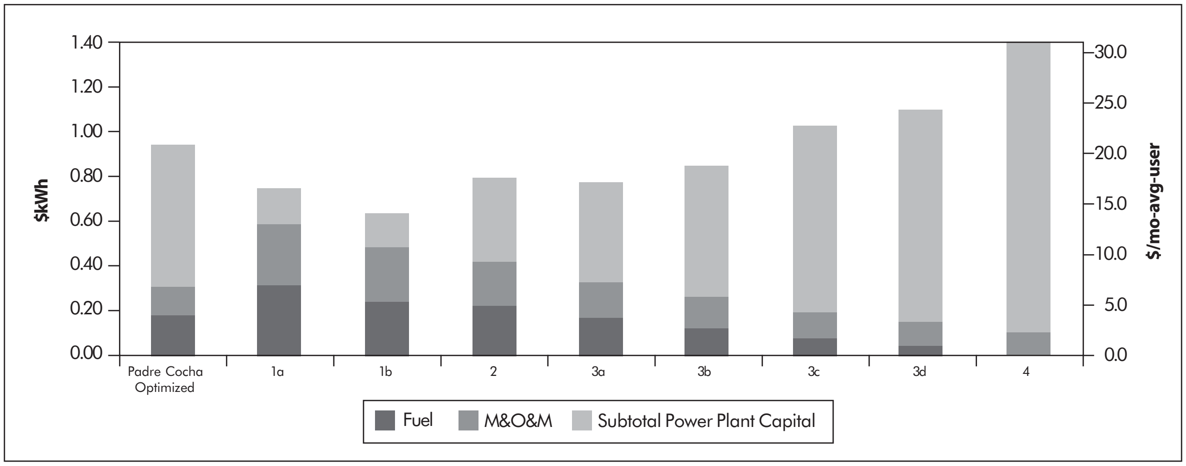


Table 3.3: Comparison between Levelized Energy Costs and Costs per Contract

	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)

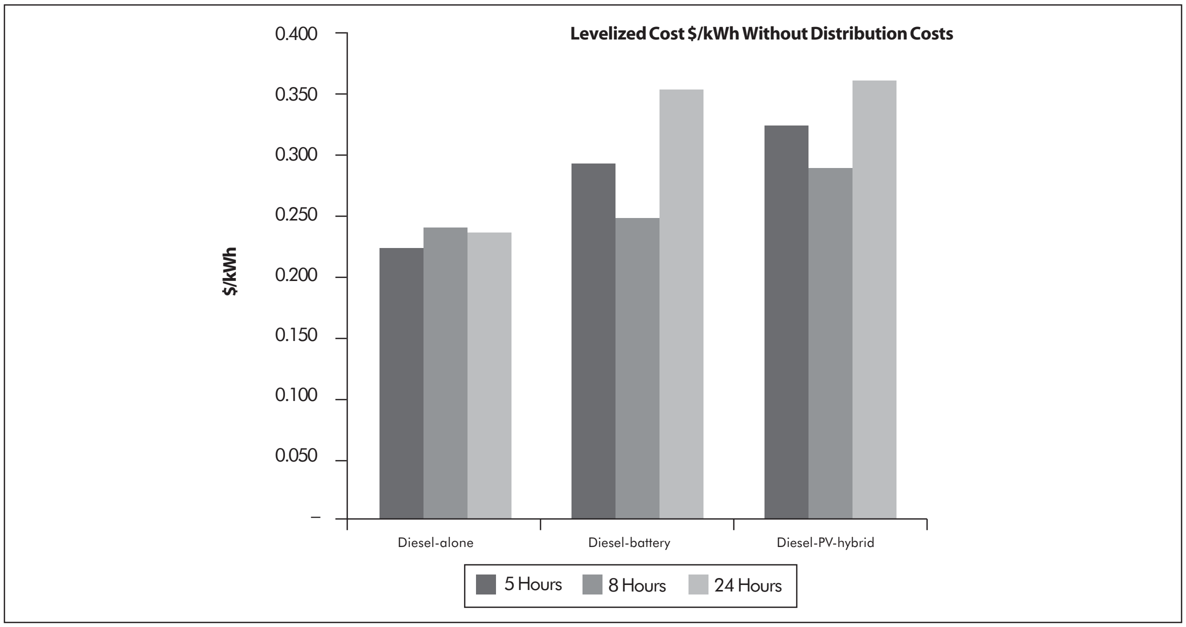
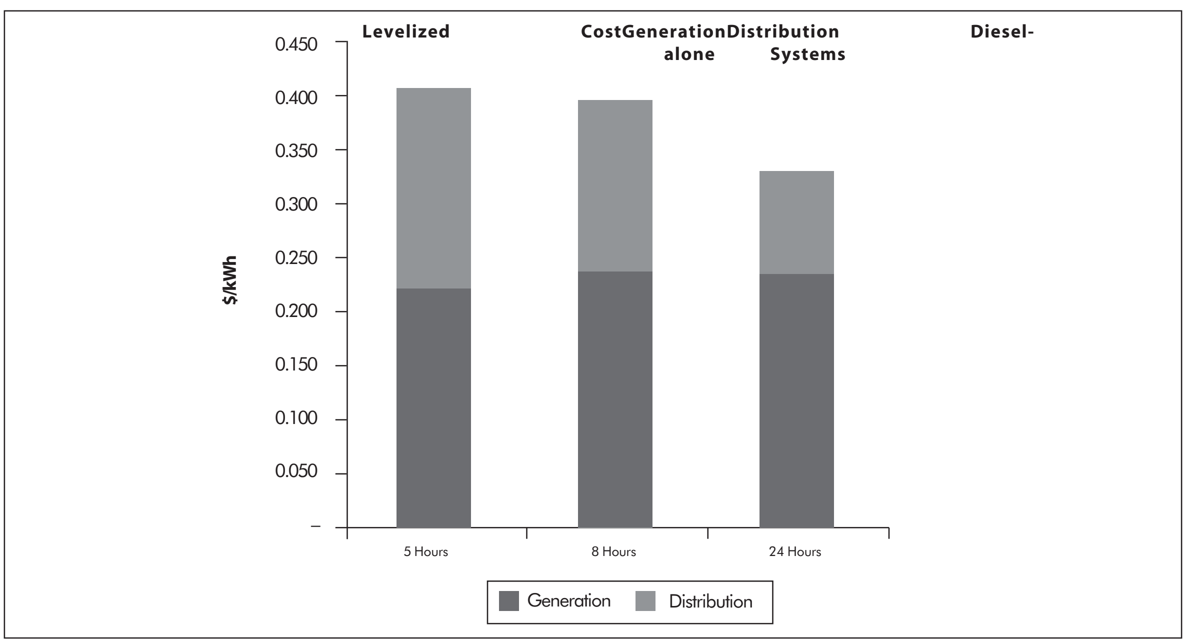


Figure 3.3: Levelized Cost Generation and Distribution: Diesel Stand-alone Options



Financial Sustainability – Tariff and Subsidy

Principle of Financial Sustainability for Renewable Energy Minigrids

Developing cost-recovery tariffs is probably the singlemost 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' WTP[1] 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:

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

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

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

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

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[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)•x (x in kWh)*	*Tariff for Average Consumption Contracts 22 kWh/mo*	*Required Subsidy on Initial Investment*	
						Total $	*per Contact $/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

Model	*Funding* Initial Investment	*Funding* M&O&M Costs	Responsible for Maintenance
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

Model	Main Advantages	Main Disadvantages
A. Utility Model	• 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	• 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	• 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	• 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.

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[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	kW	30	30
Diesel Generator	kW	1 x 128	1 x 128
Battery Units	(2 volts type)	480	480
Converter	kW	80	80
Fuel	$/liter	0.57	

COSTS

	Size/qty.	Capital Cost US$	Replacement Cost US$	Lifetime
PV (kW)	30	128,333	128333	25
Diesel Generator	1 x 128	40,495	40,495	10
Battery (Units)	480	57,600	57600	10
Converter (kW) & Others	80	122,667	122667	15
Building and Materials		23,333	0	
Project Design, Commissioning and Legalization		82,984	0	
Distribution Grid Capital Costs		121683		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
																						Residual Value	
Energy Generated	MWh/yr		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	
Distribution Losses	MWh/yr		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	
Energy Consumed	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	
Energy Generated/day	kWh/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	
Distribution Losses	kWh/day		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	
Energy Consumed	kWh/day		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	
PV Generation	kWh/day		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	
	MWh/yr		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 Net Generation	kWh/day		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	
	MWh/yr		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	
Diesel Total (Net + Losses)	MWh/yr		67.1	69.1	71.0	73.1	75.1	77.3	79.4	81.6	83.9	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	86.2	
Especifi Fuel Usage	liters/kWh		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	liters/yr		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	
EQUIPMENT																							
PV	kW		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	
Generator	kW		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	Units Number		480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	
Converter	kW		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	23.6	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	

		0 2004	1 2005	2 2006	3 2007	4 2007	5 2009	6 2010	7 2011	8 2012	9 2013	10 2014	11 2015	12 2016	13 2017	14 2018	15 2019	16 2020	17 2021	18 2022	19 2023	20 2024	21 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	–	–	–	–	–	–	–	–	–	–	57,600	–	–	–	–	–	–	–	–	–	–	–
Converter	122,667	122,667											–	–	–	–	–	–	–	–	–	–	–
Replacement	18,315	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	122,667	–	–	–	–	–	-81,778
Others	106,317	106,317																					
Distribution Grid	116,202	121,683	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-40,561
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	
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	
Carbon Emissions	–		–-	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–-	
Ditribution 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	
TOTAL COSTS	899,143	577,095	31,531	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	-148,006

PRESENT VALUE	10%	**899,142**
Energy Consummed PV		846 MWh
LEVELIZED COSTS	$/kWh	**1.063**
	S/./kWh	3.51

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Cost	
	Investment ($)	*O&M ($)*	*Replacement ($)*	*Total ($)*	*Consummp MWh*	*$/kWh*	
PV	124,865		0	124,865	846	0.148	13.9%
Generator	40,495		15,613	56,108	846	0.066	6.2%
Battery	57,600		22,207	79,807	846	0.094	8.9%
Converter	122,667		18,315	140,982	846	0.167	15.7%
O&M		107,735		107,735	846	0.127	12.0%
Fuel		147,520		147,520	846	0.174	16.4%
Others				106,317			
Carbon Emission		0		0	846	–	0.0%
Total RAPS				763,334	6,768	0.776	73.1
Distribution Grid	116,202	19,607		135,809	846	0.161	15.1%
TOTAL	461,829	274,862	56,135	899,142	846	1.063	100.0%

REVENUES

Fix Charge	0.561 $ / User / Month	1.85 S/./User/Month
Energy Charge	0.211 $/kWh	0.6976 S/./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
Energía 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**	
		US$	
Income PV		195,730	22%
Subside		703,412	78%
Costs PV			

	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	kW	0	0
Diesel Generator	kW	2 x 36	2 x 36
Battery Units	kWh	0	0

COSTS

	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 (kW)	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 kW/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
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
																							Residual Value
Energy Generated	MWh/yr		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	
Energy Generated/Day	kWh/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	
Losses	kWh/day		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	
	MWh/yr		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	
Energy Consumed	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	
EQUIPMENT																							
PV	kW		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generator	kW		2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	2x36	
Battery Units	kWh		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Carbon Emissions	ton		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	
Fuel Cons.	liters		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	
Specific Fuel Cons.	liters/kWh		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	
COSTS																							
CAPITAL COSTS AND REPLACEMENT																							
PV Array	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diesel Generator	–	21,625	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement	–	–	–	–	–	–	20,760	–	–	–	–	20,760	–	–	–	–	20,760	–	–	–	–	–	–
Battery Units	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Converter	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Distribution Grid	–	73,076	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-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	
Fuel Costs		30,017	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	
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	
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	
Carbon Emissions		44	45	45	46	47	48	49	50	51	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	
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	-24,359

PRESENT VALUE	10%	**626,282$**
Energy Consumed		846 MWh
LEVELIZED COSTS	$/kWh	**0.740**
	S/./kWh	2.44

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Cost	
	Investment ($)	*O&M ($)*	*Replacement ($)*	*Total ($)*	*Consummp MWh*	*$/kWh*	
PV	0		0	0	846	-	0.0%
Generator	21,625		25,864	47,489	846	0.056	
Battery	0		0	0	846	-	0.0%
Converter	0		0	0	846	-	0.0%
O&M		230,101		230,101	846	0.272	36.7%
Fuel		262,270		262,270	846	0.310	41.9%
Carbon Emission		411		411	846	0.000	0.1%
Total RAPS				**540,271**	**846**	**0.638**	**78.7%**
Distribution Grid	69,784	16,227		86,011	846	0.102	13.7%
TOTAL	**91,409**	**509,009**	**25,864**	**626,282**	**846**	**0.741**	**92.4%**

REVENUES

Fix Charge	0.561 $/User/Month	1.85 S/./User/Month
Energy Charge	0.000 $/kWh	0 S/./kWh

	2004	2005	2006	2007	2008	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
Energía 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		16,924	3%
Subside		609,359	97%
Costs PV		626,282	
Income		16,924	3%
Operation and Replacement	$	534,873	
Difference		-517,949	

Diesel Stand-alone: 2 units x 18 kW

SYSTEM CHARACTERISTICS		2005	2014
PV Array	kW	0	0
Diesel Generator	kW	2 x 18	2 x 18
Battery Units	kWh	0	0

COSTS

	Size/Qty.	Capital Cost US$	Replacement Cost US$	Lifetime
PV (kW)	0	0	0	0
Diesel Generator (kW)	2x18	18,250	16425	4
Battery (kWh)	0	0	0	10
Converter (kW)	0	0	0	15
Distribution Grid Capital Costs		73076		30
Distribution Grid O&M		1906 US$/yr		
Distribution Losses	Fix kW/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
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
																							Residual Value
Energy Generated	MWh/yr		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	
Energy Generated/day	kWh/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	
Losses	kWh/day		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	
	MWh/yr		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	
Energy Consumed	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	
EQUIPMENT																							
PV	kW		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generator	kW		2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	2x18	
Battery Units	kWh		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Carbon Emissions	ton		7.0	7.1	7.3	7.4	7.5	7.7	7.8	8.0	8.1	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	
Fuel Cons.	liters		38,515	39,044	39,558	40,095	40,611	41,132	41,651	42,182	42,730	43,311	43,311	43,311	43,311	43,311	43,311	43,311	43,311	43,311	43,311	43,311	
Specific Fuel Cons.	liters/kWh		0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	
COSTS																							
CAPITAL COSTS AND REPLACEMENT																							
PV Array		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diesel Generator		18,250	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	16,425	–	–	–	16,425	–	–	–	16,425	–	–	–	16,425	–	–	–	–	–
Battery Units		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Converter		–											–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Distribution Grid		73,076	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-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	
Fuel Costs			21,954	22,255	22,548	22,854	23,148	23,445	23,741	24,044	24,356	24,687	24,687	24,687	24,687	24,687	24,687	24,687	24,687	24,687	24,687	24,687	
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	
Technical O&M			9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	9,084	
Carbon Emissions			35	36	36	37	38	38	39	40	41	41	41	41	41	41	41	41	41	41	41	41	
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	
INVESTMENT SUBSIDY		–																					
TOTAL COSTS	535,544	91,326	47,743	48,045	48,338	48,645	48,940	49,237	49,534	49,838	50,151	50,482	50,482	50,482	50,482	50,482	50,482	50,482	50,482	50,482	50,482	50,482	-24,359
PRESENT VALUE	10%	**535,544**																					
Energy Consumed		846 MWh																					
LEVELIZED COSTS	$/kWh	**0.633**																					
	S/./kWh	2.09																					

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Cost	
	Investment ($)	*O&M ($)*	*Replacement ($)*	*Total ($)*	*Consummp MWh*	*$/kWh*	
PV	0		0	0	846	-	0.0%
Generator	18,250		27,689	45,939	846	0.054	8.6%
Battery	0		0	0	846	-	0.0%
Converter	0		0	0	846	-	0.0%
O&M		203,026		203,026	846	0.240	37.9%
Fuel		200,239		200,239	846	0.237	37.4%
Carbon Emission		329		329	846	0.000	0.1%
Total RAPS				**449,533**	**5,922**	**0.531**	**84%**
Distribution Grid	69,784	16,227		86,011	846	0.102	16.1%
TOTAL	**88,034**	**419,821**	**27,689**	**535,544**	**6,768**	**0.633**	**100.1%**

REVENUES

Fix Charge 0.561 $/User/Month 1.85 S/./User/Month

Energy Charge 0.000 $/kWh 0 S/./kWh

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Users Number	1.03		244	251	258	265	272	280	288	296	304	313	322	331	340	350	360	370	381	392	403	415
Energía 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		16,924	3%
Subside		518,621	97%
Costs PV		535,544	
Income		16,924	4%
Operation and Replacement	$	447,510	
Difference		-430,586	

Diesel-battery-hybrid. Diesel 1 unit x 36 kW. Large Battery

SYSTEM CHARACTERISTICS		2005	2011
PV Array	kW	0	0
Diesel Generator	kW	1x36	1x36
Battery Units	kWh	310	310

COSTS

	Size/qty.	Capital Cost US$	Replacement Cost US$	Lifetime	Each Unit $
PV (kW)	0	0	0	0	
Diesel Generator (kW)	1x36	10,813	10,380	6	
Battery (kWh)	310	74,400	74,400	5	240
Power Conditioning + Control		42,000	35,000	15	
Distribution Grid Capital Costs		73,076		30	
Distribution Grid O&M		1,906	US$/yr		
Distribution Losses	Fix kW/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
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
																							Residual Value
Energy Generated	MWh/yr		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	
Energy Generated/day	kWh/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	
Losses	kWh/day		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	
	MWh/yr		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	
Energy Consumed	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	
EQUIPMENT																							
PV	kW		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generator	kW		1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	
Battery Units	kWh		310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	
Carbon Emissions	ton		7.0	7.1	7.3	7.4	7.5	7.7	7.8	8.0	8.1	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	
Fuel Cons. Liters	liters		35,490	36,147	36,819	37,507	38,210	38,930	39,666	40,419	41,190	41,978	41,978	41,978	41,978	41,978	41,978	41,978	41,978	41,978	41,978	41,978	
Specific Fuel Cons.	liters/kWh		0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
COSTS																							
CAPITAL COSTS AND REPLACEMENT																							
PV Array	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diesel Generator		10,813	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	10,380	–	–	–	–	–	10,380	–	–	–	–	–	10,380	–	–	-6,920
Battery Units		74,400	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	74,400	–	–	–	–	74,400	–	–	–	–	74,400	–	–	–	–	–	–
Converter		42,000											–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	35,000	–	–	–	–	–	-23,333	
Distribution Grid		73,076	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-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	78,325		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	190,054		20,229	20,604	20,987	21,379	21,780	22,190	22,610	23,039	23,478	23,928	23,928	23,928	23,928	23,928	23,928	23,928	23,928	23,928	23,928	23,928	
Diesel Operators	31,578		3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	3,709	
Technical O&M	47,761		5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	5,610	
Carbon Emissions	329		35	36	36	37	38	38	39	40	41	41	41	41	41	41	41	41	41	41	41	41	
Distribution Grid O&M	16,227		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	669,287	200,289	40,689	41,065	41,448	41,841	116,643	53,033	43,074	43,504	43,944	118,794	44,394	54,774	44,394	44,394	153,794	44,394	44,394	54,774	44,394	44,394	-54,612

PRESENT VALUE	10%	**669,287**	
Energy Consumed		846	MWh
LEVELIZED COSTS	$/kWh	**0.791**	
	S/./kWh	2.61	

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					*Levelized Cost*	
	Investment ($)	*O&M ($)*	*Replacement ($)*	*Total ($)*	*Consummp MWh*	*$/kWh*	
PV	0		0	0	846	-	0.0%
Generator	10,813		10,098	20,911	846	0.025	3.1%
Battery	74,400		92,692	167,092	846	0.198	25.0%
Converter	42,000		5,226	47,226	846	0.056	7.1%
O&M		157,664		157,664	846	0.186	23.6%
Fuel		190,054		190,054	846	0.225	28.4%
Carbon Emission		329		329	846	0.000	0.0%
Total RAPS				**583,276**	**846**	**0.690**	**87.2%**
Distribution Grid	69,784	16,227		86,011	846	0.102	12.9%
TOTAL	**196,997**	**364,273**	**108,016**	**669,287**	**846**	**0.792**	**100.1%**

REVENUES

Fix Charge	0.561 $/User/Month	1.85 S/./User/Month
Energy Charge	0.000 $/kWh	0 S/./kWh

		2004	2005	2006	2007	2008	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
Energía 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		16,924	3%
Subside		652,363	97%
Costs PV		669,287	
Income		16,924	4%
Operation and Replacement	$	472,289	
Difference		-455,366	

PV-diesel-battery-hybrid: 1 x 36 kW Diesel Units. 25 kWp PV Array

SYSTEM CHARACTERISTICS		2005	2011
PV Array	kW	25	25
Diesel Generator	kW	1x36	1x36
Battery Units	kWh	310	310

COSTS

	Size/Qty.	Capital Cost US$	Replacement Cost US$	Lifetime	Each Unit $
PV (kW)	25	127,175	127,175	25	5,087
Diesel Generator (kW)	1x36	10,813	10,380	8	
Battery (kWh)	310	#VALUE!	#VALUE!	10	.
Power Conditioning + Control		42,000	35,000	15	
Distribution Grid Capital Costs		73,076		30	
Distribution Grid O&M		1,906	US$/yr		
Distribution Losses	Fix kW/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
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
																							Residual Value
Energy Generated by PV	MWh/yr		25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	
Energy Generated by Diesel	MWh/yr		70.37	72.14	73.96	75.82	77.72	79.67	81.66	83.69	85.77	87.90	87.90	87.90	87.90	87.90	87.90	87.90	87.90	87.90	87.90	87.90	
Energy Generated	MWh/yr		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	
Energy Generated/day	kWh/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	
Losses	kWh/day		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	
	MWh/yr		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	
Energy Consumed	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	
EQUIPMENT																							
PV	kW		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Generator	kW		1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	
Battery Units	kWh		310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	
Carbon Emissions	ton		5.1	5.3	5.4	5.5	5.7	5.8	6.0	6.1	6.3	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	
Fuel Cons. Liters	liters		26,036	26,694	27,366	28,053	28,757	29,476	30,212	30,966	31,736	32,525	32,525	32,525	32,525	32,525	32,525	32,525	32,525	32,525	32,525	32,525	
Specific Fuel Cons.	liters/kWh		0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
COSTS																							
CAPITAL COSTS AND REPLACEMENT																							
PV Array		127,175	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-25,435
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Diesel Generator		10,813	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	10,380	–	–	–	–	–	–	–	10,380	–	–	–	–	-5,190
Battery Units		#Value!	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	#Value!	–	–	–	–	–	–	–	–	–	–	–
Power Conditioning+Control		42,000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	35,000	–	–	–	–	–	-23,333
Distribution Grid		73,076	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-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	
Fuel Costs		14,841	15,215	15,598	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	
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	
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	
Carbon Emissions		26	26	27	28	28	29	30	31	31	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	
INVESTMENT SUBSIDY	–																					
TOTAL COSTS	#Value!	32,160	32,534	32,918	33,311	33,712	34,123	34,544	34,974	35,414	#VALUE!	35,864	35,864	35,864	35,864	35,864	35,864	35,864	35,864	35,864	35,864	-78,317

PRESENT VALUE	10%	**#Value!**
Energy Consumed		846 MWh
LEVELIZED COSTS	$/kWh	**#Value!**
	S/./kWh	#Value!

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Cost				
	Investment ($)	*O&M ($)*	*Replacement ($)*	*Total ($)*	*Consummp MWh*	*$/kWh*		*kWh*	*Annuity$*	*$/kWh*
PV	123,738		0	123,738	846	0.146	#Value!	19,332	14,534	0.7495
Generator	10,813		6,400	17,213	846	0.020	#Value!			
Battery	#Value!		#Value!	#Value!	846	#Value!	#Value!			
Converter	42,000		5,226	47,226	846	0.056	#Value!			
O&M		130,998		130,998	846	0.155	#Value!			
Fuel		144,179		144,179	846	0.170	#Value!			
Carbon Emission		250		250	846	0.000	#Value!			
Total RAPS				**#Value!**	**846**	**#Value!**	**#Value!**			
Distribution Grid	69,784	16,227		86,011	846	0.102	#Value!			
TOTAL	**#Value!**	**291,654**	**#Value!**	**#Value!**	**846**	**#Value!**	**#Value!**			

REVENUES

Fix Charge	0.561	$/User/Month	1.85	S/./User/Month
Energy Charge	0.000	$/kWh	0	S/./kWh

	2004	2005	2006	2007	2008	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
Energía 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		16,924	#Value!
Subside		#Value!	#Value!
Costs PV		#Value!	
Income		16,924	#Value!
Operation and Replacements	$	#Value!	
Difference		#Value!	

PV-diesel-battery-hybrid: 1 x 36 kW Diesel Units. 50 kWp PV Array

SYSTEM CHARACTERISTICS		2005	2011
PV Array	kW	50	50
Diesel Generator	kW	1x36	1x36
Battery Units	kWh	310	310

COSTS

	Size/Qty.	Capital Cost US$	Replacement Cost US$	Lifetime	Each Unit $
PV (kW)	50	254,350	254,350	25	5,087
Diesel Generator (kW)	1x36	10,813	10,380	12	
Battery (kWh)	310	74,400	74,400	10	240
Power Conditioning + Control		42,000	35,000	15	
Distribution Grid Capital Costs		73,076		30	
Distribution Grid O&M		1,906	US$/yr		
Distribution Losses	Fix kW/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
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Energy Generated by PV	MWh/yr		51.1	51.1	51.1	51.1	51.1	51.1	51.1	51.1	51.1	51.1
Energy Generated by Diesel	MWh/yr		44.82	46.59	48.41	50.27	52.17	54.12	56.11	58.14	60.22	62.35
Energy Generated	MWh/yr		95.92	97.69	99.51	101.37	103.27	105.22	107.21	109.24	111.32	113.45
Energy Generated/day	kWh/day		262.8	267.7	272.6	277.7	282.9	288.3	293.7	299.3	305.0	310.8
Losses	kWh/day		17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0	18.1	18.2
	MWh/yr		6.3	6.3	6.4	6.4	6.4	6.5	6.5	6.6	6.6	6.6
Energy Consumed	MWh/yr		89.6	91.4	93.1	95.0	96.8	98.7	100.7	102.7	104.7	106.8
EQUIPMENT												
PV	kW		50	50	50	50	50	50	50	50	50	50
Generator	kW		1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36
Battery Units	kWh		310	310	310	310	310	310	310	310	310	310
Carbon Emissions	ton		3.3	3.4	3.5	3.7	3.8	4.0	4.1	4.2	4.4	4.6
Fuel Cons. Liters	liters		16,583	17,240	17,912	18,600	19,303	20,023	20,759	21,512	22,283	23,071
Specific Fuel Cons.	liters/kWh		0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
COSTS												
CAPITAL COSTS AND REPLACEMENT												
PV Array		254,350	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–
Diesel Generator		10,813	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–
Battery Units		74,400	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	74,400
Converter		42,000	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–
Distribution Grid		73,076	–	–	–	–	–	–	–	–	–	–

		11	12	13	14	15	16	17	18	19	20	21
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
												Residual Value
Energy Generated by PV	MWh/yr	51.1	51.1	51.1	51.1	51.1	51.1	51.1	51.1	51.1	51.1	
Energy Generated by Diesel	MWh/yr	62.35	62.35	62.35	62.35	62.35	62.35	62.35	62.35	62.35	62.35	
Energy Generated	MWh/yr	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45	113.45	
Energy Generated/day	kWh/day	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8	310.8	
Losses	kWh/day	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	
	MWh/yr	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	
Energy Consumed	MWh/yr	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	
EQUIPMENT												
PV	kW	50	50	50	50	50	50	50	50	50	50	
Generator	kW	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	
Battery Units	kWh	310	310	310	310	310	310	310	310	310	310	
Carbon Emissions	ton	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	
Fuel Cons. Liters	liters	23,071	23,071	23,071	23,071	23,071	23,071	23,071	23,071	23,071	23,071	
Specific Fuel Cons.	liters/kWh	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
COSTS												
CAPITAL COSTS AND REPLACEMENT												
PV Array		–	–	–	–	–	–	–	–	–	–	-50,870
Replacement		–	–	–	–	–	–	–	–	–	–	–
Diesel Generator		–	–	–	–	–	–	–	–	–	–	
Replacement		–	10,380	–	–	–	–	–	–	–	–	-6,920
Battery Units		–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–
Converter		–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	35,000	–	–	–	–	–	-23,333
Distribution Grid		–	–	–	–	–	–	–	–	–	–	-24,359

		0 2004	1 2005	2 2006	3 2007	4 2008	5 2009	6 2010	7 2011	8 2012	9 2013	10 2014	11 2015	12 2016	13 2017	14 2018	15 2019	16 2020	17 2021	18 2022	19 2023	20 2024	21 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	
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	
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	
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	
Carbon Emissions			16	17	18	18	19	20	20	21	22	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	
INVESTMENT SUBSIDY		-																					
TOTAL COSTS	715,583	454,639	25,484	25,860	26,244	26,636	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	-105,482

PRESENT VALUE	10%	**715,583**	
Energy Consumed		846	MWh
LEVELIZED COSTS	$/kWh	**0.846**	
	S/./kWh	2.79	

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Cost				
	Investment ($)	O&M ($)	Replacement ($)	Total ($)	Consummp MWh	$/kWh		kWh	Annuity$	$/kWh
PV	247,476		0	247,476	846	0.293	34.6%	19392	29068	1.4990
Generator	10,813		2,372	13,185	846	0.016	1.8%			
Battery	74,400		28,684	103,084	846	0.122	14.4%			
Converter	42,000		5,226	47,226	846	0.056	6.6%			
O&M		120,126		120,126	846	0.142	16.8%			
Fuel		98,303		98,303	846	0.116	13.7%			
Carbon Emission		170		170	846	0.000	0.0%			
Total RAPS				629,571	846	0.744	87.9%			
Distribution Grid	69,784	16,227		86,011	846	0.102	12.0%			
TOTAL	444,473	234,826	36,282	715,582	846	1.591	99.9%			

REVENUES

Fix Charge	0.561 $/user/month	1.85 S/./user/month
Energy Charge	0.000 $/kWh	0 S/./kWh

	2004	2005	2006	2007	2008	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
Energía 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		16,924	2%
Subside		698,659	98%
Costs PV		715,583	
Income		16,924	6%
Operation and Replacement	$	271,109	
Difference		-254,186	

PV-diesel-battery-hybrid: 1 x 36 kW Diesel Units. 75 kWp PV Array

SYSTEM CHARACTERISTICS		2005	2011
PV Array	kW	75	75
Diesel Generator	kW	1x36	1x36
Battery Units	kWh	524	524

COSTS

	Size/Qty.	*Capital Cost US$*	*Replacement Cost US$*	*Lifetime*	*Each Unit $*
PV (kW)	75	381,525	381,525	25	5,087
Diesel Generator (kW)	1x36	10,813	10,380	20	
Battery (kWh)	524	125,760	125,760	10	240
Power Conditioning + Control		57,000	47,500	15	
Distribution Grid Capital Costs		73,076		30	
Distribution Grid O&M		1,906	US$/yr		
Distribution Losses	Fix kW/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***
		2004	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***	***2022***	***2023***	***2024***	***2025***
																							Residual Value
Energy Generated by PV	MWh/yr		71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	71.175	
Energy Generated by Diesel	MWh/yr		24.74	26.52	28.34	30.19	32.10	34.04	36.03	38.07	40.15	42.28	42.28	42.28	42.28	42.28	42.28	42.28	42.28	42.28	42.28	42.28	
Energy Generated	MWh/yr		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	
Energy Generated/day	kWh/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	
Losses	kWh/day		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	
	MWh/yr		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	
Energy Consumed	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	
EQUIPMENT																							
PV	kW		75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	
Generator	kW		1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	
Battery Units	kWh		524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	
Carbon Emissions	ton		1.8	1.9	2.1	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	
Fuel Cons.	liters		9,155	9,812	10,484	11,172	11,875	12,595	13,331	14,084	14,855	15,644	15,644	15,644	15,644	15,644	15,644	15,644	15,644	15,644	15,644	15,644	
Specific Fuel Cons.	liters/kWh		0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
COSTS																							
CAPITAL COSTS AND REPLACEMENT																							
PV Array		381,525	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-76,305
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diesel Generator		10,813	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Battery Units		125,760	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Replacement		–	–	–	–	–	–	–	–	–	–	125,760	–	–	–	–	–	–	–	–	–	–	–
Converter		57,000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	47,500	–	–	–	–	---	-31,667
Distribution Grid		73,076	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-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	
Fuel Costs		5,218	5,593	5,976	6,368	6,769	7,179	7,599	8,028	8,467	8,917	8,917	8,917	8,917	8,917	8,917	8,917	8,917	8,917	8,917	8,917	
Diesel Operators		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Technical O&M		1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	1,777	
Carbon Emissions		9	10	10	11	12	12	13	14	15	15	15	15	15	15	15	15	15	15	15	15	
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	
INVESTMENT SUBSIDY	-																					
TOTAL COSTS	648,174	18,110	18,486	18,869	19,262	19,664	20,074	20,495	20,925	21,365	21,815	21,815	21,815	21,815	21,815	69,315	21,815	21,815	21,815	21,815	21,815	-132,330

PRESENT VALUE		**862,196**	
Energy Consumed		846	MWh
LEVELIZED COSTS	$/kWh	**1.019**	
	S/./kWh	3.36	

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Cost				
	Investment ($)	*O&M ($)*	*Replacement ($)*	*Total ($)*	*Consummp MWh*	*$/kWh*		*kWh*	*Annuity $*	*$/kWh*
PV	371,214		0	371,214	846	0.439	43.1%	19,392	43,603	2.2485
Generator	10,813		0	10,813	846	0.013	1.3%			
Battery	125,760		48,486	174,246	846	0.206	20.2%			
Converter	57,000		7,092	64,092	846	0.076	7.4%			
O&M		93,453		93,453	846	0.110	10.8%			
Fuel		62,259		62,259	846	0.074	7.2%			
Carbon Emission		108		108	846	0.000	0.0%			
Total RAPS				**776,185**	**5,922**	**0.918**	**90.0%**			
Distribution Grid	69,784	16,227		86,011	846	0.102	10.0%			
TOTAL	**634,571**	**172,047**	**55,578**	**862,196**	**6,786**	**1.02**	**100.0%**			

REVENUES

Fix Charge	0.561	$/User/Month	1.85	S/./User/Month
Energy Charge	0.000	$/kWh	0	S/./kWh

	2004	2005	2006	2007	2008	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
Energía 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		16,924	2%
Subside		845,272	98%
Costs PV		862,196	
Income		16,924	7%
Operation and Replacement	$	227,624	
Difference		-210,701	

PV-diesel-battery-hybrid: 1 x 36 kW Diesel Units. 95 kWp PV Array

SYSTEM CHARACTERISTICS		2005	2011
PV Array	kW	95	95
Diesel Generator	kW	1x36	1x36
Battery Units	kWh	524	524

COSTS

	Size/qty.	Capital cost US$	Replacement Cost US$	Lifetime	Each Unit $
PV (kW)	95	483,265	483,265	25	5,087
Diesel Generator (kW)	1x36	10,813	10,380	20	
Battery (kWh)	524	125,760	125,760	10	240
Power Conditioning + Control		57,000	47,500	15	
Distribution Grid Capital Costs		73,076		30	
Distribution Grid O&M		1,906	US$/yr		
Distribution Losses	Fix kW/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
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
																							Residual Value
Energy Generated by PV	MWh/yr		83.22	83.22	83.22	83.22	83.22	83.22	83.22	83.22	90.155	90.155	90.155	90.155	90.155	90.155	90.155	90.155	90.155	90.155	90.155	90.155	
Energy Generated by Diesel	MWh/yr		12.70	14.47	16.29	18.15	20.05	22.00	23.99	26.02	21.17	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	23.30	
Energy Generated	MWh/yr		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	
Energy Generated/day	kWh/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	
Losses	kWh/day		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	
	MWh/yr		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	
Energy Consumed	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	
EQUIPMENT																							
PV	kW		95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	
Generator	kW		1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	1x36	
Battery Units	kWh		524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	524	
Carbon Emissions	ton		0.9	1.1	1.2	1.3	1.5	1.6	1.8	1.9	1.5	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	
Fuel Cons.	liters		4,698	5,356	6,028	6,715	7,419	8,138	8,875	9,628	7,832	8,621	8,621	8,621	8,621	8,621	8,621	8,621	8,621	8,621	8,621	8,621	
Specific Fuel Cons.	liters/kWh		0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	
COSTS																							
CAPITAL COSTS AND REPLACEMENT																							
PV Array		483,265	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-96,653
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–-
Diesel Generator		10,813	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–-
Battery Units		125,760	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–-
Replacement		–	–	–	–	–	–	–	–	–	–	125,760	–	–	–	–	–	–	–	–	–	–	–-
Converter		57,000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–-
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	47,500	–	–	–	–	–-	-31,667
Distribution Grid		73,076	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-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	
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	
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	
Carbon Emissions		5	5	6	7	7	8	9	9	8	9	9	9	9	9	9	9	9	9	9	9	
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	
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	-152,678

PRESENT VALUE	10%	**930,514**
Energy Consumed		846 MWh
LEVELIZED COSTS	$/kWh	**1.100**
	S/./kWh	3.63

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Cost	
	Investment ($)	O&M ($)	Replacement ($)	Total ($)	Consummp MWh	$/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**	**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	Annuity$	$/kWh
19,392	55,230	2.8481

REVENUES

Fix Charge	0.561 $/user/month	1.85 S/./user/month
Energy Charge	0.000 $/kWh	0 S/./kWh

		2005	2006	2007	2008	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
Energía 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		16,924	2%
Subside		913,591	98%
Costs PV		930,514	
Income		16,924	9%
Operation and Replacement	$	196,953	
Difference		-180,029	

PV-only. 140 kWp PV Array

SYSTEM CHARACTERISTICS		2005	2011
PV Array	kW	140	140
Diesel Generator	kW	1x36	1x36
Battery Units	kWh	765	765

COSTS

	Size/qty	Capital Cost US$	Replacement Cost US$	Lifetime	Each Unit $
PV (kW)	140	712,180	712,180	25	5,087
Diesel Generator (kW)		0	0	20	
Battery (kWh)	765	183,600	183,600	10	240
Power Conditioning + Control		57,000	47,500	15	
Distribution Grid Capital Costs		73,076		30	
Distribution Grid O&M		1906 US$/yr			
Distribution Losses	Fix kW/day	12 Variable	2%		
Fuel	$/liter	0.57			
Carbon Emission Costs		5 US$/ton			
Inflation O&M	0.0%				

Cash Flow (US$)

		0 2004	1 2005	2 2006	3 2007	4 2008	5 2009	6 2010	7 2011	8 2012	9 2013	10 2014	11 2015	12 2016	13 2017	14 2018	15 2019	16 2020	17 2021	18 2022	19 2023	20 2024	21 2025
																							Residual Value
Energy Generated	MWh/yr		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	
Energy Generated/day	kWh/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	
Losses	kWh/day		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	
	MWh/yr		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	
Energy Consumed	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	
EQUIPMENT																							
PV	kW		140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	140	
Generator	kW		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Battery Units	kWh		765	765	765	765	765	765	765	765	765	765	765	765	765	765	765	765	765	765	765	765	
Carbon Emissions	ton		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Fuel Cons	liters		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Specific Fuel Cons	liters/kWh		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
COSTS																							
CAPITAL COSTS AND REPLACEMENT																							
PV Array		712,180	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-142,436
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Diesel Generator		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Battery Units		183,600	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	183,600	–	–	–	–	–	–	–	–	–	–	–
Converter		57,000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Replacement		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	47,500	–	–	–	–	–	-31,667

		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	
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	
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	
Investment Subsidy		-																					
TOTAL COSTS	1,180,003	1,025,856	11,606	11,606	11,606	11,606	11,606	11,606	11,606	11,606	11,606	11,606	11,606	11,606	11,606	11,606	59,106	11,606	11,606	11,606	11,606	11,606	-198,461
PRESENT VALUE	10%	**1,180,003**																					
Energy Consumed		846	MWh																				
LEVELIZED COSTS	$/kWh	**1.395**																					
	S/./kWh	4.60																					

LEVELIZED COSTS BY COMPONENTS

	Present Value ($)					Levelized Costs				
	Investment ($)	O&M ($)	Replacement ($)	Total ($)	Consummp MWh	$/kWh		kWh	Annuity$	$/kWh
PV	692,933		0	692,933	846	0.819	58.7%	19,392	81,392	4,1972
Generator	0		0	0	846	-	0.0%			
Battery	183,600		70,786	254,386	846	0.301	21.6%			
Converter	57,000		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%**			

REVENUES

Fix Charge	0.561	$/User/Month	1.85	S/./User/Month
Energy Charge	0.000	$/kWh	0	S/./kWh

		2005	2006	2007	2007	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Users Number	1.03	244	251	258	265	272	280	288	296	304	313	322	331	340	350	360	370	381	392	403	415
Energía 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		16,924	1%
Subside		1,163,080	99%
Costs PV		1,180,003	
Income		16,924	10%
Operation and replacement $		176,686	
Difference		-159,763	

Annex 2

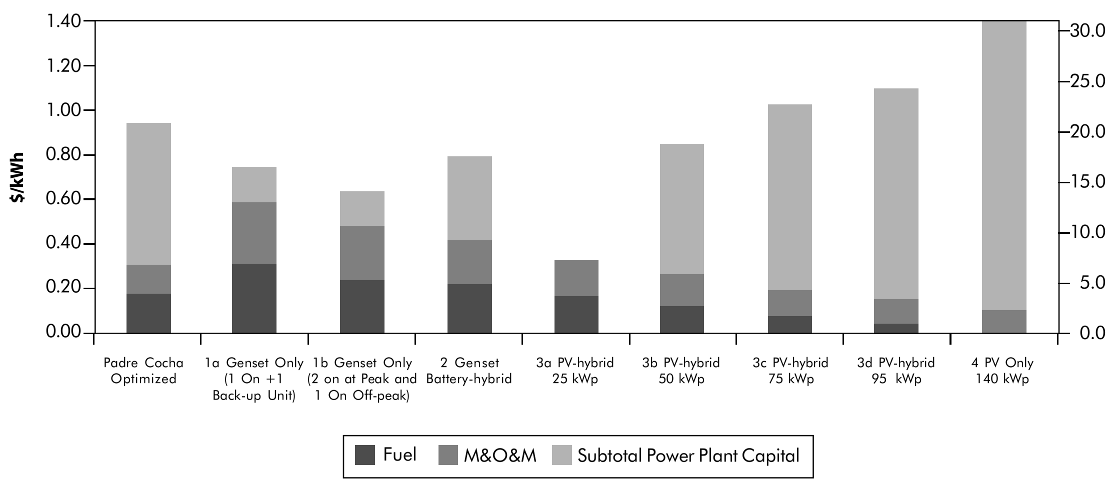
Levelized cost comparison sustainability analysis for different options, discount rates and fuel prices

Levelized Cost Analysis of Sustainability of Different System Configurations

Condition10057:

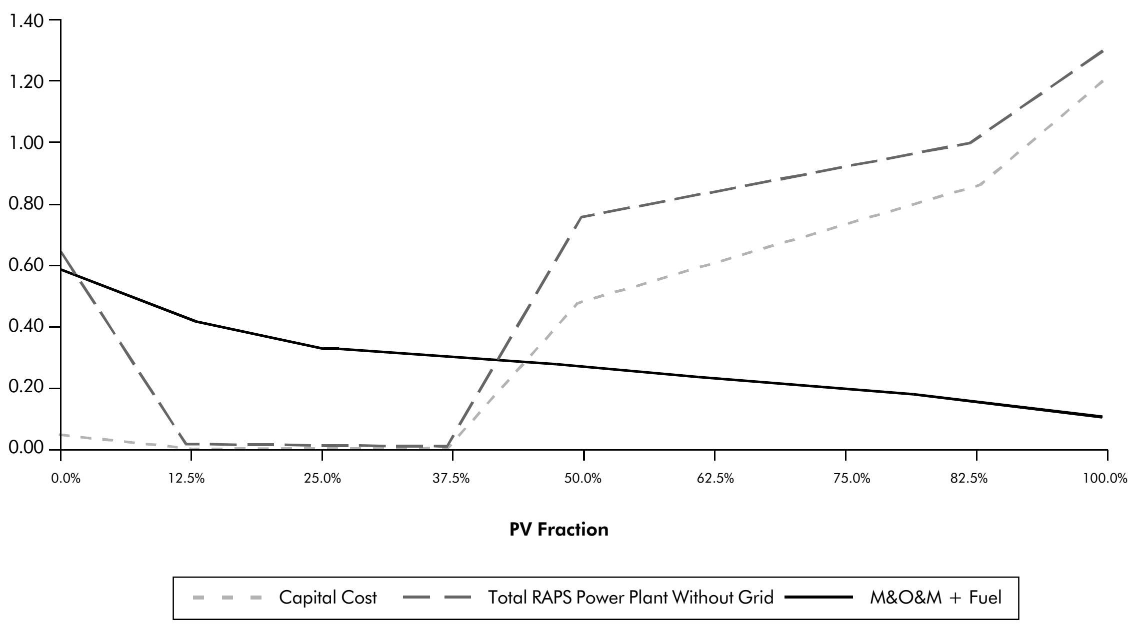
Discount Rate Idealized	$/liter	Net Demand (kWh/day)	hp
10%	**0.57**	**245**	**4.00**

						Levelized Costs, Breakdown $/kWh											
	PV Array kW	*Genset kW*	*Battery kWh*	*Power Conditioning Inverter/Charger*	*Total Present Costs US$*	*PV*	*Generator*	*Battery*	*Power Conditioning*	*M&O&M*	*Fuel*	*Carbon Emissions*	*Subtotal Power Plant Capital*	*Subtotal Power Plant*	*Distribution Grid Capital*	*Total Capital Incl. Grid*	*Total*
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	**.0772**
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**



	PV Fraction	*Capital Cost*	*M&O&M + Fuel*	*Total RAPS Power Plant Without Grid*
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

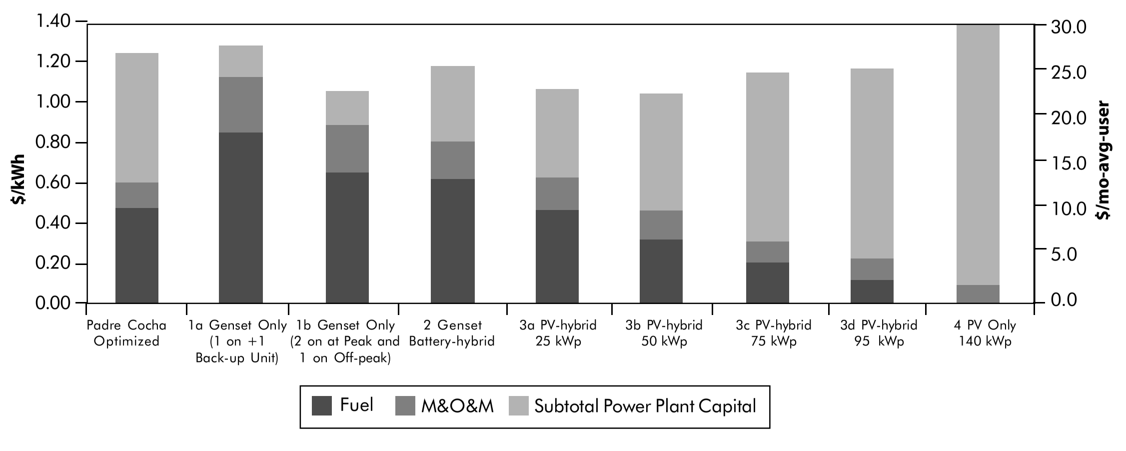


Levelized Cost Analysis of Sustainability of Different System Configurations

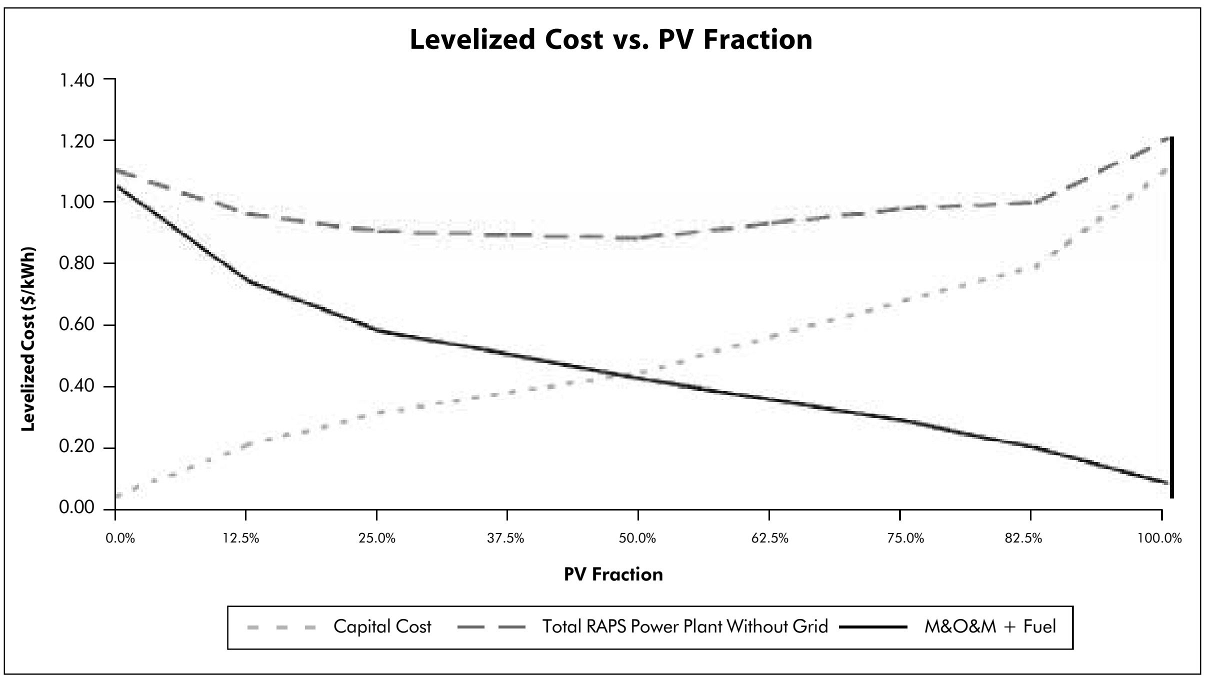
Condition10158:

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: PV	Genset	Battery	Power Conditioning	M&O&M	Fuel	Subtotal Power Plant Capital	Subtotal Power Plant	Distribution Grid Capital	Total Capital Incl. Grid	Total
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	0.588	**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**



	PV Fraction	*Capital Cost*	*M&O&M + Fuel*	*Total RAPS Power Plant Without Grid*
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

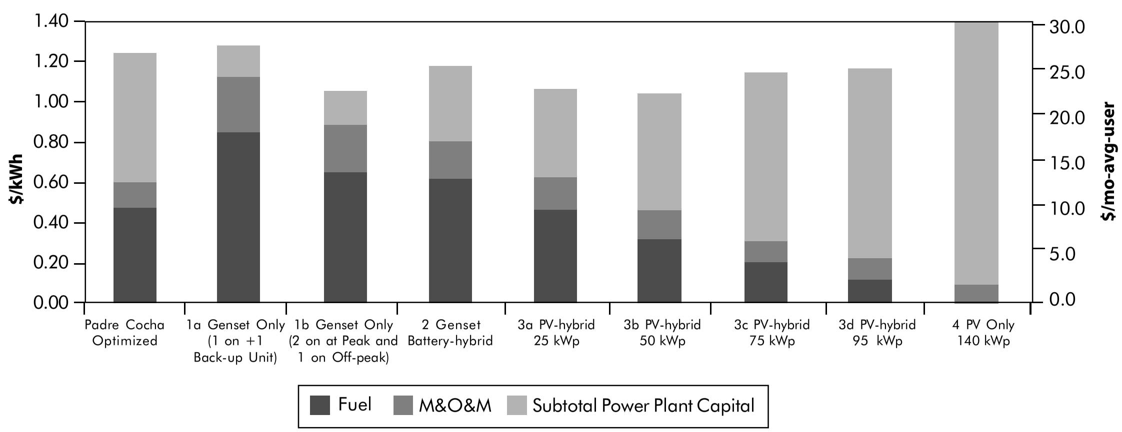


Levelized Cost Analysis of Sustainability of Different System Configurations

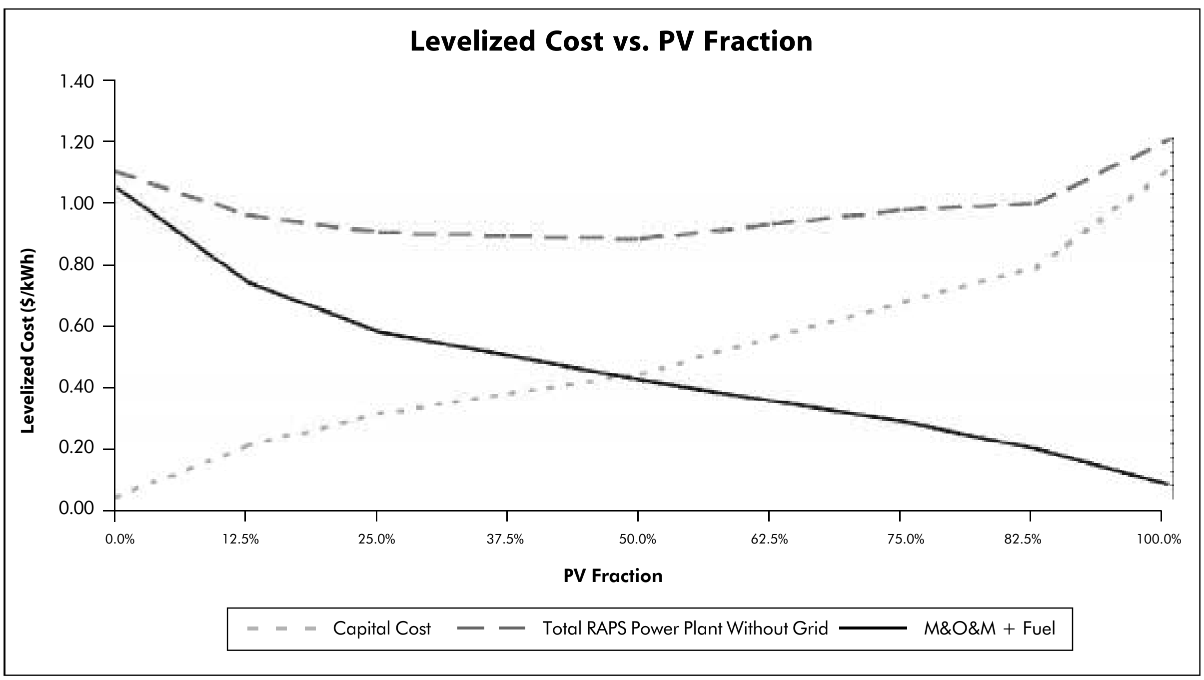
Condition10158:

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* PV	*Genset*	*Battery*	*Power Conditioning*	*M&O&M*	*Fuel*	*Subtotal Power Plant Capital*	*Subtotal Power Plant*	*Distribution Grid Capital*	*Total Capital Incl. Grid*	*Total*
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	0.588	**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**



	PV Fraction	*Capital Cost*	*M&O&M + Fuel*	*Total RAPS Power Plant Without Grid*
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

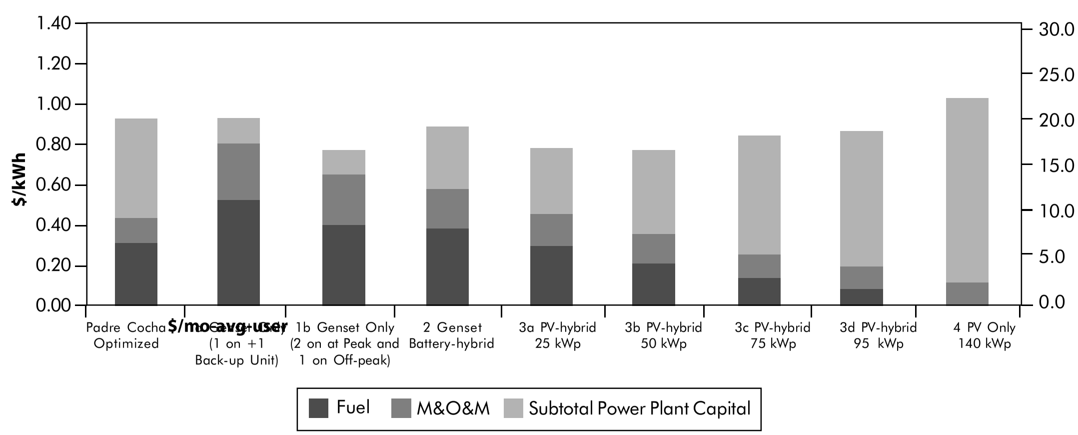


Levelized Cost Analysis of Sustainability of Different System Configurations

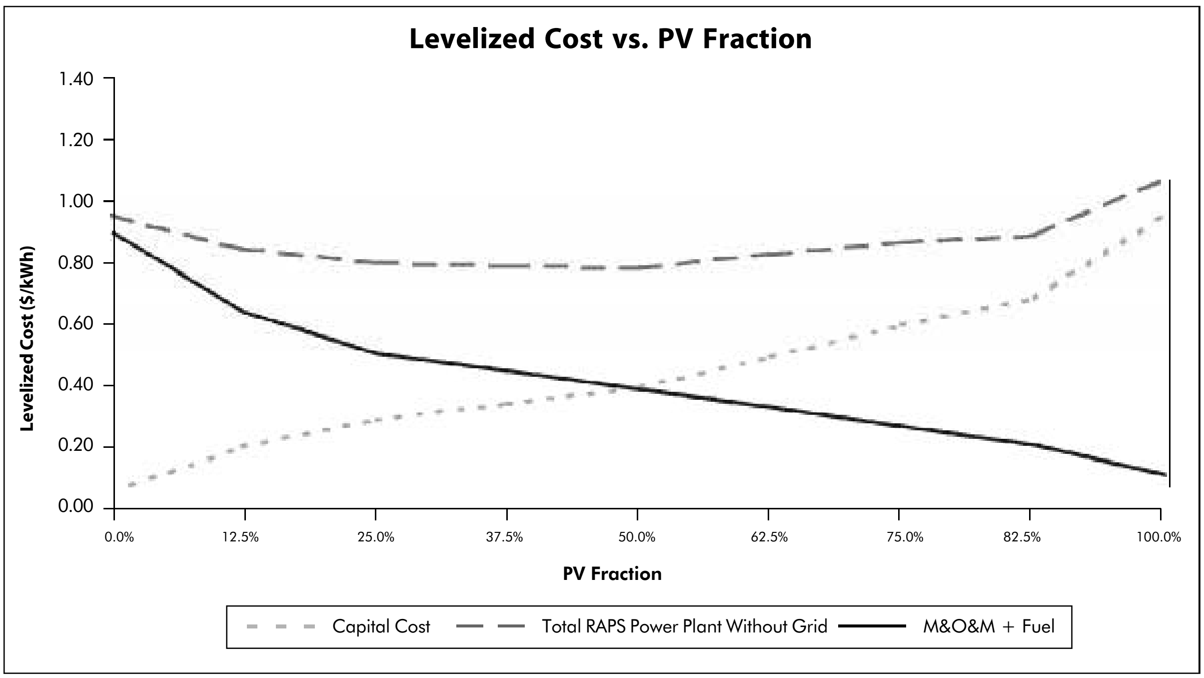
Condition05092:

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

	PV Array kW	Genset kW	Battery kWh	Power Conditioning Inverter/Charger	Total Present Costs US$	Levelized Costs, Breakdown $/kWh: PV	Generator	Battery	Power Conditioning	M&O&M	Fuel	Subtotal Power Plant Capital	Subtotal Power Plant	Distribution Grid Capital	Total Capital Incl. Grid	Total
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	0.475	**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	0.118	**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	0.117	**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	0.301	**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	0.316	**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	0.405	**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	0.576	**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	0.652	**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	0.886	**0.983**



	PV Fraction	*Capital Cost*	*M&O&M + Fuel*	*Total RAPS Power Plant Without Grid*
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

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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. *(Atelier sur l'Energie en régions rurales et le Développement durable 30-31, janvier 2002)*	04/05	068/05
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	Phase-Out of Leaded Gasoline in Sub-Saharan Africa	04/02	028/02
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	Lead Elimination from Gasoline in Sub-Saharan Africa. Sub-regional Conference of the West-Africa group. Dakar, Senegal March 26-27, 2002 *(Deuxième comité directeur : La route à suivre - L'initiative sur l'assainissement de l'air. Paris, le 13-14 mars 2003)*	12/03	046/03
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