CONF-9505427--

Photovoltaic rural electrification and the electric power utility. Workshop. [Selected Papers]

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Lastly:

- Experience has shown that rural populations are capable of taking charge of their own development, given assistance in start-up when this development calls for new technology.
- It would appear to be possible to meet this organizational challenge confronting the possessors of technology and know-how, and local political leaders, within the time frame of a single generation.
- The crucial vector lies in the elaboration of new forms of partnership between the private and public sectors.

QUESTIONS AND ANSWERS

Q. On the issue of standards, I appreciate that you did cover it in your paper a little bit. It would seem to me, that is probably the most important aspect if you want to avoid exploitation of the end user, who may have to buy special end-use equipment in order to use that electricity. Are you aware if there is any movement or any organization to set some standards?
A. About standards, in the Workshop they said that it is at the beginning that countries need to elaborate standards. When the project is at the pilot level, the problem is to think about that, and maybe to aim a workshop specially focused on standardization. Because the technology is too new, we have to think about that and to mobilize persons to see what countries can do with standards. It is very important to avoid to have new goods and not very good quality.

Q. Are you aware of any workshop that deals specially on standards?
A. Not myself. Maybe some other participant knows about that,
A. There is work going on right now at Sandia National Labs (in the USA) and the program Renewable Energy for African development, on standards for the solar home systems. They draft those standards. You may want to contact Dr. Gary Jones in Washington.

EU-SPONSORED PHOTOVOLTAIC SYSTEMS FOR RURAL ELECTRIFICATION

Gerhard Riesch
Joint Research Centre of the EU (European Union), JRC, Ispra (Italy)

ABSTRACT

Development and proliferation of renewable energies are sponsored since 1983 by the European Union, normally up to 40 % of the cost. (Programme THERMIE and predecessors).

In the frame of this programme far more than one hundred projects of all kinds with thousands of photovoltaic energy supply systems have been implemented in Europe, 29 of these projects with 939 single pv-systems concern electrifications of rural sites (e.g. agriculture) or isolated sites (e.g. mountain huts).

Most of the single systems are of small size, 50 to 1000 Wp. A few of the systems are larger, up to 25 kWp, and supply local isolated mini-grids.

In this paper the main features of the systems in six european countries are presented: The technical, economical and social results as well as the contributions of the EPU's to these electrifications are discussed.

Main conclusions are:

- *For pv electrifications in rural areas the supply of AC through an appropriate inverter is the most preferable alternative. Hybrid systems are much better than pv-only systems.*
- *Electricity costs are well above 4 ECU/kWh and especially for systems mounted in sites with difficult access very much higher.*
- *The inverters are presently the weakest component of the systems.*
  More often than expected the systems on isolated sites are damaged by lightnings.
  Batteries so far show good quality.
- *For isolated sites it is essential, that system failures are reported rapidly. The distant survey devices are still very expensive and sometimes unreliable.*
- *Preventive maintenance of the installed systems is essential but unfortunately it exists only in very few cases. A general solution for the maintenance problem has still to be found.*
- *The utility companies should play a more important role in the electrification of rural sites than they actually are willing to.*

IMPLEMENTATION OF THE SYSTEMS
TECHNICAL ASPECTS
Initiative for implementation

The Commission of the European Union (formerly European Communities) sustains and continues to encourage projects intended to promote energy technologies. (From 1979 to 1989: Community Energy Demonstration Programme, from 1990 to 1994: THERMIE 1, from 1995 onward THERMIE 2).

The energy technology projects cover four areas such as “rational use of energy”, “solid fuels”, “hydrocarbons” and also the field “renewable energies”, with sub-areas “solar”, “wind”, etc. Photovoltaic projects started in 1982 in the “solar”-frame.

Everybody was invited to propose projects; the accepted projects were financially supported (by 40 or 35 % of the total cost) by the Commission.

From 1979 to 1989 76 pv-projects with together 1.0 MWp were implemented, from 1990 to 1994 further 88 pv-projects with together 5.8 MWp were implemented or are still going on.

From these 164 pv-projects 29 selected projects concerning rural electrifications and isolated sites are discussed in this paper. The main data of the projects are shown in Table 1.

Selected EU sponsored rural electrifications. (Main data).

Ref. Nr.	Number	Country	Short title	Place	Power (kWp)	Nr. of systems	Contractor	Contr.type
1	86327	ES	57 dwellings	Sierra de Segura	21.8	79	Compania Sevillana De Electricidad	EPU
2	88073	ES	Village electrif.	Los Arcos, Murcia	11.0	1	Hidroelectrica Espanola Sa	EPU
3	83466	FR	40 isolated houses	Southern France	26.6	40	A. F. M. E.	EPU
5	85138	IT	30 isol. houses	Eolian islamds	10.5	30	Ente Nazionale Per L'energia Enel	EPU
6	89416	IT	Island electrification	Stromboli + Alicudi	34.5	17	Ente Nazionale Per L'energia Enel	EPU
7	83314	HE	Isolated houses	Antikythira isl.	33.6	12	Public Power Corporation	EPU
8	83404	HE	Remote village	Arki island	25.0	1	Public Power Corporation	EPU
					163.0	180		7
9	87421	ES	Remote village	Rambla del Banco	11.8	2	Selected Electronics Technologies (Set)	Manuf.
10	88116	ES	Farm houses	Granada(Cabeza del Buey)	12.3	38	Acander Sa	Manuf.
11	90063	ES	Rural electrific.	Andalucia	12.3	24	Acander Sa	Manuf.
12	86103	FR	Isolated houses	Corsica	8.6	22	Total Energie	Manuf.
13	87034	FR	Electrification	Roya valley	6.9	98	Total Energie	Manuf.
14	85540	IT	7 dairy farms	Liguria	26.7	5	Ansaldo Spa	Manuf.
15	84084	DE	Oberlinhouse	Orbey-le-Schoultzbach	2.2	1	Fraunhofer-Gesellschaft	Manuf.
					80.8	190		7
16	86337	ES	35 houses	Solsones	13.9	35	Andreu Alet Espagna	User
17	89061	ES	Rural electrification	Catalan Pyrenees	16.9	18	Ecotecnica Sociedad Cooperativa Catalana Ltd.	User
18	90111	ES	Pyreenes electrific.	Catalonia	15.6	28	Ecotecnica Sociedad Cooperativa Catalana Ltd.	User
19	92084	ES	Rural electrification	La Garrotxa	47.4	70	Serveis Energetics Basics	User
20	84696	FR	Alpine huts	French Alps	5.4	13	La Grande Traversee des Alpes.	User
21	85501	FR	29 mountain huts	Alps + Pyrennes	6.0	23	Club Alpin Francais	User
22	87167	FR	Nat.cycling museum	Parc Nat.des Crins	3.6	34	Parc National Des Ecrins	User
23	88213	FR	Mountain huts	Queyras park	8.6	61	Parc Naturel Regional Du Queyras	User
24	88389	FR	Natural parc electr.	Vercors park	16.5	34	Parc Naturel Regional Du Vercors	User
25	89073	FR	Nature parks	Southern France	14.3	30	Federation Des Parcs Naturels De France	User
26	89075	FR	40 pyrenean sites	Pyrenees	30.4	40	Comite Intereg. Devept. Amengt. Pyrenees (Cidap)	User
27	90205	FR	Nature parks	France	11.4	73	Federation Des Parcs Naturels De France	User
28	91124	FR	Mountain farming	Rhone-Alpes	7.7	53	Rhonalpenergie	User
29	86215	PO	Rural dwellings	Portugal	26.5	52	Centro De Estudos Em Economia Da Energia	User
30	89283	DE	5 Alpine huts	German alps	13.3	5	Deutscher Alpenverein Ev	User
					237.6	569		15

Table 1.

Seven contractors of the 29 projects are EPU's, seven are manufacturers or installers of pv equipment and 15 are the final users, however most of the final users were urged by manufacturers and installers to apply for the EU support.

Geographic distribution: Spain (9 projects, with emphasis on agricultural use), France (11, with emphasis on mountain huts), Italy (3), Portugal (1), Germany (2), Greece (2). Some of these projects are mainly of the type "mountain huts", hence not quite typical for "rural" applications that are typically isolated farms, shepherd shelters, etc.

In the group of EPU installed systems

- In Spain, Compañía Sevillana de Electricidad has made great efforts, Hidroeléctrica Española much less.
- In France, EdF shows very little interest in isolated electrifications; AFME is not a EPU properly speaking, but is somehow related to it and promotes the use of regenerative sources.
- In Italy, ENEL shows interest in rural electrification, but the factual realizations are less convincing.
- In the northern european countries with very low potential for rural electrification the EPU's are not interested; they show interest more recently (since 1990) for grid connected pv-systems e.g. in Germany.

SCOPE OF THE PV ELECTRIFICATIONS

The scope of the selected projects was quite generally to supply electric power in modest size

- To isolated, rural, agricultural, cattle-breeding farms or sheepfolds (permanent or seasonal use) [1], [2], [3], [7], [8], [10], [11], [13], [14], [16], [17], [18], [19], [28], [29],
- Or to isolated mountain refuges and shelters, holiday houses, etc. [5], [6], [12], [15], [20], [21], [22], [23], [24], [25], [26], [27], [30].

In addition to this general scope, in some of the projects special attention was given to:
evaluate advantages and disadvantages of pure dc-systems versus pure ac-systems and versus mixed systems [1], [11],

- Evaluate advantages and disadvantages of individual systems versus mini-grid systems, [1],
- Evaluate advantages and disadvantages of pv only systems versus hybrid systems [15], [30],
- Evaluate social, administrative (coordination, assistance to owners) and economic implications [3], [29],
- Study the management (load adaption) of the isolated systems and maintenance aspects [1], [2], [19],
- Set up good data monitoring and rapid alarming in case of failures, [10], [26],
- Implement the systems without damage to the rural environment, [2], [16], [22], [24], [25], [26], [27].

POTENTIAL FOR FURTHER INSTALLATIONS

Concerning the potential for rural, and/or isolated pv electrification the following statements were made in the projects:

In Europe: 1.2 Mio. in Europe live in "no-electricity" houses. There is hence a potential of 100000 pv systems of 400 Wp in Europe. Total potential: 40 MWp. But only 5 % concern weekend and/or vacation huts, mountain shelters, etc. for which such electrifications can be financed by interested users. 95 % of the "no-electricity" houses belong to "low income" people, e.g. farmers, shepherds, fisherman in southern Europe, that cannot afford to pay for pv systems. They would need public help [4], p.78.

In France: There are about 10,000 unelectrified sites in southern France which could potentially be electrified by installing pv generators [3].

In Spain: The follow-up programme (VALOREN) has installed 560 kWp in about 2000 systems of 240 to 400 Wp and with ac supply and separate dc supply. [1]. There are more than 300 isolated farms in Andalucia, that could use pv-electrification; the only problem is to get enough subsidies (of any sponsor) because the potential users have no money. [11].

In Italy: Small stand-alone pv plants could be used also to supply users that live temporarily in vacation houses. The potential market in Italy is very large (at least 10000 vacation houses.) [6].

In Germany: In the German and Austrian Alps exist about 520 refuges. By 1986 about 110 were connected with the grid, 133 had motor generators, 5 wind generators, 65 hydrogenerators, and 30 pv-generators. The rest uses gas, oil, etc. [21], [30].

GRID CONNECTION VERSUS ISOLATED PV SYSTEMS

Concerning the choice of isolated pv systems versus grid connection it has to be considered that power line cost range from 7000 to 30000 ECU/km and that maintenance cost for grid connections are not at all negligible (storms, snow) [4].

Advantages of pv systems are: respect of environment (noise, optical integration), static energy production, autonomy (no fuel supply), automatic electricity supply (user safety and comfort), lower maintenance. [4].

For France: The use of pv generators to electrify isolated sites in France begins to become economic for loads of less than 1 kWp, at distances greater than 2 km from the grid. [3]. In [4], p.45, the following figures are quoted: Low voltage connections are more economic than pv systems only up to 500 m.

For medium voltage connections: PV is cheaper for more than:

600 m distance for	400 Wp systems,
1100 m distance for	800 Wp systems,

1500 m distance for 1200 Wp systems.

Option: dc or ac or both dc+ac

The following statements are made concerning the choice ac or dc or mixed:

In France:	Unavailability of dc appliances (washing machines, hand tools) is largely deplored by the users. [3].
In Spain:	There is a trend in the spanish pv market towards the general use of ac systems and the use of two independent grids for dc (lighting) and ac (household appliances) [1]. In the rural farm surroundings ac-systems (220 V with inverters) are preferable over dc-systems also for lighting. (Electricians have no experience with dc installations; material (bulbs) is not available, etc.) [11].
In Italy:	Inverters and standard ac equipment prove to be better than special dc-equipment [14].
In Portugal:	There is a lack of 24 V dc-appliances [29].

Conclusion

Pure lighting applications with very low power (<100 Wp) can be equipped with simple dc systems (12V or 24 V).

For all other pv electrifications in rural areas the supply of ac, via an inverter, is the preferable alternative.

Of course, seen strictly from the technical point of view, often it appears to be absurd, to convert dc to ac. But as long as good, reliable and cheap dc-appliances and tools are unavailable, it is absolutely necessary to supply standard ac-electricity to the users. Otherwise they feel, and in deed they are, “second class” users.

Option: hybrid or pv-alone

Statements of the contractors:

Greece:	The use of hybrid systems gives a more reliable power source for remote communities: in summer the pv production is much higher, a wind generator could supply valuable power in winter [7]. The problems, mainly for incomplete battery charging, led to the decision to install a Diesel generator set to boost charge the batteries and thus maintain continuity of supply [8].
Italy:	Experience shows, that back-up motor generators are useful [14].
Germany:	The advantage of a hybrid system are fully confirmed here: The pv part must be dimensioned only for the summer months and large appliances (washing machine) can be run anytime [15].

Conclusion

For isolated rural needs hybrid systems (motor generator or, if possible wind generator), are much better than pv-only systems.

Summary description of the systems

There are 939 single systems considered in this paper.

The total installed power is 483 kWp. Average installed power per system: 0.5 kW. All systems are of the stand-alone type with pv modules, charge-and discharge controllers, batteries. Some have inverters and some other have data monitoring.

For more details see Table 2. (Photowatt/ Isofoton/ AEG/ Siemens/ Italsolar/ BP/ others).

Selected EU sponsored rural electrifications. (Descriptive data).

Ref. Nr.	Number	Country	Short title	Power (kWp)	Nr. of systems	Peak p.(W)	Peak p.(W)	Peak p.(W)	Modules	Batteries	Inverter	Back-up
						of smallest system	of largest system	average of all systems				
1	86327	ES	57 dwellings	21.8	79	800	3600	276	ISOFOTON M402	FEMSA	PASSCO	Diesel
2	88073	ES	Village electrif.	11.0	1	11000	11000	11000	BP SOLAR 345	TUDOR	VICTRON	none
3	83466	FR	40 isolated houses	26.6	40	400	1500	665	PWP 400 + 402	OLDHAM	SGTE/FAIVELEY	none
5	85138	IT	30 isol. houses	10.5	30	350	350	350	PRAGMA/ANSALDO	VARTA	none	none
6	89416	IT	Island electrification	34.5	17	1300	6000	2029	HELIOS H30C	FULMEN	TELETECNICA	none
7	83314	HE	Isolated houses	33.6	12	700	25000	2803	AEG	TUDOR	AEG	Diesel
8	83404	HE	Remote village	25.0	1	25000	25000	25000	PHOTON BOS 401 (B)	TUDOR	AEG	Diesel
All EPU contractors				163.0	180							
9	87421	ES	Remote village	11.8	2	2800	9000	5900	AEG + CHRONAR	FEMSA	MARATHON	none
10	88116	ES	Farm houses	12.3	38	90	450	323	PHOTOWATT BPX 47402	FULMEN	AMBAR	none
11	90063	ES	Rural electrific.	12.3	24	180	1350	513	PHOTOWATT BPX 47451	HOPPECKE	AMBAR	none
12	86103	FR	Isolated houses	8.6	22	80	3100	390	PHOTOWATT BPX 47500	OLDHAM + FULMEN	SFEI 3	none
13	87034	FR	Electrification	6.9	98	40	80	70	PHOTOWATT 40 W	VARTA + SAFT	none	none
14	85540	IT	7 dairy farms	26.7	5	80	6900	5340	ANSALDO	MARELLI	A G F	none
15	84084	DE	Oberlinhouse	2.2	1	2200	2200	2200	AEG PQ 10/40	VARTA	EL-Bektronik	Diesel
All manufacturers contractors				80.8	190							
16	86337	ES	35 houses	13.9	35	158	474	398	ISOFOTON M-40-L	TUDOR	AMBAR	Diesel
17	89061	ES	Rural electrification	16.9	18	240	5460	941	ISOFOTON M 401	TUDOR	SUNPOWER	Wind+Hydro
18	90111	ES	Pyreenes electrific.	15.6	28	94	4230	557	ISOFOTON M-75-L + BP 275	FULMEN	ASP	Wind+Hydro
19	92084	ES	Rural electrification	47.4	70	280	1800	677	ISOFOTON M-75-L + BP 276	FULMEN+TUDOR	SIEMENS	Diesel
20	84696	FR	Alpine huts	5.4	13	280	650	415	PHOTOWATT PWP 402	FULMEN	none	none
21	85501	FR	29 mountain huts	6.0	23	80	480	261	PHOTOWATT+Helios+Chronar	STECO +	none	Diesel
22	87167	FR	Nat.cycling museum	3.6	34	45	1300	105	PHOTOWATT BPX 47451	OLDHAM + SAFT	CONVERSOL	none
23	88213	FR	Mountain huts	8.6	61	45	900	142	PHOTOWATT BPX 47451	OLDHAM + SAFT	CLEMESY	none
24	88389	FR	Natural parc electr.	16.5	34	80	4000	485	PHOTOWATT+SIEMENS+BP	STECO+OLDHAM	VICTRON	none
25	89073	FR	Nature parks	14.3	30	100	2300	478	PHOTOWATT BPX 47500	OLDHAM + STECO	MARATHON	none
26	89075	FR	40 pyrenean sites	30.4	40	160	1890	760	PHOTOWATT+ISOFOTON	FULMEN+TUDOR	MARATHON	Diesel
27	90205	FR	Nature parks	11.4	73	48	1152	156	PHOTOWATT BPX 47500	STECO,VARTA,FULMEN+	VICTRON	none
28	91124	FR	Mountain farming	7.7	53	38	530	144	PHOTOWATT+others	STECO	none	none
29	86215	PO	Rural dwellings	26.5	52	45	1600	510	AEG+PHOTOWATT	FULMEN,VARTA +	VICTRON	Diesel
30	89283	DE	5 Alpine huts	13.3	5	900	5400	2660	AEG/SIEMENS	BAYERN,HAGEN +	EL-Bektronik	Diesel, gas
All users contractors				237.6	569							

Table 2.

Economical aspects

Cost and specific cost of the systems

The total cost of all described 29 systems was about 17 million ECU.
The average specific cost of these projects was 38 ECU/W_p.

Cost of electricity

From the implemented systems it can be seen, that the cost of electricity is high.
Costs are well above 4 ECU/kWh and especially for systems mounted in sites with difficult access very much higher.

The contractors quote the following figures:

7.3 ECU/kWh, replication 6.7 ECU/kWh [1].
3.4 ECU/kWh, replication 2.5 ECU/kWh [3].
18.1 ECU/kWh [7].
6.8 ECU/kWh [8].
21.7 ECU/kWh, replication 8.9 ECU/kWh [15].
(to be compared to 9.5 ECU/kWh for a grid extension at that specific site and to 3.4 ECU/kWh for Diesel generation.)
26.6 ECU/kWp [20],
(of which about 13.5 ECU/kWp just for the costly installation in the mountains. They are approximately as high as the cost for a comparable Diesel generator. Grid connection is not feasible for these refuges.
32.0 ECU/kWh, replication 9.1 ECU/kWh [22].
7.1 ECU/kWh, replication 3.4 ECU/kWh [23].
In many of the sites grid connection is not possible. In cases were grid connection would be possible the energy cost would be of the order of 15 ECU/kWh.
Many similar systems were implemented in other natural parks, which proves the interest of the users for this improvement of comfort (lights) and safety (radio telephones) in these isolated sites.

Use of available electricity

In the average the consumption of electricity is often much lower than the potential of the system would allow: The final yields are low and often below 1 kWh/(d.kWp).
Modular design of system size is necessary, with the possibility of up-sizing if the consumption increases.

MAINTENANCE OF THE SYSTEMS
TECHNICAL ASPECTS

Frequency of failures and need for intervention

The contractors report the following problems concerning failures and interventions:

- The frequent breakdowns of the inverters had a strong negative impact on the users confidence; explanations why this and that happened does not interest the user. If it takes several days to repair an inverter breakdown, this has a large effect on the everyday life of the user [1].
- The main problems encountered were:
  - with the batteries (precipitation, low capacity, charge regulator, deep discharging)
  - with the modules (oxidation - short circuit, eventual destruction and replacement)
  - with the autonomous units (charge regulator-replaced).
- The project apart from its social success and acceptance by the public, which is no mean achievement in itself, had its share of technical problems and exceeded its budget [7], [8].
- The users are satisfied, as long as the inverter works. But the inverters fail too often. The contractor is trying to propose a maintenance contract to the users, but the reactions are scarce so far. An agreement with the unsatisfied users should be reached in order to avoid damage to the reputation of pv electrification [10].

Conclusion

The inverters are presently the weakest component of the systems. Problems with low quality ac (harmonics and perturbation of electronic equipment as well as difficulties starting all kinds of motors) have to be solved yet for many inverter types.

More often than expected the systems on isolated sites are damaged by lightnings.
Batteries so far show good quality; but the problems may show up with increasing age of the batteries.

Reporting of failures

In detail the contractors report:

- Data collection by radiotelephone becomes more difficult or impossible because the telephones are modified by the users for other purposes (frequency sharing) [10].
- Data transmittance via radio, as used in the monitoring systems of project 88116, despite of its problems, is much more convenient than the collection of the memory cards [11].
- Fourteen of the systems are remotely controlled via EnerSat. Five levels for intervention are fixed ranging from "small perturbation" (no intervention) to "stop" (immediate intervention). Intervention cost must be in a reasonable relation to the value of the systems. For efficient intervention are necessary: good qualification of the repair staff, availability of spare parts, repair staff available near the site, sufficient profit for the repair staff to make such work attractive [26].
- Some monitoring data can be called by minitel [27].

Conclusion

For isolated sites it is essential, that system failures are reported rapidly.

Some sites have only seasonal users; in these cases distant survey of the status of the system is necessary in order to avoid larger damage in case of certain failures (battery deep discharge).

The distant survey devices (telephone modem or satellite transmission) are still rather expensive and sometimes unreliable. But once installed, they can be used not only for giving alarms but also for continuous monitoring data transmission.

Types of preventive maintenance

In detail the contractors quote:

- It has turned out to be very difficult to establish a contractual relationship between the EPU and the users. No possible management schemes have emerged from this project. But Sevillana has subcontracted, with considerable cost, to the installer firm a maintenance contract to keep the systems in perfect operating conditions for a number of years [1].
- Installation life depends very much on the care taken by the users. The most sensitive element from this point of view is the battery, the extent of discharge, the maintaining of the electrolyte level and regular equalizing charges [3].
- PPC will continue to provide service, maintenance and spare parts, aiming at providing as reliable a power supply as possible [8].

Conclusion

Preventive maintenance of the installed systems exists only in very few cases, because nobody of the users is willing to pay for it. Yet it would be an essential factor, if the systems shall continue their satisfactory operation for many years.

ECONOMICAL ASPECTS
COST OF MAINTENANCE

Concerning maintenance the contractors report:

- Two damaged inverters had to be repaired. As the users refuse to pay for the global maintenance contract they have to pay each reparation separately [10].
- The installations need a certain maintenance and checking. Replacement of the batteries is not foreseen at the start of projects in order to limit the initial cost. But experience shows, that it would be better provide from the very beginning funds for repair and maintenance. For healthy development, solar pv electricity needs "guaranteed results", similar to the ones of grid connections [22].
- More attention has to be paid in future projects to battery maintenance (accumulation of funds for replacement) [23].
- For operation assistance a trained, local responsible exists. He is in contact with the users and the installers. This procedure seems to be satisfactory for getting the best operation of the pv plants [29].

Conclusion

The expense of adequate maintenance and repair service is too often underestimated. Apart of the mere cost for the maintenance work, it is to be taken into account, that reaching the isolated, dispersed sites of the systems is often very difficult and time consuming. So nobody is really interested to do such work.

Many rural pv systems have been implemented by small or medium sized installers with insufficient monetary resources for the provision of later repairs and maintenance. The users, that in the first hand had no money to buy their pv systems, later don't have the money to pay for repairs and maintenance. Hence this necessary work is not done, often not because of lack of good-will but simply because of lack of money.

But without maintenance the user will soon become very dissatisfied with the service provided by the installation. If he has made investments in appliances and equipment, that later become useless for lack of electricity supply, his anger will be yet stronger. So the maintenance aspect can be predominant for the long-term acceptance of pv as a means of reliable rural electrification.

Funding only the installation of rural systems is hence double-edged: On the one hand it helps the user to get electricity that he never could afford with his own means, but without the provision of after-sales maintenance service this benefit can rapidly turn into nuisance and frustration of the user.

A solution could be to encourage and subsidize follow-up contracts for maintenance for systems of "low-income" users.

But a general solution for the maintenance problem has still to be found. The user should not be left alone to look for a valid and capable maintenance technician once the system has been installed. The installer or a public unit have to care for it. A solution could be that the user pays into a maintenance fund as much as a grid-connected user pays for the consumed electricity. Perhaps the EPU's could play a role in this field.

Insurance of the pv equipment is actually inexistant.

SOCIAL EFFECTS

FOR THE USER

Change of lifestyle. Acceptance of electrification ?

The following aspects have been mentioned by the contractors, concerning social effects:

- The project started with three years long social inquiries, with frequent visits to the site, to learn about the needs. Old people do not want electrical appliances, but only "the light". People that at the beginning did not want electrification came later asking for it. Younger people manage their energy resources very well. The use of pv systems can be a fundamental step helping to create the necessary infrastructure to stabilize rural life in its environment. As a matter of fact the youngest families in the village have built new homes and made investments that clearly show their will to establish themselves in the village, to which effect comfort enabled by pv electrification has been of the greatest importance. Regarding ac consumption there is a clear trend towards increase in demand due to an increase in the purchase of household appliances [1].

- The main success is the global satisfaction of users whose essential electricity needs, lighting, refrigeration, television are provided for. TV application helps to overcome the solitude of geographically isolated users, bringing them news and culture [3].
- The huge effort made for the installation of the systems has given extremely positive results. The users are very satisfied with the comfort and safety attained by the use of solar energy. After the end of this project already 50 other refuges have been equipped with pv systems. In our days the shepherds have a modern lifestyle and they want to maintain this in their summer huts. The available amenities help to maintain this rather unusual profession [21].
- The installations operate to the complete satisfaction of the refuge wardens, who have enough energy for their needs [27].
- A survey in Portugal of the 52 sites which were pv-electrified showed the following alternatives in case this electrification had not become available:

  8 refuges: continue with gas illumination.
  23 rural sites: waiting for the technically feasible mains connection.
  8 rural sites: continue without electricity.
  3 rural sites: buy a Diesel generator.
  10 rural sites: abandon the site.

  Solar generators were accepted by the local authorities as a costless alternative to grid connection. This lead to a compromise: on the one hand inhabitants have electricity, but not "as good" as mains, on the other hand they do not have to pay for it. Most of the inhabitants are aged and poor people, that continue to live in these isolated sites The authorities try to break the feeling of isolation [29].
- Our experience shows, that for smaller refuges, pv systems sized around 1 kWp offer a remarkable increase in comfort compared to the former electricity supply by a motor generator. For larger refuges the use of pv systems makes only sense if the initial electric demand is reduced by a total energy concept [30].

Conclusion

Shortly after installation of the system most users are very satisfied.

Information on energy efficient use and maintenance

In detail the projects showed:

- Progress can still be made in informing the users how to run their installation better (more detailed and clearer instructions, what to do in case of incidents) [3].
- Due to the relatively high cost of pv generated electricity, consumers are encouraged to use

high efficiency domestic appliances, and were generally educated about the use of electricity [8].

- The installer shall prepare proper information and maintenance documentation for the owners and for the end users. (Two types of manuals: 1.) One manual at the intention of the end user, who has no technical knowledge: On one A4-page the essential points should be summarized. These simplified operation instructions should be sandwiched between plastics and fixed on the wall near the installation. 2.) Another manual containing full operation and maintenance details. This manual should be given to the end user at the moment of the commissioning.) It has to be emphasized, that the batteries will have to be replaced after some years and that proper reserve funds should be created by the owners for this purpose [22].
- On the Portuguese market low consumption refrigerators are not available [29].

Conclusion

Most pv users are older people; Especially they, but also most other users need technical help.

Role of the utility companies

The results of the EU projects concerning the role of EPUs.

- It is certain, that a positive attitude concerning this type of electrification from the part of the "Fonds d'Amortissement des Charges d'Electricité" would have considerably facilitated matters and would be a factor of development for such programmes in France in the future. One of the failures of the project is that we did not manage to obtain funding from an institutional source [3].
- ENEL is interested in rural electrification as it presents an alternative to the conventional electric power line whenever the cost of hook-up to the grid would be too high and the demand for electricity too low to justify such expenses [5]. ENEL has made feasibility studies for electrification of 600 potential sites, finding it most interesting to continue studies for modular systems with less than 1 kWp and in combination with a solar water heater unit [6].
- PPC goes ahead with the realization of a commercial pv programme, which involves the installation of 70 autonomous small pv units of 700 Wp each in about 24 small and isolated islands. Furthermore PPC has announced that its pv installations by the year 2000 will have reached 1 MWp [7].

Conclusion

The utility companies should play a much bigger role in the electrification of rural sites than they actually are willing to.

The cost of rural electrification cannot be carried by the rural users. The EPU's should intervene with money, that they collect from all electricity consumers by adding a very low contribution to the cost of the kWh.

In the early days of electrification the local municipalities provided the power stations in the towns. Something similar has to be organized now for the provision of pv electricity to the isolated sites.

In view of the electrification of the third world, where pv is the only valid alternative, it is also important to take from the pv electricity the idea of "second class electricity".

REFERENCES

[1] - Project 86327 FINAL REPORT: Photovoltaic Rural Electrification of 79 Dwellings at Sierra de Segura (Jan), EUR 15167 ES/EN, Corporate authors: CSE, CIEMAT-IER, IES-ETSI, ISOFOTON, (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-826-7449-5 (1994).

[2] Project 88073 TITLE: 10 KWP PV POWER SUPPLY FOR "LOS ARCOS" VILLAGE. Intermediate report nr. 6, J. Garcia Martin (1992).

[3] - Project 83466 FINAL REPORT: PROGRAMME OF RURAL ELECTRIFICATION BY PHOTOVOLTAIC GENERATORS. P. Coroller, B. Aubert, AFME. EUR 12755 FR/EN, (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-826-1491-3 (1990).

[4] - Project 83466 Atelier sur les "40 maisons en France", AFME/CEE (1987)P. Roller, W. Kaut, EUR 11436 FR/EN, (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-825-8279-5 (1988).

[5] - Project 85138 TITLE: PV ELECTRIFICATION OF 30 HOUSES IN THE AEOLIAN ISLANDS (GINOSTRA).Intermediate report nr. 9, A. Previ (1990)

[6] - Project 89416 TITLE: STAND ALONE PV PLANTS FOR ISOLATED USERS ON ISLANDS Intermediate report nr. 6 A. Previ (1993).

[7] - Project 83314 FINAL REPORT: ANTIKYTHIRA PHOTOVOLTAIC PLANT. EUR 14827 EN. Corporate author: Public Power Corporation, Greece (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-826-6578-X (1993).

[8] - Project 83404 FINAL REPORT: ARKI PHOTOVOLTAIC PLANT.EUR 14825 EN, Corporate author: Public Power Corporation, Greece (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-826-6307-8 (1993).

[9] - Project 87421 TITLE: PV POWER SUPPLY FOR REMOTE VILLAGE RAMBLA DEL BANCO. Intermediate report nr. 6, J. Kr_ger (1992).

[10] -Project 88116 TITLE: PV POWER SUPPLY FOR FARM HOUSES WITH RADIOCOMMUNICATION CONTROL. Intermediate report nr. 9, A. Candil Toribio (1994).

[11] -Project 90063 TITLE: PV SYSTEM FOR RURAL EXPLOITATIONS. Intermediate report nr. 6, A. Candil Toribio (1994).

[12] -Project 86103 TITLE: PV ELECTRIFICATION OF HUTS AND HOUSES IN N. E. CORSICA. Intermediate report nr. 5, R.Barthez (1992).

[13] - Project 87034 Final report: Photovoltaic equipment for the Roya Valley.R. Barthez. B. Ouaida, TOTAL ENERGY. A "Yellow" report, to be obtained from: Commission of the European Communities. Directorate General XVII "Energy", 200, rue de la Loi, B - 1049 Brussels].

[14] - Project 85540 TITLE: PV ELECTRIFICATION OF DAIRY FARMS IN ALPINE PASTURES Intermediate report nr. 5, E. Varengo (1993) ANIT.

[15] - Project 84084 FINAL REPORT: PV SYSTEM WITH GAS-POWERED GENERATOR SUPPORT IN STAND-ALONE OPERATION. H. K. Koethe, E. Roessler, EUR 14523 DE/EN,(Office for Official Publications of the European Communities), Luxembourg, ISBN 92-826-5204-1, 1993.

[16] - Project 86337 TITLE: PV ELECTRIFICATION OF 35 RURAL HOUSES IN THE COUNTY OF "EL SOLSONES". Intermediate report nr. 4, X. Vallv_ (1992) and monitoring reports.

[17] - Project 89061 TITLE: PV/WIND HYBRID ELECTRIFICATION OF 22 RURAL HOUSES Intermediate report nr. 4, E. Llobet (1993) and monitoring reports.

[18] - Project 90111 TITLE: PV/WIND ELECTRICITY AND SOLAR HEATING FOR ISOLATED FARM HOUSES. Intermediate report nr. 2, E. Llobet (1994).

[19] - Project 92084 TITLE: RURAL PV ELECTRIFICATION IN THE CATALAN REGION OF LA GARROTXA. Intermediate report nr. 2, J. Serrasolses (1994).

[20] - Project 84696 FINAL REPORT: PHOTOVOLTAIC EQUIPMENT FOR 12 LODGINGS AND HUTS IN THE FRENCH ALPS. J. B. Dufrien, C. Marquet, EUR 14121/FR/EN, (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-826-4361-1 (1992).

[21] - Project 85501 FINAL REPORT: INSTALLATION OF PHOTOVOLTAIC GENERATORS AND SOLAR POWERED HEATING SYSTEMS IN 23 REFUGES IN THE FRENCH ALPS AND PYRENEES. P. Waldner (CLUB ALPIN FRANCAIS), J. Guerry (ENERPOLINGENIERIE) EUR 13244 EN/FR, (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-826-2004-2 (1991). Book: L'Electrification photovoltaique de 35 refuges alpins en France. Projets de démonstration SE/696/84 et SE/501/85. L. Lefébvre; K. Kaut, EUR 12213 FR, (Office for Official Publications of the European Communities), Luxembourg, ISBN 92-825-9977-9 (1989).

[22] - Project 87167 FINAL REPORT: PHOTOVOLTAIC ELECTRIFICATION OF A CYCLING MUSEUM AND OF MOUNTAIN SHELTERS FOR SHEPHERDS - HAUTES-ALPES, FRANCE, Corporate auth.: Parc National des Ecrins, et al. EUR 14393 FR/EN, (Office for Official Publications of the European Communities), Luxemburg, ISBN 92-826-5967-4, (1993).

[23] Project 88213 FINAL REPORT: PHOTOVOLTAIC ELECTRIFICATION FOR HUTS, REFUGES AND HOTELS IN THE FRENCH ALPS, Corporate auth.: Parc naturel régional du Queyras, EUR 14455/FR/EN,

(Office for Official Publications of the European Communities), LUXEMBURG, ISBN 92-826-6191-1, (1993).

[24] - Project 88389 TITLE: SOLAR ELECTRICITY AND HEAT FOR THE VERCORS NATURAL PARK. Intermediate report nr. 5, D. Jaques (1994).

[25] - Project 89073 TITLE: PV ELECTRIFICATION OF REMOTE HOUSES AND FOR WATER TREATMENT. Intermediate report nr. 7, JL Sadorge, JL Barret (1994).

[26] - Project 89075 TITLE: TRANSPYRENEAN ISOLATED PV SITES PROGRAM MANAGED BY METEOSAT SYSTEM. Intermediate report nr. 7, J.Y. Quinette, J. Serrasolses (1994).

[27] - Project 90205 TITLE: PV ELECTRIFICATION FOR PROTECTED NATURAL AREAS IN FRANCE AND OVERSEAS. Intermediate report nr. 5, J.L. Barret, (1994).

[28] - Project 91124 TITLE: SOLAR ENERGY FOR MOUNTAIN FARMING IN RHONE-ALPES. Intermediate report nr. 6, L. Lefebvre,1994).

[29] - Project 86215 TITLE: PV ELECTRIFICATION OF ISOLATED RURAL DWELL-INGS. Final monitoring report, P. Felix, (1992).

[30] - Project 89283 TITLE: PV HYBRID SYSTEMS FOR 5 REMOTE SITES IN THE GERMAN ALPS Report with monitoring data, E. Reler, (1993).

QUESTIONS AND ANSWERS

Q. There is a new proposal known as **PV Power for the World**, which will be implemented and will be funded DG XII European Commission. This is going to be a joint program where UNDP will be collaborating with DGXII. There will be standard equipment developed which will be tested at ISPRA. So I thought It was appropiate to bring that additional information on the European Union's program with PV.
A. Yes, thank you very much I didn't have time to mention that just on Thursday this week, Mr. Ernesto Pérez Carbonell will introduce for the DGXII this proposal; that is, this request for collaboration. Hopefully something will come out of it, and we will see in the future.

Q. I just want to ask you something about grid versus stand alone. You mentioned that grid connection was economical for distances less then 1200 to 1100 meters. Did you make studies for that? or is it the result of some experimentation?
A. These are not old studies. These are studies made mainly in France. In fact, if you look in the references of the paper, you will find that (I think it is no. 4) a book sur le "40 maisons en France", made in 1987 already. And these figures, they did not change so much. They came out of these studies.

Q. You should consider that in reality in The European Union, photovoltaics has very few applications for rural electrification. Very isolated places. But I understand, perhaps I am wrong and I want your comment, that a different approach is made in Switzerland. That the Swiss government supports relatively massive effort on photovoltaic systems.

A. Yes, I don't know whether I understood completely the question. Of course you might now have the impression that PV is a specially only for isolated sites. However, this was just a selection. There are in our project many more applications. In fact now, in the recent years, grid coupled PV systems have been installed over the roofs. Was your question concerning the use of PV in general? or just the financing of the isolated sites?

Q. The use of PV in general.
A. Right, of course it is much broader. I limited my paper here to rural electrification.

ELECTRIFICATION PROJECT IN THE REPUBLIC OF KIRIBATI

Masahide Takahashi
Shikoku Research Institute Inc.
Japan

INTRODUCTION

Shikoku Research Institute Inc (Group of Shikoku Electric Power Co.) has performed an electrification project of the Republic of KIRIBATI for 2 years, from 1992 to 1994. This has been performed upon the decision by the JICA (Japan International Cooperation Agency) to execute the district electrification project by PV (Photovoltaic) power generation, in the northern TARAWA district of TARAWA Island in KIRIBATI, based on the request by the Republic of KIRIBATI. Its outline is as follows:

1. OUTLINE OF THE REPUBLIC OF KIRIBATI

There are 33 islands (23 islands are inhabited) in the South Pacific Ocean, crossing over both the international date line and the equator.

The population is about 72,000. The land area is only 725 km2. Most is composed of flat coral reef with a height of a few meters over sea level.

The sea area is as wide as 3.5 million km^2.

Fig.1-1 shows the locality of the Republic of KIRIBATI. Fig.1-2 shows the outline of TARAWA Island surveyed by this project.

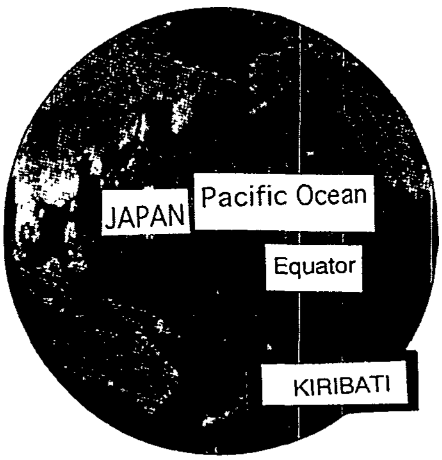


Fig. 1-1 Locality of the Republic of KIRIBATI.

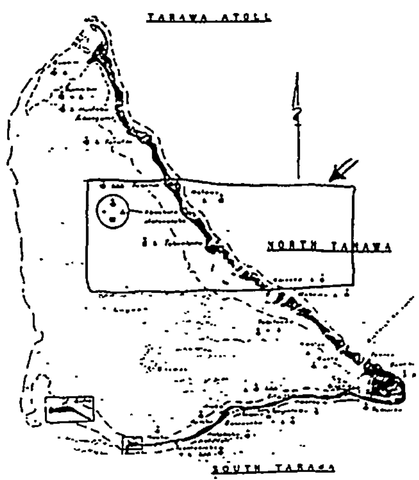


Fig. 1-2 Outline of TARAWA Island.

MX9900018

PV RURAL ELECTRIFICATION IN KIRIBATI: A CASE STUDY

Dr. Suresh Hurry
Energy and Atmosphere Programme, SEED/BPPS
UNDP - New York

ABSTRACT

In collaboration with the Japan International Cooperation Agency (JICA), UNDP participated in the implementation of a photovoltaics (PV) rural electrification project in Kiribati. Under this project, assistance was provided to the Kiribati Solar Energy Company (SEC) in order to enable it to provide electricity service as a micro utility in an effective manner. The assistance provided included installation of 55 PV-based solar home systems and one community system. In addition, the assistance focussed on technical training of SEC personnel on PV systems and management training on accounting, billing, spare parts inventory, etcetera.

INTRODUCTION

Kiribati consists of 33 islands located in the mid-Pacific, astride both the equator and the international date line, constituting the three main groups of Gilbert, Phoenix and Line Islands. The total land area amounts to only 810.5 km^2 and, as per the 1990 census, the total population was 72,298 inhabitants with approximately 21% living on the central island of Tarawa. The per capita GDP is estimated to be A $562. (1 US$ = 1.31 A$)

The Public Utilities Board (PUB) owns a 3.18 MW diesel power station on the main island of Betio in South Tarawa, but in view of the lack of spare parts and the limited reliability and age of the equipment, only the 1 MW generator is available at all times, with the 2 X 750 Kw units used for handling the peak load as well as for providing the reserve capacity in the event of maintenance or forced outage of the 1 MW unit. PUB distributes electricity through an 11 KV underground cable distribution system extending 35 km to Nabeina in North Tarawa. PUB's total electricity sales in 1989/90 were 6,502 MWh which were supplied to a total of 3,021 consumers, of which 2,200 were classified as residential, 234 commercial and 455 industrial, including Government facilities and offices[1]. Aside from Tarawa, the only other location with a public generation and distribution system, albeit extremely limited, is Kiritimati Island in the remote Line Islands.

INSTITUTIONAL FRAMEWORK

An Energy Planning Unit (EPU) was established within the Ministry of Works and Energy

---

[1] *By "sustainable" we mean in particular "economically viable", both for the public institutions and for private operators.*

(MWE) in January 1984, following the adoption of the Kiribati National Energy Plan in December 1983.

As outlined in the "Energy Planning Unit Development Plan 1992-1995" prepared in July 1991, one of EPU's objectives is "to reduce Kiribati reliance on imported fuels through the application and use of renewable energy sources, energy conservation and fuel substitution". In line with this, EPU proposes "to promote and encourage the use of solar PV systems in the rural areas" where diesel electricity generation is neither technically feasible due to the difficulties in ensuring a regular supply of fuel and providing efficient and reliable operation and maintenance, nor economically viable in view of the high cost of generation.

SOLAR ENERGY COMPANY

In its effort to promote development of the rural/remote areas and conscious of the tremendous difficulties encountered in providing a reliable and economical supply of electricity to these areas through diesel power generation and/or grid extension, the Government decided in 1984 to establish a Solar Energy Company (SEC) with the responsibility for undertaking rural electrification through the use of photovoltaic (PV) systems. SEC was established with assistance from the United States Agency for International Development through the Foundation for the Peoples of the South Pacific. As a corporate body owned by the Government of Kiribati and placed under the responsibility of the Ministry of Works and Energy, SEC has been provided with the mandate to undertake rural electrification utilizing PV systems. PUB grid extension beyond Nabeina is considered unviable due to the small electrical loads to be supplied; hence, the proposal to utilize small decentralized PV systems/solar home systems (SHS). As outlined in the May 1992 World Bank PREA Report [1], "recent experience (among the Pacific Island Countries) indicates that PV systems for remote island communities, although initially expensive, can be competitive at current costs (on a life cycle cost basis) with small diesel-based electric power systems". Since its establishment, SEC has been involved in the sale and installation of PV systems among the rural population as well as in the installation of systems under Government-funded projects. By 1986/87 it had sold some 200 PV systems. However, by 1989, only a small number of these systems were still operating, the others having failed for a variety of reasons including cost saving, after-purchase installation undertaken by "unqualified" owners rather than SEC, as well as repairs being attempted by owners to avoid the cost of an SEC technical visit. This led to the reputation of PV systems in Kiribati to be badly damaged, with the result that sales of SHS fell to a level that was too low to sustain SEC.

In 1990 the Government decided to reorganize SEC into a "Utility Company" from its original role of being a "Sales and After-Service Company", along the lines of the successful experience of the Tuvalu (neighboring small island country) Solar Electricity Cooperative Society. This concept is based on the institutional approach for the provision of PV-based electricity as a utility service, rather than through the mere sale and installation of hardware. Consequently, the utility (in the present case, SEC) will retain ownership of and provide maintenance, for a service fee, to the SHS installed on the customers' premises.

THE JICA/UNDP PROJECT

The Japan International Cooperation Agency (JICA)[2] agreed in March 1991 to provide technical assistance to the Government of Kiribati for a PV programme under which 55 houses and 1 Maneaba (community hall) on North Tarawa would be electrified with PV Systems in January/February 1993. While hands-on training would be provided by JICA during installation of the PV systems, SEC would require additional technical and management support in order to enable it to perform effectively as a "Utility Company". This was recognized by the World Bank PREA mission which recommended that "SEC train its staff for the management and design of renewable energy projects, with emphasis on Solar technologies". In line with this, at the request of the Government of Kiribati, UNDP agreed to provide assistance to the Solar Energy Company in order to enable it to perform in an effective manner as a micro-utility. The assistance provided focussed on technical training of SEC personnel on PV systems and management training on accounting, billing, spare parts inventory, etc.

Under the project, 55 solar PV home systems and 1 community PV system (Maneaba) were installed in January 1993 on the following islands in North Tarawa:

Island	No. of PV Systems Installed
Taratai	2
Notoue	15
Abaokoro	25
Tabonibara	6
Kainaba	4 + 1 in Maneaba
Marenauka	3
TOTAL	55 + 1 in Maneaba

Each solar home system consists of 2 x 55 Wp poly-crystalline silicon panels, 1 x 100 Ah deep discharge battery, a battery control unit (BCU), 3-PL type lamps (1 x 11 W, and 2 x 7 W) and 1 x 1/4 W LED night lamp. The PV system installed at the Maneaba consists of 6 x 55 Wp panels, 300 Ah of battery capacity and 4 x 11 Watt lamps. A monthly fee of A$9 - this represents the average monthly expense incurred per household for the purchase of kerosene/flash-light batteries/candles for lighting - 50% of which is set aside for amortizing the system, is paid to SEC by each individual consumer while the Island Council pays A$25 a month for the community system.

Each consumer paid an installation fee of A$50 (the average monthly income per household is A$160) which provided for internal wiring and lamps. The solar system up to the circuit breaker at the battery output is owned by SEC, with the consumer owning the internal wiring and lamps.

[2] *By "solvent" we designate consumers who pay a price for access to service; this price does not necessarily cover all costs, that may be met in part by governmental bodies.*

FINDINGS OF TECHNICAL ASSESSMENT

An assessment of the project was undertaken in February 1994, one year after the installation of the PV systems. This assessment revealed the following:

TECHNICAL ISSUES

Except for minor technical problems, all systems have been performing as per their design specifications. The two minor technical problems were:

a) The battery cut-off voltage on the BCU is set at 15.6 V instead of the "normal" setting of 14.4 V adopted on other installations in the region and this gives rise to excessive gassing. Consequently, distilled water has to be added to the battery every two weeks instead of every 2 months (on an average) for similar systems. This would not be a problem if the cost of distilled water in Kiribati were not very high, i.e. almost A$1.00 per liter (Gasoline sells for Australian 73 cents per liter). As rain water in Kiribati meets the requirements of the battery manufacturers, it can be used to top up the batteries, provided that the rainwater is collected free of any contaminants. But rainwater contamination can create serious problems for the batteries and, therefore, it was recommended to SEC to modify the cut-off voltage on the BCU to 14.4 V, thus decreasing the frequency of "top-ups" and, consequently, reducing the likelihood of battery damage.
b) The 7 W lights have had a failure rate of approximately 20% due to faulty ballasts. The manufacturers have replaced these lights under the one-year warranty and will upgrade the ballasts to prevent a repetition of these faults in the future. It was noted that 250 solar home systems had been ordered under funding provided by the European Union under Lome II and would soon be installed on the islands of Marakei, Nonouti and North Tarawa (all in the Gilbert group of islands). In this connection, it is worth mentioning that the training provided to SEC has strengthened its technical capability to such an extent that it was awarded a contract by the European Union for the supply of 750 BCUs and 800 night lights to the region under Lome II and III. The total value of the contract is US$ 130,000.

SOCIO-ECONOMIC ISSUES

a) There is a high level of satisfaction among the users of the solar home systems. Also, most of the users would like to have a socket outlet for a transistor radio and future systems will make a provision for this.
b) There has been increased social activity on the islands where the solar home systems have been installed and there is also extended time for studies.
c) Present economic activity on the islands is limited to fishing and weaving of thatch. The introduction of electricity has, to some extent, increased economic activity as repair of fishing nets and weaving can be undertaken into the night.

CONCLUSIONS

Several modalities have been utilized for the introduction of PV systems in the rural areas. One of them is the outright purchase of these systems by the consumers, but has mainly been utilized by the "rich" consumers and has not benefitted the poor. A second approach has been to set up cooperatives with the users obtaining a loan for the PV systems and making payments on a monthly basis for approximately 3 to 4 years to cover the capital cost, interest and maintenance. At the end of the payment term, the users become owners of the systems. One problem with this approach is that after the payment period, some users, in order to reduce costs, have not subscribed to a maintenance contract and have refrained from calling the service technician when technical problems arose. Instead, they unsuccessfully tried to fix the problem themselves and this resulted in some systems getting damaged and being left unutilized. A third modality, described above, has been to set up a private company (micro utility) to install solar home systems and the users are charged a monthly fee. The micro utility owns the solar home systems up to the circuit breaker after the battery, while the user owns the wiring, lights, etc. The monthly fee paid by the user is equivalent to the user's present monthly expenses for kerosene, candles and/or flashlight batteries, and approximately 50% of the monthly fee goes towards the overhead of the micro utility with the remaining 50% saved for equipment replacement. Under this approach, the system remains the property of the micro utility and is maintained without having the user enter into a separate service contract. In case of non-payment of the monthly fee by the user for more than two months, the Island Council has the option of making a loan to the user for the amount of the outstanding payment; otherwise, the system is disconnected and removed by the micro utility.

The micro utility approach can be and is being extended to involve the participation of regular Electric Utilities in the implementation of rural electrification programmes through decentralized PV systems. This enables the utilization, at least in the initial stage, of the existing technical, managerial and financial capacities of these Utilities.

REFERENCE

[1]World Bank Pacific Regional Energy Assessment (PREA) Report No. 10441-EAP: Kiribati - Issues and Options in the Energy Sector, May 1992.

[2]JICA: A Study of Utilization of Photovoltaics for Rural Electrification in the Republic of Kiribati - Executive Summary of Final Report, March 1994.

QUESTIONS AND ANSWERS

Q. Thank you for your very interesting description of a quite different world. I want to discuss in some detail the monthly charge cultural issues. I noted in your paper there was all installation fee of substantial proportions. Did that create cultural difficulties? As well the "why do we have to pay up front? We didn't pay 50 dollars a month to buy candles". Could you put that in

perspective for us?
A. Yes. The installation fee covered. It was explained to the people that they had to pay for the systems, or part of the system that they will own -they own the lighting, they own the internal wiring- And that installation costs/covered all the four lights and the wiring. And they readily agree to pay for that.

Q. Congratulations. It was a great presentation. I was curious to know: the monthly fee of 9 australian dollars, how much of the cost of the program and the equipment costs is actually covered by that fee?
A. To put in perspective, the systems were provided as a grant. So nobody had to buy the systems. They are a grant by the Japanese government. Now, of the 9 australian dollars fee, that is payed for by each consumer every month, 50% of it goes for the overhead of the solar energy company, and 50% is set up as the revolving fund. We have very few systems, only 55 systems, so you can imagine the revolving fund is very small. But then according to our own calculation in the context of Kiribati one of the small island countries, there will be a break even point when 500 systems would be installed. This has not been reached yet. We are close to it, but it has not been reached. Which means that the solar energy company cannot go to the open market, get a loan and buy the systems, and then make a profit. It won't a this moment. But when it reaches 500 systems, it will be able to do so.

Q. The question is along the same lines. You can reach a break even point from the economic point of view but, how do you envision this scheme getting larger and larger, in a larger territory like India or Mexico with very difficult access to the communities? Do you think charging, I mean, collecting is going to be something worth doing? Currently, some electrical companies prefer to give away electricity in very remote sites, because of the collecting costs.
A. I think that even in Latin America there are utilities working with PV. I think, one of the main reasons for my coming to this workshop was that I felt that in the workshop we would have people who have been promoting the utility concept. Either through a separately created utility, like the **micro utility**. And there is a disadvantage in the sense that, when you set out a **micro utility** like the Solar Energy Company, you have to provide the **micro utility** with technical capability; that is, technical training. It has to be provided with managerial training, with accountancy, they have to do accounting, billing and all that. All this could be short circuited if we work to get existing utilities to think, not initially to implement, but to think not always in terms of line extension, grid extension, but descentralized rural electrification. So I felt that we should have people from utilities that are "converted", so to say. And for those that are not converted, and lets talk and see what is it, how, IERE for example could be a facilitator to bring these two parties together. And try to find the common ground. I'll give you an two months ago I was in Zimbabwe. UNDP has a project in Zimbabwe, a GEF-funded project: 7 million dollars project, for solar home systems, including capacity building and all that. The utility, ZESA (The Zimbabwe Electricity Supply Agency) when it heard of descentralized rural electrification reacted: "what is all this we are not aware of that; we are not interested at all". We have been working over the last two years with ZESA. Now ZESA has agreed, has identified five villages, out of which one will be selected for descentralized rural electrification. And, it is on the basis that they are disperse -African Villages are quite disperse- There is going to be somebody who is going to be living there. I agree with you cannot do descentralized RE in the outskirts, in the

suburbs of all the outline areas of Mexico; that is, managing it from Cuernavaca. It has to be somebody who sits close by there, who has access to this people, by bicycle for example. In Kiribati we contributed to buy a bicycle for the technician, so that he could move around; or a horse here. But yet, there are all kinds and lots of difficulties, and we still have to work on that. And I think, that is the way to go, by trying to convince utilities that it is in their interest. It is cost effective. Also, from the point of view of the environment. It is cost effective to go for a discentralized rural electrification. But we have to make sure that, me as a consumer, as soon as there is something that goes wrong, I know where to go. I can not afford to wait for 5 days to get it fixed. Then I loose confidence totally. It has to be fixed the same day; if not, the next day.

Q. Can you comment on the end-use equipment? Who supplies it? is it part of the system? I know you said that it will be owned by the consumer, but then, what about new purchases of let say another lamp or something? Are these standard items that are available from somewhere? How is that handled?

A. The lamps are standard items that are freely available in the market. The solar energy company has got goods from a number of suppliers and from them they bought the lamps. So for the consumer, if there is a lamp there is a guarantee period, and any failure is taken care of during the guarantee period. It is a three year guarantee. But beyond that, the consumer knows that he can go to the same technician say "My lamp is not working" And for example if the tube needs to be replaced, it will be replaced and the user will be told that he will have to bear the cost. Now, we have also one point I should have indicated, but I forgot. I will mention it now. Very often people talk of collaterals. They say what is the collateral on the system? These are people who are poor. But the system itself is the collateral. We have placed a system whereby, if I do not pay (that is in Kiribati) my consumption over two months, the technician informs the Island Council Chairman, that the rent has not been payed over the last two months. There are two options available: one is that the Island Council will say, they have the "gramming bank concept". In the Bangladesh, where it's be a pressure, so the rest of you will pay and then put pressure on me to reinvert. So this is one way. The other way is, there are three people of the island community who will come to my house and remove the solar home system. Otherwise I might beat up the technician. We want to prevent that from happening. So that three people will come, they remove it. This has not happened. We didn't have to resort to that.

Q. You mentioned that after the people got the initial system, they wanted additional plugs for their transistor radios. I have read a number of reports where the people wanted more of, in addition to the lights, maybe television, VCR, things for sewing machines, so that they could produce products. Do you see that starting there in the islands? And the question is, are the systems expandable to do this?

A. It is very important, at the very beginning, as I said, to let the people know what is it that we can provide. And they are aware of that. Now, Kiribati is a place where the economy is fed from money. Everybody has a relative working outside somewhere: They are working on the japanese fishing boats; they are in New Zeland; They are in Australia. Of course they send them money. And people are aware that if they want to add on, -and those who get money from their relatives, they want to add on; -they want a VCR, they want to have a refrigerator, or whatever it is) they know that they can go to the solar energy company and buy. The solar energy company will maintain because they have the smaller systems. So that they will still have to pay the other fee. But the rest, they can buy. They will have a maintenance contract: every month they will have the technician coming over and looking over to make sure that everything is working. Yes it is expandable. They can do it.

Q. Are there any replication projects now, that are being planned or being implemented, that would use the results of the Kiribati project, that we know is being very good? Any other of the neighboring islands in the pacific?
A. Yes. The answer to this question is yes. All these neighboring countries, they are all using that system. As you may find in my paper, I mention the Tubalu Cooperative Solar Energy Company, similar to that. That is being replicated in many of these islands.

Q. How are they being financed?
A. They are being financed for the time being, by assistance, mainly from donors from Australia, New Zeland, Japan, the European Community. But the same kind of a **FINESSE** concept, energy service concept, is being financed as I indicated earlier, in Asia. The same thing is going to happen in Africa and also will eventually move into Latin America.

MX9900019

PV RURAL ELECTRIFICATION PROGRAMME AT THE BOLIVIAN HIGH PLATEAU

E. Lorenzo and J. Aguilera
Instituto de Energía Solar, ETSI Telecomunicación
España

ABSTRACT

Since 1988 the Institute of Solar Energy of the Universidad Politécnica de Madrid is carrying out a pv rural electrification programme at the Bolivian high plateau. This programme has been focused in three aspects: the domestic electrification, users participation and transfer technology. At present, there are about 1,500 electrified dwellings distributed in the Bolivian high plateau. We have got deep knowledge about life style and organization of the aymara Indians who are the inhabitants of the working zone. We think that this knowledge can be very useful for a large scale introduction of PV solar energy in this region.

Finally, we present a new way to transfer PV technology to developing countries. Thanks to this programme a group of aymara Indians is able to manufacture charge regulators and electronic ballast to use in the PV installations of the programme.

1. INTRODUCTION

Since 1988 the Institute of Solar Energy of the Universidad Politécnica de Madrid is carrying out a PV rural electrification programme at the Bolivian high-plateau. At the beginning, this programme was supported by the Spanish government but at present, it is also supported by CE. This programme was focused in three aspects:

- The domestic electrification by means of stand-alone systems composed of a PV module of 47 wp, a charge regulator, a 150 Ah battery and five fluorescent lamps and a plug for radio and TV.
- The users participation is structured around the Association of Solar Electrification (ADES) which is the owner of all the equipment.
- The local production of equipment used in the PV installations.

The total number of electrified dwellings (1,500) and manufactured equipment (7.000 lights and 1,200 charge regulators) shows the high level of maturity reached in this programme.

2. ENERGY SITUATION IN BOLIVIA

According to the last studies of the World Bank and CEE about energy situation in Bolivia, 700,000 families live in the rural areas and only 10% have available commercial energy resources. The consumption of these energy resources hardly gets 2% of the national demand of these resources[1]. In urban areas the situation is quite different. There is a large utilization of electricity. Table 1 shows the average consumption for the rural and urban family for different energy sources.

The present energy situation in Bolivia can be defined by the following characteristics:

1. Absence of forecast related to the energy demand in the cities. For example, at the present La Paz has a dramatic situation due to the population increase as a consequence of a migration process from the rural areas.
2. Absence in the national energy plan of measures to improve the present energy situation in the rural areas.
3. The investment in rural electrification plans is very low (3 USA$/year and inhabitant)[2].

ENERGY SOURCE	URBAN FAMILY	RURAL FAMILY
Biomass	0.104 TON/year	4,18 TON/year
Kerosene	25 lit/year	12-60 lit/year
Gas	195 kg/year	23 kg/year
Electricity	2,220 kwh/year	27 kwh/year

Table 1. Average consumption for rural and urban family for different energy sources.

Relating to conventional electricity, it is quite difficult that the present situation of the rural areas of Bolivia can change. The high investment costs (750 - 1,700 USA$/family)[2] due to disperse the habitat of this population and the poor access, joined to low economic level of the peasants (average yearly income of 250 USA$) make it difficult to change this situation. In this way, it is worth pointing out that there are some areas in Bolivia where the electricity is very expensive (0.7 USA$/kwh). Therefore, the biomass is, practically, the only oil used in rural areas, in fact over four million Has. of forest have disappeared in the 20 last years[4]. In the Bolivian high-plateau the biomass consumption is based, exclusively, in the use of the cows dung. This consumption accelerates the process to convert land into desert.

Related to the lightning, kerosene lamps are very used in this zone even though it low quality level and the high hazard of fire (most of the rural houses are built with easily fire materials).

In this general context, the PV solar energy appears as a real alternative to solve the energy problems of the rural areas in Bolivia. In this way, PV solar energy thanks to the high reliability and illumination quality is very attractive for this population.

3. PROGRAMME SITE

The programme has been developed at the Bolivian high-plateau. The most significant characteristics of the Bolivian high-plateau are:

- Altitude: 4,000 meters above sea level.
- Mean daily irradiance: 5 kwh/m^2.
- Mean ambient temperature: 10^0 C.
- Surface area: 150,000 km^2.
- Population: 3,000,000 inh.

The combination of a great deal of sunshine and low temperature is ideal, making it of the most suited areas in the world for PV generation. The disperse nature of the population and the fact they do not require many electricity makes photovoltaic the most viable solution.

INDIVIDUAL SYSTEMS

Living conditions on the high-plateau (isolated dwellings and cold climate) mean that a great part of their lifes goes on inside home. Consequently, the benefits of domestic electrification are closely felt by the users and have therefore been the focuses of this programme. With the twin objectives of keeping down costs and easing maintenance, all homes are equipped with identical systems each having a 47 wp PV module, a 150 Ah accumulator, a charge regulator, five light fittings with fluorescent tubes and reflectors and a power point for radio and TV. The whole system works at 12 volts DC. Table 2 resumes the consumption scenario used for sizing purposes.

APPLICATION	ESTIMATE CONSUMPTION (WH/DAY)
Lighting	72
Radio	32
Television (B/W)	60
Total	164

Table 2. Consumption scenario for sizing purposes.

In order to analyze the appropriateness of such scenario, 10 Ah counters were installed in some representative houses. The data was recorded daily by the users. Figure 1 shows the evolution of the consumption and generation in a representative house.

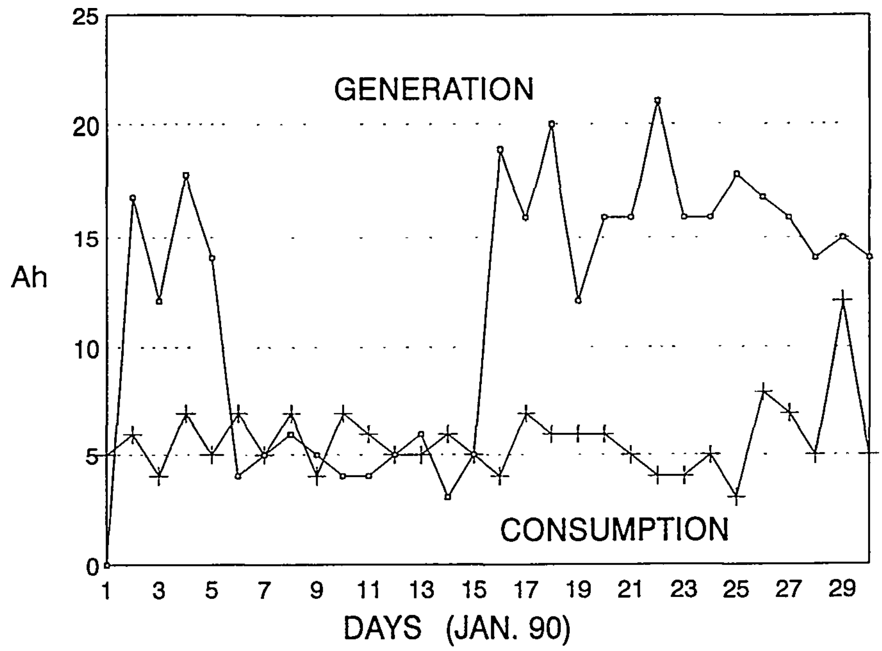


Figure 1. Monthly Evolution of consumption and generation in a representative dwelling.

Figure 2 shows the evolution of the number of the electrified dwellings in this programme. The present total of nearly 1,500 illustrates the size and maturity reached by this electrification programme.

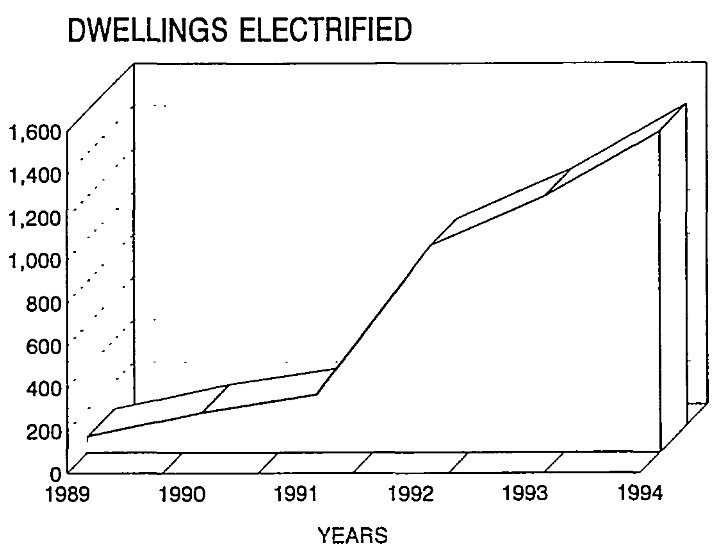


Figure 2. Evolution of the number of electrified dwellings.

Related to the cost, at the present the direct cost per dwelling is 630 USA$. Figure 3 shows the breakdown of this cost.

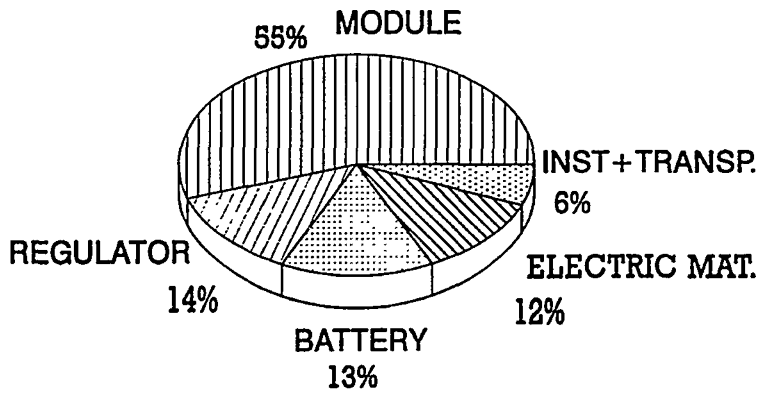


Figure 3. Breakdown of the cost of electrifying a dwelling.

The reasonableness of this cost becomes evident when we compare it with the associated with the extension of the conventional grid that, in this zone, is typically more than 1,500 USA$ per dwelling.

5. USERS PARTICIPATION

The social aspects related to the users participation have had an important role in the developing programme. The high participation level of the peasants, not very usual in rural developing countries, joined to 20,000 request (put in writing) for the families to participate in the programme show, clearly, the social repercussion in the work zone.

According to the strongly communal traditions of the inhabitants of the Bolivian high-plateau, the users have created the Association of Solar Electrification (ADES). In this way, ADES is the legal owner of the installations. ADES is governed by a council having one representative of each community that is involved in the project, and is legally inscribed in the Register of Associations in Bolivia.

In order to participate in the programme, each family has to conform some requirements established by ADES. These requirements are the following:

- Payment of an initial fee of 80 USA$ when the system is installed.
- Monthly maintenance fee of 1 USA$.
- Construction of a small building (1 m x 1 m x 2 m) to house the accumulator and charge regulator.
- To render and paint white all of the walls of the illuminated areas.
- To give manually help in the installation process.

Such conditions represent a rather strong effort for the users given that the average annual income per family in this area is about 300 USA$.

Currently, ADES has assumed the following functions:

1. Establishment of a priority order for new installations. This function has taken an special importance in the current situation, with demand exceeding the supply capacity. It might be thought that such a situation could lead to conflicts although so far this has not happened. With each round of new installations, priorities are assessed by the following criteria: length of time on the waiting list and half the installations are to be carried out in communities already having some electrification and half in new communities.

2. To collect and manage the economic contribution of the users. At the beginning, this function has been performed with great honesty and integrity but last year some problems related to the economic contribution of the users. At the beginning, this function has been performed with great honesty and integrity but last year some problems related to economic management appeared. We hope to solve these economic problems at the end of 1994. Currently, the fees are collected (in Bolivian currency) by the representatives of each community who, in turn, pass them on to the treasurer of ADES who, after changing them into USA dollars, pays them in to the branch of the Banco de La Paz. These appropriate receipts are kept from all payments. Fifty percent of the total income is invested straight into the programme, generally for the purchase of local materials (batteries, cables, etc.) The remaining 50% remains temporarily in the account.

3. To correct actions contrary to the rules of ADES. In this context, it must be pointed out that the founding statutes of ADES contain detailed rules covering the sanctions to be imposed in the case of default of payments, mistreatment of materials, absence of meeting, etc.

A detailed analysis of the developing programme we permit to show up some negative and positive aspects of the ADES performance. As negative aspects, we can mention the following:

- Because of the programme size, ADES manages high economic resources inside aymara context. A lot of problems related thieving can appear.
- Due to limited experience the founding statutes of ADES have not been able to foresee some conflictive situations.

As positive aspects, we can mention the following:

- ADES has developed an important speaker role between the Bolivian institutions and aymara Indians.
- ADES has shown a high efficiency to establish a priority order for new installations.
- ADES has corrected severely actions contrary to the founding statutes.

Related to the users participation, we can conclude that:

- The speaker role of ADES has been essential in the developing programme.
- It is important to assure the families participation not involved in the programme.

- It is important to guarantee a professional management of the economic resources.
- It is important to require the correct use of the equipment.

6. LOCAL FABRICATION

This aspect of the programme shows an interesting novelty related to the transfer technology. Usually, PV transfer technology in developing countries has been related with the PV module assembling. In our opinion, this way to transfer technology is inadvisable due to high investment cost, low added value and low industrialization level of these countries. Our work philosophy is totally different and based in the local fabrication of electronic ballasts and charge regulators. In this case, the investment cost is, relatively, low and the added value are very high.

The first 75 installations were carried out entirely with material imported from Spain. Now, only the PV modules are imported. We are using car batteries, made in Bolivia, with the electrolyte density modified (from 1.28 gr/cm^3 to 1.22 gr/cm^3) to give them a longer serviceable life.

The support structures, charge regulators and lamps are produced in a small factory, created under this programme. Table 3 shows the most important statistics of the production process.

EQUIPMENT	UNITS CURRENTLY MANUFAC.	UNITS MANUF. PER MAN PER WEEK	UNITS MANUF. PER MAN PER WEEK	COST IN BOLIVIA (usa$)
Electronic ballast	7,000	40	10,3	9
Charge regulator	1,500	3	115	90
Support structure (module)	1,400	8	40	33
Reflector and fitting (Fluor. lamp)	7,000	100	5	3

Table 3. Statistics of the production process.

The production process finishes with a quality control of all the equipment.

This factory constitutes one of the very few examples of technology transfer that has materialized in the context of aid and development. It is staffed exclusively by aymara workers, has screen printing equipment, mechanical workshop, solar simulator, oscilloscope, power

desarrollo rural, La Paz (Bolivia) 1993.

supplies, etc. At the moment there are 9 people working there and the investment in it has accumulated around 30,000 USA$. Experience in the field shows that rate of failure in the products from this factory is lower than in the products initially imported from Spain.

Regarding the economic benefit of this set up (production is cheaper and simultaneously employment is provided) we must add the maintenance and repair capabilities, which give rise to a high degree of self-sufficiency. To a large extent, the programme can now install and maintain photovoltaic equipment in a systematic manner, thanks to the existence of this factory.

A good indication of the success of this experiment in local fabrication is the fact that there is a demand for the products. In fact, Bolivia like other Latin-American countries is witnessing a development of a PV market that relies mainly on imported equipment. So, in August 1992 this factory started selling its products on that market and since then there has been a steady growth in demand.

7. INSTALLATION AND MAINTENANCE PROCESS

The programme currently has at its disposal the necessary means to work practically independently in the installation and maintenance processes. The installation of systems is carried out under the supervision of the same people who work in the above mentioned factory. At the moment the rate of installation is greater than 1 dwelling per installer per day, which gives an idea of the competency reached by these people. In this way, it is worth pointing out the success of some own initiative such as design modifications of electronic ballasts and charge regulators, local training, etcetera.

In this context, it has been promoted the creation of a private company formed by the young group of aymara Indians who are involved in the programme. This company is named EBES (Empresa Boliviana de Electrificación Solar).

As far as maintenance is concerned, this was initially the responsibility of these installers, who visited periodically the dwellings to clean the systems, replace faulty equipment and collect data concerning use and the degree of user satisfaction, which allowed data to be compiled concerning reliability, etc. This has been very useful for evaluating the progress of the programme and for the planning of subsequent stages. In this way, it is worth pointing out that thanks to a detailed analysis of broken batteries we were able to detect a high corrosion in the positive plates. This suggested a problem of batteries overcharging. In the fabrication unit, the disconnection levels of the charge regulator were corrected.

Currently, a two-level maintenance system is been used in the programme. We trained one person in each community involved in the programme and the first maintenance level is carried out by these persons. This group is the responsible of a primary maintenance that consist in changing lamps, topping up the battery electrolyte, general cleaning, etc. The aim is to have a person responsible for maintenance in every community. The second level, covering repair of faulty equipment is carried out in the fabrication unit.

Especially interesting is the study of recurrent costs arising from the maintenance of installations and their relation with contributions of the users intended for this end. Figure 4 sums up the situation.

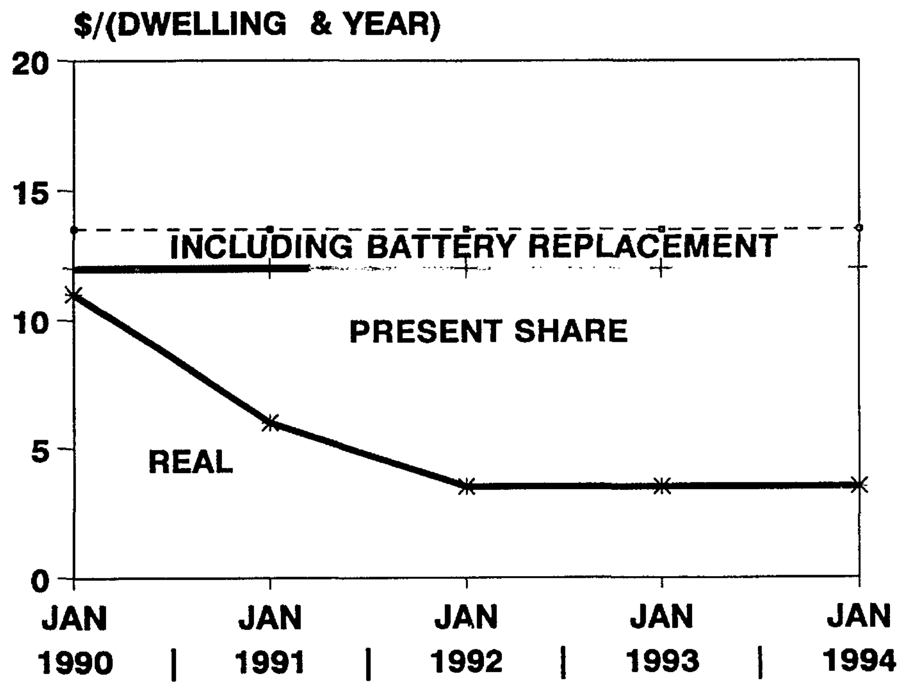


Figure 4. Maintenance costs.

The real costs of maintenance are of the order 4.5 USA$ per dwelling per day. To this should be added the cost replacing the battery every 7 years. Thus, we arrive at the figure of 14.5 USA$ per dwelling per year. The fees contributed by each user are, at the moment, 12 USA$ per dwelling per year. The discrepancy is really quite small and can be easily met by the users themselves. Thus, the future of the systems is safe.

8. CONCLUSIONS

In our opinion the results of the programme show the maturity of photovoltaic technology to rural electrification projects in developing countries. In our particular case, besides, it is the cheapest way to undertake the rural electrification of the Bolivian high-plateau.

It has been demonstrated that this way to transfer technology is very appropriate in these countries.

REFERENCES

[1]César Sevilla, "Energía y Desarrollo Rural", Seminario Nacional sobre energía para el desarrollo rural, La Paz (Bolivia) 1993.

[2] Willen Floor, "Situación Energética Rural en Bolivia", Seminario Nacional sobre energía para el desarrollo rural. La Paz (Bolivia) 1993.

[3]Ismael Montes de Oca, Geografía y Recursos Naturales de Bolivia, Ed. Educacional del Ministerio de Educación y Cultura 1989. Bolivia.

QUESTIONS AND ANSWERS

Q. It is a pretty unique situation on top of the Bolivian plateau. The lighting strikes damage was pretty horrific. Are there any other extreme weather conditions you experienced on top of that plateau?
A. Not specially. The only extreme condition is also the very low temperatures. That is good and bad. It is good for the life time of batteries. But is bad because you have to be specially careful with the voltage threshold in the charge regulator. Extremely careful with that.

Q. It is probable good for the efficiency of the photovoltaic modules.
A. It is very good for the efficiency of photovoltaics. In fact, we started with modules of 36 solar cells, but you can live very well in Bolivia with no more than 31 solar cells and still keeping standard wires.

Q. It seems like, from your consumption diagram you have a lot of surplus energy here. Did you find some uses for that? If your consumption is 5 ampere-hour average your consumption and production curves show considerable surplus. You have potential for doubling the load.
A. Yes, you are right. I realize that there is surplus energy. But our design is for 160 Watt hour per day. I am afraid that I have not shown the more representative housing. Let me say that when we installed the systems, we selected houses with different compositions of the inhabitants, which is in fact the factor that later determines the consumption. And it is in the houses with a lot of young people, that the consumption becomes higher. But we never had more than 140 Watt-hour per day in consumption.
Let me comment that the situation can change in the short term, because there is a radio broadcast station in Bolivia, whose name is "Radio San Gabriel", that is planning now to broadcast television programs in the Imara language. And then maybe the consumption for television can be higher. We will see.

Q. My question relates to an institutional issue. In fact, it is two barreled. Can you please tell us what is done, whether you say each consumers consigning up is 80 US dollars. What happens to that money? That's the first question. And then, correct me if I am wrong but I understand also that in Bolivia (I am looking up on my notes, that date is November 1993) there is or there was maybe it is still going on, an NRECA project in Santa Cruz and La Paz. The micro utility concept. Now in your case, which is undertaken by Spanish bilateral assistance, the consumers pay 1 dollar a month. Whereas in the other one, and it is in the same country, the consumers were suppossed to pay 7 dollars a month. I was wondering whether this might not create a problem

at the level of the government, because if you have one part of the country, one region, paying 1 dollar and another paying 7 dollars; and one region paying 80 dollars of deposit and the other 125, does it not create a conflict? Can you comment on that?
A. I am going to answer in the opposite order. I will answer the second question first. Yes, it is a problem in Bolivia. I think that when we started, we were the only people working in photovoltaics in Bolivia. But after some years, at the same time in Bolivia which is a little country, one can find some 4 different bilateral cooperation organizations working at the same time and without uniformity. The problem is still bigger because, in fact, not only there are official cooperation organizations, but there are plenty of NGO's, for example, that also use photovoltaics with different types of financing. This is a big problem in all these kinds of situations. It is not easy. This is not only the case in Bolivia. I can tell you of the same problem in Senegal, Cameroon and plenty other countries where the situation is like that. The problem is not only that there is different ways of financing, which at the end is not such a big problem, in my opinion. The problem is in fact that all the projects are pilots and they do not have sufficient power or sufficient means to really impose very high technical standards. So this is a problem to solve and, like you commented this morning, fortunately we are now in a moment in which some initiatives like "Power for the World" or similar, are trying to solve that. Let me say that in the past photovoltaics was not considered very seriously in most of the administrations, and I think now we are in a turning point regarding that. So maybe we can be successful in this case.

Q. Regarding the first question, what happened with the money. The money was put in a bank account. Half of the money was used to buy materials for the projects and the other half of the money is still in the bank. It is a good question what to do with it. On the one side, of course you need to do something with that money because, if not, plenty of questions will be asked. But let me say that on the other side, the existance of this money is also important, because it has given in the past some very important credibility to the user's association; -at the same time it has given us also some problems. Unfortunately, I can not go into more detail here, unless you want me to.- But the existance of such huge quantity of money in the bank has given very positive things. For example, it was interesting when we asked for money in Brussels for this project, to show a photocopy of the bank statement with 200,000 dollars in it and see the good impression it caused. So in this sense the rentability of this money has been very good. But it also has given us problems, because the control of this huge quantity of money is not so easy to do.
A. I come from Bolivia. I want to complement what was told, to satisfy your inquietude. We had some problems. We discussed them a lot with the people of the Spanish Cooperation in Bolivia, because it was really bad. The explanation, and that was between the government and the international cooperation acting in Bolivia, was that the Spanish Cooperation is a social one. So it has a social goal. The rest of the cooperation had to be fashioned of solar energy without subvention. And actually, the word is that the Spanish Cooperation is going further, now only in community projects, not family solar home systems, but schools and hospitals and this kind of things. And now there is no problems ever since this was settled and arranged.

Chairman: This may show that cultural problems far outweight the technical problems in this whole photovoltaic world. Technical problems, I think, are very easy to solve. The cultural ones require much further, deeper understanding. But I would like to move on, if we can thank you again, Eduardo.

THE SOLAR ENERGY PHOTOVOLTAIC ONE OPTION TO THE CUBAN RURAL ELECTRIFICATION

J. A. Alabart, D. Friedman*, R. Ramos, J. Moreira, I. Batista, R. García M. Rodríguez

Centro de Investigaciones de Energía Solar (CIES), *ECOSOL (COPEXTELL S. A.) Cuba

ABSTRACT

This paper analyzes the work done in Cuba over the last years in the field of photovoltaics, from its R&D and Industrial capacities to the Rural Electrification Program.

Based on this work a Development Program for the PV industry is proposed, which is defected towards the integration of all necessary factors that will ensure a sustainable Rural Electrification Program. This program is divided in 5 main stages:

1. Import of solar cell and other elements for the assembly in Cuba of modules and diverse system components (1995-2005).
2. Production of solar cells from imported wafer (17-2005).
3. Production of monocrystalline silicon wafers from imported polycrystalline silicon (1998-2005).
4. Production of polycrystalline silicon from cuban silica sand (2002-2005).
5. Development and introduction of new technologies for the production of solar cells (2000-2005).

The combination of the PV Development program and the Rural Electrification program will guarantee the supply of electricity to lOO% of the cuban population, and at same time accelerate the technological, industrial and research infrastructure on which a large scale national PV industry would be supported. The implementation of such a program would also make cost on the National Electrical Grid (NEG), avoiding the need for new generation facilities based on fossil fuels.

1. INTRODUCTION

The development of Photovoltaic Solar Energy during the last years has been characterized by a constant reduction of the cost and a steady increase in the production volumes, even though many of the prognostics have not been fulfilled. One way of further decreasing the cost of Photovoltaic systems in the Third World is through the development of national PV production integration programs and the comprehensive Rural Electrification programs simultaneously which will mutually sustain each other.

At this moment more than one billion people in the Third World has no electricity at all. Solar Electricity stands as their only viable option, both from a technical & economical points of view, as well as from a social one. This has been proven by practical experiences and studies that have been done in different countries of Latin America and Africa.

This is why a global Photovoltaic Action Plan geared towards the electrification of the rural communities the Third World is so important. This plan would substantially increase the standards of living of the population of this areas, decrease the mortality rate, lower the demographic explosion and from a financial point of view its costs would be less than 1% of global military expenses [1,2].

Cuba's effort in its Rural Electrification program has been centered at solving the basic needs of the remote rural population, and extending the social and cultural benefits that come with electrification. It was through this program that the use of PV system became known in our country. At today's cost Solar Electricity is already a technically and economically viable solution for the electrification of remote and isolated rural homes, this is why PV is becoming a major force in Cuba's Rural Electrification Program.

The purpose of this work is to survey the experiences in the field of PV in Cuba and to complete a comprehensive program that will sustain the development of national PV industry, supporting in this manner the completion of the Rural Electrification Program.

2. RURAL ELECTRIFICATION

Cuba's development program over the last 35 years has achieved significant results in public health and education. This program has also included a wide-spread electrification plan that reaches over 94% of the population, which is one of the highest levels of electrification in the Third World.

However, a coverage of 94% still leaves 723 600 people, that live in 160 800 remote rural homes without electricity [3]. Due to the location of these homes, extending the NEG is not a cost effective solution. At the present rate, it is estimated that by the year 2000 approximately 200 000 rural homes would not have electricity. Table 1, shows the present levels of electrification by provinces.

At the same time a similar number of homes do not have a reliable wafer supply, since wafer must be transported for long distances in order to reach its consumers. This leaves these most of these homes with unstable wafer supply throughout most of the year.

Province	NEG %	Others	Total %
1. Guantanamo	82,2	5,7	87,9
2. Santiago de Cuba	84,8	2,5	87,3
3. Granma	84,6	4,9	89,5
4. Holguín	78,7	13,1	91,8
5. Las Tunas	83,8	7,1	90,9
6. Camagüey	96,8	1,0	97,8
7. Ciego de Avila	95,4	0,3	95,7
8. Santi Spíritus	95,2	1,4	96,6
TOTAL	91,5	2,7	94,2

Table 1. Level of Electrification by Provinces.

To guarantee an appropriate living standard and to increase the educational and cultural level of the remote rural population in Cuba, a PV system has been developed and optimized over the last year, that takes into consideration the specific climatological conditions of each region and the socio-cultural characteristics of population. Table 2, list the main components and costs of such a system.

Taking such a system as typical, for the electrification of 200 000 homes a total of 16 MWp would be needed and the total cost of the system components would be $ 200 million USD. If to this we were to add the power needed for wafer supply and other social services, 20 MWp would be needed, and the total cost would be of $ 250 million USD, which taken over a ten year period would amount to $ 25 million USD per year.

. 2	PV Modules 40 Wp
. 1	Charge Regulator 8 A
. 1	Battery PB-Acid 150 Ah
. 5	Fluorescent Lamps 20 W
. 1	Television 12", 12 VCD
. 1	Radio
Total Cost $1000 USD	

Table 2. PV System components.

3. PHOTOVOLTAICS IN CUBA

3.1 PHOTOVOLTAIC INSTALLATIONS

Practical Experiences in PV installations in Cuba go back over ten years, which over 250 system that over 25 kWp. Table 3 gives an overview.

Installation	Qty	Power Wp
1. Rural Homes	75	90-108
2. Rural Community	1	2 500
3. Rural Medical Post	16	200-300
4. Tourist Installation	1	720
5. TV Repeaters	3	720
6. Marine Signalization	100	36
7. Electric Fences	20	16
8. Forest Guard Post	7	100-288
9. Others	30	-----

Table 3. PV Installation in Cuba.

Over the years the main malfunctions and faults detected in PV systems have been due to its electronic components (Charge regulators, lighting and inverters), which have been caused in great extent due to the fact that most of the equipment has not been designed for use in tropical conditions.

Degradation of the EVA has been present in many modules, which we believe is due to the joint action of high levels of radiation, humidity and temperature [4,5]. Due to these same factors, a decrease of up to % of the module peak power output has been observed [6]. The CIES is presently involved in an in-depth study of these phenomena to be able to obtain data that will give realistic design criteria, given the local climatological conditions.

4. PV RESEARCH INSTITUTIONS

Research in Photovoltaic Solar Energy is done mainly in the CIES of Cuban Academy of Sciences, specifically in its PV division, that is dedicated to the R&D of PV systems and component, as well as a detailed study of the level of solar radiation in Cuba. Presently the PV division is focusing its work on the implementation of a test laboratory for PV modules and components for tropical climates and the installation of an experimental 25 kWp PV power plant, to study the long term effects of tropical climatological conditions on PV systems.

The Institute of Materials and Reactives for Electronics (IMRE) of the University of Havana, has a division that is dedicated to the development of solar cell technologies. This Institute has obtained commercial size cells of up to 14% efficiency and has developed a new technology for the production of solar cells.

The IMRE counts with a materials division in which they are developing a technological process to produce silicon from local high grade silica sand (sponsored by the UNDP). This project is presently at its pilot plant stage. In this division the use of hydrogen as an energy storage for use in solar energy system is also being studied.

5. INDUSTRIAL CAPACITIES

Cuba has a large and mature electronic industry, which at this moment has low production levels, due to lack of financing and markets for its products because of the socio-political changes that have occurred in Eastern Europe over the last years. Some of these industrial complexes can be reoriented to produce PV equipment with only minor capital investments. The most suitable such installation are: CCE "Che Guevara", COPEXTEL and the Battery Factory of Manzanillo. Table 4 gives an overview.

Industry	Products	Production Volume	Installed Equipment
1. LACETEL	PV Module Assembly	200 kWp	100%
	PV Systems Components	50 000 pcs	100%
		3 MWp	
2.CCE-Ché Guevara	Solar Cell Manufact	180kWp	80%
	Silicon wafer Line	3 MWp	75%
3.COPEXTEL	Solar cell Manufact	100000 pcs	75%
	PV System Components		100%
4.Manzanillo	Batteries	500000 pcs	80%
Batteries Factory			

Table 4. Overview of industrial capacities.

Ten year PV development program Cuba's has all the necessary research and industrial infrastructure, as well as many highly qualified specialists that can guarantee the fulfillment of a comprehensive PV Solar Energy Program that will include everything from the production of solar grade silicon to the development and design of PV systems.

Based on this work a Development Program for the PV industry is proposed, which is directed towards the integration of all necessary factors that will ensure sustainable Rural Electrification Program. This program is divided in 5 main stages:

1. Import of solar cells and other elements for the assembly in Cuba of modules and diverse system components (1995-2005).
2. Production of solar cells from imported wafers (1997-2005).
3. Production of monocrystalline silicon wafers from imported polycrystalline silicon (1998-2005).
4. Production of polycrystalline silicon from Cuban silica sand (2000-2005).
5. Development and introduction of new technologies for the production of solar cells (2000-2005).

The first stage is presently being implemented at LACETEL, now in use. For the second stage of this program, an in COPEXTEL or CEE "Che Guevara") is needed to complete a solar cell production facility that would use imported either mono or polycrystalline silicon wafers. The manufacturing line would have an annual capacity of 3 MWp and it is estimated that this could lower the costs of the modules by 15%. The production of monocrystalline silicon wafers from imported polycrystalline silicon could take place in the CEE "Ché Guevara", with some changes in the present equipment, its capacity would be of up to 180 kWp.

Since Cuba has large deposits of high grade silica sand, it is of almost interest to continue and accelerate the research done by the IMRE, that will allow us to obtain polycrystalline silicon from local raw materials.

For an industry implementation at this stage an appropriate technology must be selected that would be cost-effective for the required production volume.

All over the world a great amount of work is being done in the field of solar cell technology, IMRE is taking part of this global effort. During the next few years the developments in this field will be studied detail by our researchers, in this manner the most appropriate technology will be selected for its use by national PV industry.

6. CONCLUSIONS

Cuba has many highly qualified specialists as well as the necessary industrial and technological foundation, that could permit the country to have its own PV industry based on cuban raw materials in the near future, with only a modest investment. The combination of these factors would also assure competitive generation costs of PV energy by the first years of the XXI century, guaranteeing in this way a sustainable Rural Electrification Program that could reach 100% of the Cuban population.

To develop this joint PV Development & Rural Electrification Program $25 million USD/year are needed over the next ten years. However, with the present economic situation in the country, the complete implementation of this joint program will not be possible without the support from international organization and financial institutions.

The development of such a program in Cuba could operate as a pilot project and the experiences obtained could be used in other countries in the Third World. Cuba could also become a source of low-cost PV equipment and serve as a training center for program leaders and technicians from other countries.

REFERENCES

[1]W. Palz, "A Global Photovoltaic Action Plan", ISES Solar World Congress, Budapest, 1993.
[2]H. Scheer, "Towards a Solar Proliferation Treaty", ISES Solar Congress, Budapest, 1993.
[3]Base de datos de la Unión Eléctrica 1992, La Habana, 1992.
[4]F. J. Pem, A. W. Czadema, R. A. Emergy and R. G. Dhere, "Weathering degradation of EVA encapsulant and the effect of its yellowing on solar cell efficiency", Proceedings of the 22"nd IEEE PV Specialists Conference, 1991.
[5]R. C. Peterson and J. H .Wohlgemuth, "Stability of EVA in modules", Proceedings of the 22"nd IEEE PV Specialists Conference, 1991.
[6]W. H. Bloss, "Photovoltaics: Solar Electricity", UNESCO Headquarters, Paris, 5-9 July, 1993.

QUESTIONS AND ANSWERS

Q. Maria, It is the first time I've heard it or seen it in any of these presentations, the traditional culture of people leaving in remote areas. I think it has been changing drastically as the younger generations migrate to the towns, away from their traditional homes to the cities; and your comment that with the introduction of photovoltaics for the electrification of homes there is a lower migration rate from the remote areas to the towns, is fascinating. Can you make a comment on that?
A. One time in Cuba, most of the rural areas were electrified by commercial means, and it was very clear how people from non electrified communities moved into the towns with electricity. After they started installing the photovoltaic systems, that migration was not so apparent.

Q. Maria, all this equipment, where does it come from? Is it being manufactured in Cuba? Is it commercially sold? is it donations from other governments, NGO's or what?
A. PV Modules have been assembled in Cuba and there is also equipment which has been donated by other governments.

JOINT U.S./BRAZIL RURAL ELECTRIFICATION PROGRAM

Cecile Leboeuf Warner, Roger Taylor, David Corbus
National Renewable Energy Laboratory (NREL), Golden, Colorado, USA
Mauricia Moszkowicz, Jorge Lima, and Claudio Ribeiro
Centro de Pesquisas do Energia Eletrica (CEPEL),
Rio de Janeiro, Brazil

1. INTRODUCTION

Over 20 million people in Brazil are not currently served by the electric grid. Much of the unelectrified population lives in the northern and northeastern regions of Brazil, where access is extremely difficult, but renewable energy resources of wind and solar energy are abundant. The U.S. Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL) is implementing a joint technology research and demonstration effort with the Centro de Pesquisas de Energia Eletrica (CEPEL) in Brazil, the Brazilian equivalent of the Electric Power Research Institute. In this program, DOE is cost-sharing renewable energy pilot projects with Brazilian state-owned utilities. The pilot projects demonstrate renewable energy systems in a variety of applications. DOE commits a maximum of 50% of project cost, with the states supplying the remainder. The DOE contribution takes the form of U.S. PV modules and system components that cannot be found in Brazil, such as controllers and inverters. The approach of this joint program has been designed to meet three key objectives. The first of these objectives is to establish technical, institutional, and economic confidence in using renewable energy (PV and wind) systems to meet the needs of the citizens of rural Brazil. Secondly, the program will establish on-going institutional, individual, and business partnerships with Brazil that are necessary to implement sustainable programs and commitments that benefit both countries. Finally, it will lay the groundwork for large-scale rural electrification through the use of renewable energy systems.

2. PROJECT HISTORY

The Joint U.S./Brazilian Renewable Energy Rural Electrification Project was established following the Earth Summit in Rio de Janeiro in June of 1992.

Phase I of this technology research and demonstration assessment program consisted of providing PV electric lighting systems to about 750 homes and a few dozen schools in two remote areas of northeastern Brazil, in the states of Pernambuco and Ceará. Key system components were provided by NREL to CEPEL under a contractual agreement, for subsequent installation and operation by the state utilities in Pernambuco and Ceará. Those utilities were

The Development of Renewable Resources at Arizona Public Service Company

Herb Hayden, P.E.
Arizona Public Service Company
USA

ABSTRACT

APS has been pursuing the development of solar energy for many years, through feasibility studies, solar monitoring, photovoltaics testing, demonstration projects, and internal applications of solar. Key examples are our comparative testing of photovoltaics (PV) at our Solar Test And Research (STAR) Center, the construction of a 225 kW grid-connected PV system, about 20 kW of rooftop PV systems at several customers properties, our participation in the development of Solar Central Receiver technology, and two recent studies on the value of solar in centralized and distributed generation. The costs and performance of solar technologies has been steadily improving, and there are current needs for energy services in APS service territory which cannot be economically served by power line extensions. These off-grid demands provide an opportunity for the initial application of solar for customer service, which can expand as costs are further reduced. It is expected that with continued development support, the costs of solar will decrease to a level which will be competitive in certain grid-connected applications before 2000. Recently, APS established a goal of installing 12 megawatts of solar by 2000 in applications that are cost-effective or can be made cost effective, for the economic and environmental benefit of our customers and shareholders. In order to achieve this goal, APS will develop cooperative working relationships with suppliers and other utilities that have a similar interest in the cost-effective use of solar energy for customer service.

1. INTRODUCTION

APS GOAL

12 MW of renewable resources by 2000, that

- provide a valuable, marketable energy service are,
- or can be made cost effective
- have low environmental impact
- produce few emissions, including greenhouse gasses
- enable the further development of renewables after 2000

APS is committed to the development of renewable resources for their potential economic and environmental benefits. The Company has a long history in solar research, and uses solar energy in powering remote applications such as communications systems.

In 1993, APS established a goal of 12 MW of renewable energy generating capacity by December 31, 2000. Our intent in pursuing this goal is to participate in the development of the renewable energy technologies and applications that can provide the greatest benefit to our customers and our shareholders. It may also enable us to develop larger renewable energy resources to meet future generating needs that may develop beyond 2000.

2. RENEWABLES DEVELOPMENT

METHODS OF REDUCING COST

- cost-reducing innovation and improvements.
- economies from standardization and larger-scale production.
- favorable financing and tax treatment.
- improved information on technology and applications.

The development of solar and other renewables depends upon cost reductions of all kinds. The costs of the systems themselves can be reduced by technical innovation and improvements, and by standardizing the equipment and increasing the volume of manufacturing and sales.

Taxes and financing costs place a greater burden on solar and other capital intensive renewable energy generation than fossil generation because they have a greater purchase cost component. During our development of renewables, we will look for ways to reduce such costs where possible.

In addition, the total costs of solar and other renewable energy services can be minimized by appropriate and efficient use of energy. For example, photovoltaic solar energy is most practical for consumer uses that have high value, such as energy-efficient televisions, microwave ovens and power tools, but not for large energy uses such as air conditioning or stoves. Water heating can be done effectively with solar water heaters and home heating can be assisted through architectural design. It will be important to inform customers about these distinctions in energy usage and conservation in order to find early cost-effective applications of solar for off-grid energy service.

APPLICATIONS PLAN

- cost-effective applications of renewables.
- applications that can become cost-effective.
- development and research projects.

APS will pursue solar energy through applications of cost-effective systems and services, early application of systems that can become cost-effective, and by supporting commercial development and research directed to lowering the cost of renewable energy applications in the future.

3. COST-EFFECTIVE APPLICATIONS

COST EFFECTIVE APPLICATIONS

- Carol Spring Mountain solar hybrid generating system.
- Alternative Energy Service Option (off-grid).
- Solar water heating education and assessment.

In order to immediately increase the availability and use of renewable resources, APS is working to identify and offer those renewable energy services available today that can meet nontraditional customer needs. This includes offering a new electric service option using solar equipment in remote areas where grid-tied services are not yet present, and to evaluate the use of solar water heating for residential and commercial customers, whether grid-served or not.

Carol Spring Mountain solar hybrid

APS is currently constructing a solar/diesel hybrid system at Carol Spring Mountain to serve existing telecommunications customers. This site was originally served with a 14 mile underground cable, but maintenance difficulties due to the terrain caused the company to abandon the cable, and service was continued using diesel generators operating 24 hours a day. APS is now adding 25 kW of photovoltaic generation and about 500 kWh of battery storage to the system in order to reduce the run time of the generators, and to improve reliability, and reduce the fuel, operation and maintenance expense.

Estimates of the performance and costs of the solar hybrid system have significant uncertainties, in terms of solar resource, equipment performance, customer loads, and other factors. In order to improve future application plans and system designs, this installation will include electronic metering of customer loads at a 15 minute intervals, and research instrumentation, provided by Sandia National Labs, to monitor critical subsystem performance.

Alternative Energy Service

Development of rural areas is significant in Arizona, but the costs and environmental restrictions of installing new power lines to serve remote areas that have relatively low load growth potential have limited the ability of the company to provide conventional electric service.

APS has begun to offer solar as an off-grid service option to new customers that are remotely located, but cannot readily be connected to a power line. This will begin with a small number of installations, and as we gain experience with the new service, the availability will gradually be increased to meet the market demand. Typical customers for solar services off-grid are remote homes and ranches, water pumps, and lighting and communications sites. Real estate brokers and developers may take advantage of APS solar services for isolated communities that want the convenience and assurance of utility service without the presence or costs of a power line extension.

Since the initiation of this service, there have been enough inquiries and interest to indicate a substantial market, but as of yet the market potential has not been quantified. Our first years experience with this program is expected to provide significant insights, and an indication of the magnitude of our future role in this area.

Solar Water Heating

APS recently contracted with Arizona State University to develop a current Solar Water Heating Consumers Guide, and is planning a small number of test installations to measure economic and technical performance in order to help our customers make intelligent decisions about purchasing solar water heaters. Solar water heating services may also be included in our Alternative Energy Service option.

4. APPLICATIONS THAT CAN BECOME COST-EFFECTIVE

APPLICATIONS THAT CAN BECOME COST-EFFECTIVE

- Distributed generating systems.
- Residential and commercial customer PV systems (grid-connected).

In grid connected use, solar generation is first expected to become cost effective at locations where it helps delay or avoid upgrades of transformers or power lines. In some cases, the solar system could be installed on utility property in the power distribution system, and in other cases it could be in the form of PV panels located on the customers rooftop. A few of the photovoltaic technologies are expected to fall in cost to economical levels in these applications, but they will require continued development and increased sales to utilities and willing customers in order to make these cost reductions.

During 1994, a review was conducted of possible grid-connected solar sites using criteria APS established in APS 1992 study of distributed solar benefits. Several sites were identified as technically acceptable candidates for a solar plant. APS is collecting preliminary plant design information from solar system manufacturers to develop a program for distributed generating plant construction.

APS has reviewed the commercially available solar generating systems and selected several which have potential for economic use on a larger scale. A limited amount of these systems (about 1 kW to 20 kW each) will be installed at the APS Solar Test And Research (STAR) center in order to validate their cost and performance. Larger, subsequent installations will be planned in cooperation with suppliers and co-funding sources, to be constructed in a way that will help lower the cost or facilitate the use of such systems in the future, and provide significant energy service benefit to APS.

Such larger systems are anticipated to be up to several hundred kilowatts, and would be located at a new site to be selected in the APS distribution system in order to increase their visibility to the public and avoid the space limitations of the existing APS STAR test site. This new site may be chosen to allow megawatt-scale installations to follow in later years.

When appropriate, some PV systems will be installed on-site with residential and commercial customers in order to gain experience and enhance the public awareness of solar. The projects that are installed on customers property can also be designed to reduce installation costs by integrating the PV panels with building structures, or to gain additional benefits such as shading for parking spaces.

APS research has indicated that some customers will consider paying more for renewables, but they want to know exactly what is being done, and would like to directly benefit from the renewable energy project. APS will look for ways to allow interested customers to voluntarily contribute toward projects placed upon their premises. If this is successful, it would provide an actual measure of the willingness of some to voluntarily pay for some of the early costs of renewable energy, a concept that has often been referred to as green pricing.

5. RESEARCH AND DEVELOPMENT PROJECTS

RESEARCH AND DEVELOPMENT PROJECTS

- advanced photovoltaics.
- central receiver.
- dish Stirling.
- energy conversion, storage, other.

New technologies and approaches in using renewables are continuously being developed, including lower cost and more efficient photovoltaics and solar thermal generators, and batteries, flywheels and renewable hydrogen fuel for energy storage, and electronics for energy conversion and control.

During 1993, APS installed PV systems on three residential and commercial customer buildings for performance and DSM evaluation. Our testing of PV systems at the APS STAR Center is assisting manufacturers and national labs in their development efforts. And late in 1994, APS installed the first full scale 20 kW High Concentration PV system, which could become cost effective within a few years, depending upon the volume of production and sales achieved.

Also during 1994, APS supported the leading solar thermal technologies. The Solar Two Central Receiver project is in construction, scheduled to become operational in 1995, and could lead to commercial plants after 2000. APS participated in several meetings with all of the potential Solar Dish Stirling system suppliers, and organized and hosted a utility-supplier workshop meeting in Phoenix.

APS will continue to study technologies in their various stages of development at a moderated level of effort, in the tens or hundreds of thousands of dollars. This includes test and operation at the STAR center, data and applications analysis, and collaborative studies and development at universities and research labs. These activities are essential to help plan and support our applications of renewables in which much larger expenditures are made, and to help guide the efforts of manufacturers and researchers that can lead to better and lower cost products. Installation and testing of systems with the greatest potential are then performed, directed toward reducing the overall cost in APS applications.

The following is a brief outline of the current solar technologies, and our activities with them.

Advanced PV

APS is working with several PV manufacturers who are working to lower costs by reducing the amount of PV material used, while maintaining or improving performance. Two methods of reducing the amount of material are :

1) By making thin films of PV material that are cheaper, though generally less efficient, and
2) By concentrating the sunlight using lenses or mirrors onto smaller, more efficient cells.

"Thin-Film" photovoltaics are designed to lower costs by depositing PV material in very thin layers on glass or plastic. Some stack layers of multiple-junctions to convert more of the sunlight into electricity. Others use new semiconductor materials such as Cad-Tel (cadmium-telluride) and CIS (cadmium-indium-diselenide) that have greater efficiency and could eventually be produced at low cost. APS is testing new devices as they become available, and expects to use thin-film PV in some Distributed Generation and Customer-Sited PV projects.

High Concentration PV systems use lenses or mirrors to focus light onto smaller cells, which generally are much more efficient that regular PV cells. These systems must track the sun to work, and are not well suited for small projects, but have potential for low cost when used at a medium or large scale. APS is now testing a high-performance prototype that could compete for new distributed generation when placed into commercial production, and expects to use high-concentration PV in some Distributed Generation projects.

Solar Thermal Electric

There are three main solar thermal generating technologies in use or under development: Solar Troughs, Central Receiver, and Dish Stirling. These all have the advantages of producing grid-quality energy directly using conventional generators, without requiring electronic conversion, and the potential to provide power on-demand, even during clouds or at night, using thermal storage or natural-gas fuel supplement. In addition, unlike photovoltaics, these systems can be built using readily available construction materials and techniques, though they are expected to require more maintenance than PV. Parabolic Through systems, of which several hundred megawatts were constructed in California by the Luz company, use long trough shaped mirrors to heat water or oil to make steam to turn a turbine generator. These systems have not shown enough potential for APS cost-effective use, primarily due to their low concentration efficiency and large losses out in the collection field, but we are participating in a small study for the possible renewal of its production for the international market.

Central Receiver systems, sometimes called power towers, use a large number of mirrors to heat water or molten salt at a central point to make steam to turn a turbine generator. These systems can become cost-effective when developed to a scale of hundreds of megawatts, projected to occur after 2000. One option also being studied is to use solar central receivers to provide supplementary heat for natural gas steam turbine generators. APS is a participant in the Solar Two demonstration project to validate the use of molten salt thermal storage in a 10 MW plant, which could eventually lead to 100 MW or larger commercial power plants.

Dish Stirling generating systems use dish-shaped mirrors to focus solar heat to power a piston engine called a Stirling Cycle engine. These systems also have good economic potential because they are very efficient, and could be produced in quantities at a reasonable cost before 2000. APS is working with dish Stirling developers to determine how to best minimize installation and maintenance costs and facilitate their commercial availability, and expects to install some early test units for possible later use in Distributed Generation.

Energy Conversion and Storage

Nearly every use of PV energy requires storage, electronic conversion or control of power. Most PV applications require battery storage or generator backup, along with their costs and operating expense. DC current from the batteries must be converted to AC for standard appliances, or requires ballasts for lamp lighting. In addition, solar energy can be used to make fuel, by generating hydrogen from natural gas or water. APS will monitor and study these areas, and support development and cost reductions when they are warranted for their use with renewables.

6. CONCLUSION

APS is interested in the use of solar energy to provide customer service, and is beginning to use solar to serve remotely located customers, while continuing to support development and cost reductions for grid-connected use by 2000. There are significant uncertainties in the rate of development of the solar industry, and the cost and competitive pressures in the utility industry are increasing. APS recognizes, however, that there are real benefits and opportunities in using solar for customer service in rural areas, and that the development of these early markets will help the company and its suppliers eventually achieve the costs and performance goals needed to established solar as a grid connected resource.

QUESTIONS AND ANSWERS

Q. Are you offering to customers on a lease basis?

A. Right. We have just approved that with our regulators. We have ordered some initial systems, we had discussions with customers and we are preparing to contract with them right know.

So we haven't done the first one yet.

The Photovoltaic Services Network: A Renewable Energy Partnership

Peggy Plate
Western Area Power Administration

Kirk Stokes
NEOS Corporation
USA

ABSTRACT

The Photovoltaic Services Network (PSN) is an independent organization of electric utilities established to support utility members in the use of photovoltaic (PV) power for off-grid applications. The PSN is focused on ensuring that cost-competitive, utility-grade, packaged PV products are available for various off-grid applications, such as livestock water pumping, remote residences, lighting, and cathodic protection among others. The primary objectives of the PSN are:

1) To provide education, training, and installation support as required by member utilities.
2) To establish a forum for member utilities to exchange ideas on PV program implementation and marketing strategies.
3) To create standardized system specifications for a variety of PV applications.
4) To coordinate PV product purchases for appropriate applications.
5) To identify and acquire additional funding (both public= and private) for product development and testing.
6) To pursue alliances with other organizations interested in PV.

1. INTRODUCTION

The Photovoltaic Services Network (PSN) is an independent utility association focused on ensuring that cost-competitive, utility-grade, packaged PV products are available for the numerous off-grid applications. The Western Area Power Administration's (Western) Loveland Area Office (LAO) and NEOS Corporation, its support services contractor, and a group of Western customers facilitated the organization of the PSN beginning in May of 1994.

The PSN is now ready to aggregate electric utility purchases for cost-effective off-grid applications. The mission of the PSN is to "work proactively on behalf of member utilities to ensure that the PV systems they purchase and install meet established design criteria; are competitively priced through quantity purchases; and meet the utility customer's expectations for performance and reliability.

2. HISTORY

Western and NEOS have had considerable experience working with utilities to assess, plan, and develop PV programs. As interest grew among its customers, Western established the PV Circuit Rider Program in 1993. The Circuit Rider is an energy service providing PV technical support to interested Western utility customers in Colorado, Wyoming, and Nebraska. Western felt this was a more cost-effective way to deliver technical services to a group of utilities interested in PV service. Sponsors of the Circuit Rider included the Colorado Office of Energy Conservation (OEC), Electric Power Research Institute (EPRI), Sandia National Laboratory (Sandia), and the National Renewable Energy Laboratory (NREL). NEOS, as Western's support services contractor, delivered this service to Western customers.

Recently, several of the Circuit Rider Program's 16 member utilities expressed interest in altering the program to add a focus on it toward bulk purchases of utility-oriented products and expand membership to interested utilities outside the existing program's 3-state area. These utilities want to have better products at lower cost through group buying power. Initially they were interested in stock watering, remote homes, communications, and lighting.

In pursuit of this idea, NEOS identified a larger group of utilities and proposed the PSN concept to them. This group of utilities, primarily rural electric cooperatives, wanted to include PV as primary component of their own energy services program. They wanted to be able to get the best price, the best product, and objective technical support to pursue improved products.

To date, the PSN has received endorsements from 34 electric utilities in 12 western and mid-western states, though the list continues to grow. These initial 34 utilities include 29 rural electric cooperatives, three generation and transmission cooperatives, and two investor-owned utilities. The membership drive will begin in April 1995.

3. THE SPONSORS

The PSN concept was formally published in the Utility Photovoltaic Group's (UPVG) responses to their Early Opportunity Notice for TEAMUP in July of 1994. Since that time the PSN has received financial commitments from Western, UPVG, Department of Energy's Commercialization Ventures Program, NREL, Sandia, and the Colorado Office of Energy Conservation. The vendor industry have been very supportive of the PSN and will be providing support in the future.

4. THE ORGANIZATION

Incorporated in September 1994, the Photovoltaic Services Network, Inc. (PSN) is a non-profit organization with a 9-member board of directors. The Board is made up of seven purchasing utility members and two non-purchasing utility representatives.

The primary objectives of the PSN are to:

1) To provide education, training, and installation support as required by member utilities;
2) To establish a forum for member utilities to exchange ideas on PV program implementation and marketing methods; and
3) To create standardized system specifications for a variety of applications;
4) To coordinate PV product purchases for appropriate applications;
5) To identify and acquire additional funding sources (both public and private) for product development and testing.
6) to pursue alliances with other organizations interested in PV.

During an interim start-up period of up to 12 months, the board of directors will be comprised of the following representatives from eight founding member organizations seven rural electric cooperatives and one non-purchasing utility organization:

PURCHASING UTILITIES:

Carbon P&L Electric; Saratoga, WY; Gary Garber
La Plata Electric; Durango, CO;
McKenzie Electric; Watford City, ND; Tom Miller
Northwest Rural PPD; Hay Springs, NE; Rolland Skinner
Plumas-Sierra Electric; Portola, CA; Paul Bony
San Isabel Electric; Pueblo, CO; Bill Wood
Trico Electric; Tucson, AZ; Larry Schone

NON-PURCHASING UTILITIES:

Western Area Power Administration; Loveland, CO; Peggy Plate.
Vacant position.

These eight founding organizations along with the PSN's support services contractor, NEOS Corporation, will assume a "self-appointed" leadership role during this interim start-up period to facilitate the organization's successful formation. At the end of the interim period, the PSN will be transferred to a board of directors duly-elected by the PSN membership.

5. THE MEMBERSHIP

Membership in the PSN is open to electric utilities interested in off-grid photovoltaic products and services.

Membership benefits include:

Direct PSN support for PV program development.
One vote per member.
Volume PV purchases coordinated with other members.
On-call PV service expertise.

Development and testing of PV products for the utility market.
PSN's reports and monthly newsletters.
Information exchange with other utilities.

The PSN intends to implement a membership structure based on PV purchases, though the exact purchase levels and corresponding benefits have yet to be established.

During the interim PSN start-up period through May 1996, the PSN board of directors have established an initial membership fee of $500. Each utility also understands that the precise definition of the PSN and its guiding covenants have yet to be created and that these definitions will be finalized by the utility members.

6. IMPLEMENTATION

The PSN's stated objective is to become a self-sustaining association with basic services funded by a portion of the aggregate utility purchases. Presumably, the savings accrued through these aggregate purchases will be such that each individual utility will obtain a significant price discount, yet the PSN's basic services can be sustained as well.

The business plan development will be cost-shared with funds from the Utility Photovoltaic Group. A cost-share from DOE's Commercialization Ventures Program will finance support for PSN administration, utility installations, developing strategic alliances, performance and reliability testing, implementing marketing strategies, aggregating utility purchases, and documenting results during an initial 18 month start-up period. The match from the PSN members will be both in-kind contributions for PSN development and implementation and purchases for pilot installations.

Task 1, the Business Plan Development, will be completed by May 1995 with a primary focus on disseminating it to the PSN members and addressing relevant comments and concerns.

Pilot system installations (e.g., the AC pumping system) will be the focus of Task 2 and will be completed by July 1995, and performance monitoring will occur for approximately 12 months after each system is installed.

The development of strategic alliances in Task 3 will be initiated at the project's start and will continue through the project's 18 month start-up period. The initial effort will focus on enlisting utility support and additional membership.

Task 4, Marketing Strategy Implementation, will be initiated by September 1995 with the development of the marketing templates. When the templates are completed four months later, they will tailored to each specific utility and implemented during a six month period. This marketing plan implementation will provide some of the data necessary for finalizing market forecasts.

The Task 5 effort is aimed at aggregating system purchases. When initial system purchase levels have been identified by April 1996, an agreement will be negotiated between the PSN and the system supplier(s). With the agreement in place, the PSN can begin to coordinate product deliveries and develop acceptance testing procedures.

7. THE FIRST PRODUCT

The PSN's first project is to develop specifications and standards to purchase AC water pumping systems, not readily available on the market today. Systems will be installed and tested for reliability and performance through the fall of 1995. Soon after testing is completed, products will be procured in volume by PSN members. During the first 18 months, the PSN will focus on livestock water pumping, lighting, and remote residential systems, since these are applications of most interest to the PSN members.

In response to the needs of numerous utilities interested in PV pumping, the PSN has proposed a PV pumping system concept that eliminates the use of "specialty" pumps (e.g., dc motors, diaphragm pumping mechanisms, or unique low-voltage ac motors) by operating "off-the-shelf" AC submersible pumps instead. Eliminating "specialty" pumps will eliminate several barriers for utilities and their customers including:

- The pump's high cost and low productivity compared to the conventional ac pumps often used by utility customers in grid-connected applications.
- The lack of pump availability and maintenance support because local pump dealers are not familiar with the "specialty" pumps and do not stock them as a result.
- The "specialty" pump's inferior reliability record.

In contrast, the use of traditional AC pumps in PV-powered systems has several advantages:

- A 30-year history of high performance and reliability.
- Lower capital and operating costs.
- A standard motor used by nearly all domestic pump manufacturers.
- Local vendors that presently supply and service the pumps.
- Utility line replacements (due to age or storm damage) may not require pump replacements.
- The ability to back-up the PV pumping system with a standard generator.

This AC pumping system concept was proposed to several PV system manufacturers in mid-1993 and to date at least two manufacturers (Golden Photon and Franklin Electric) have successfully demonstrated the system's technical viability.

This product development process is a prime example of how the PSN will achieve a key objective by working proactively with its utility members to develop system specifications to which the PV industry can respond. PSN member utilities will then test this prototype product to determine whether the product warrants further consideration.

If the products meets the defined specifications and standards, the PSN then coordinate with PSN members to purchase systems and to meet their agreed upon purchase levels. In this way, a goal of creating sustained utility purchases of 250 PV pumping systems per year can be achieved within 18 months. Furthermore, it is anticipated that similar goals can be achieved for other off-grid applications as well.

8. CONCLUSIONS

The PSN hopes to provide a model for utilities for other types of commercialization ventures. If the organization of the PSN (and the process it uses collaborate with PV industry partners) is successful it will achieve the following goals:

1) Enable utility members to succeed at expanding their energy service activities to include PV.
2) Focus on "market conditioning" for grid-independent applications by encouraging utility-grade product packaging; increased awareness of cost-effective PV applications; and adequate market support.
3) Establish sustainable purchases of 250 systems per year by utility members.
4) Build on requested seed funding to establish a sustainable, long-term, utility-sponsored PV market and business venture.

QUESTIONS AND ANSWERS

Q. I am just curious about the Photovoltaic Services Network. Is that an outgrowth of the, I believe it is called the Circuit Writer Program is their not longer in existence or this takes its place.
A. The Circuit Writer Program was a small effort with probably 15 utilities in Western United States. The program was essentially to hire a full time consultant- contractor, and the utilities paid, I think it was 500 or 1000 dollars. And that consultant was available to go around to each one of the utilities and do whatever they wanted: Help develop solar plans, help work with an installation that was already in installed, help them develop procurement specs, help work with manufacturers, whatever it was. That program was funded by NREL, Sandia, EPRI, Western, and the utilities themselves. And that was a very successful mark. And we learned that you have to educate not only the customers and the infrastructure, but is key to educate the utility people so that they buy into this, recognize the benefits. So that the Circuit Writer Program is phasing out and this is coming in. All the members of the Circuit Writer, I think, are included in that 25. They liked the program so well, they've gone on and joined the Services Network. So in effect it isn't dead; it is just continuing.

Q. I would like to follow up on that question. This is as an information clearing house. But you are also saying that it has basically installation capabilities, so a utility could use this organization as an intermediary for actually doing off-grid installations. Would it take the place of some of the utility's own service providing?
A. The Photovoltaic Services Network, the attempt is to provide support to the utility. I don't think it is intended to do anything in place of the utility. The utilities are coming together, the

Network is providing training, technical support, they will be working on standards, specifications, things like these. But their not intended to be something in place of the utility itself. They will be working with the infrastructure organizations, helping to train those, hold workshops, things like these. But it is not intended to really become part of the utility program. It provides technical support.

Q. In your earlier presentation, if I understood correctly, you said that 96% of manufacturing was chrystalline and 4% was thin film, and I wonder if that was in dollar amount of sales, number of companies or number of units.
A. We would have to check to make sure, but I believe it is number of units, or number of kilowatts. About 96% is chrystalline silicon and thin films four and concentrators less then one.

Photovoltaic Rural Electrification and XX Role of Electric Power Utilities in India

Inderjit Singh Anand
India

1. WHAT IS RURAL ELECTRIFICATION?

"Rural Electrification comprises all activities aimed at enabling users situated outside major cities to have access to electricity. The electrification process can be differentiated from the conventional scheme of extension of a national grid, as it covers everything up to independent configurations supplying power for a specific, determined need and the solving of specific technical and economic problems".

Rural Electrification (RE) thus implies electrification of rural areas as distinct from urban areas. This is obviously due to the very nature of dispersed layout, the low productive and consumptive loads, the low density of consumers, the meager per capita consumption, the low per capita income and comparatively low level requirements of reliability and satisfaction. While the provision of electrical network in urban areas in India caters to the industrial, commercial, transport, drinking water, domestic loads etc. in a fairly organized manner with back-up services from the utilities, the Rural Electrification caters to the needs of the villages. The major thrust on RE in India so far has been on creation of electrical infrastructure for the energisation of irrigation pumpsets to ushering green revolution leading to self sufficiency in food grains production. The electrification of villages and households has been either clubbed with the pumpset programme in agricultural areas or taken up as a part of Minimum Needs Programme (MNP) in the case of other areas.

2. DEFINITION

A precise definition has been eluding the planners and programmers in various countries due to the extent of aspirations of rural population backed with political considerations. For planning purposes, the number of localities are identified by each country through census and surveys and the programmes initiated for developing them as part of the country's priorities to develop the rural areas to meet their energy needs for improving quality of life, rural industrialization and preventing migration to the cities etcetera.

In India, there are 579132 inhabited villages as per 1981 census with population ranging as low as one and as high as 10,000 per village. These villages constitute the rural areas. In India a

A New Model for Commercially Sustainable Renewable Energy-Based Rural Electrification in Indonesia

Robb Walt
Integrated Power Corporation-Indonesia
USA

1. SUMMARY

Rapidly increasing demands and requirements for access to electricity throughout the remote areas of Indonesia coupled with annual subsidies in excess of $500 million for rural electrification have forced the Government of Indonesia to search for alternatives to the conventional utility model for rural electrification. In 1992-3 a study was conducted in collaboration with the Government of Indonesia's Agency for Application and Assessment of Technology (BPPT) and the national power utility, PLN to support the search for sustainable solutions for electrification of remote communities. This study produced a new commercial model for electrification of off-grid rural communities in Indonesia with utility quality electricity services. This new model is characterized by the use of new technologies for power generation, distribution, and sales of electricity. Key to the success of the new model are renewable energy-based hybrid power plants and the use of flexible, on-demand electricity dispensing meters. Estimated fees for electricity service are based on the current amounts now being paid by rural households for kerosene, candles and battery services at different income levels. The study showed that most rural households are willing and able to pay additional amounts for reliable, utility grade electricity for valuable services, such as better lighting, TV entertainment and for productive (economic) uses during daytime hours.

A financial assessment was conducted for investments in hybrid power systems for off-grid communities with revenues generated on the basis of market fees, and collected through new technology for electricity purchase and prepayment on a commodity basis. The assessment demonstrates that this approach would provide superior electricity services on a full-time basis, with little or no subsidy required during the three- to five-year commercialization phase, and with profitability as an achievable goal in the full commercial phase.

2. INTRODUCTION AND OVERVIEW

2.1 CONFLICTING MANDATES IN OFF-GRID RURAL ELECTRIFICATION

PLN faces serious challenges in its efforts to expand electricity services to off-grid communities throughout rural Indonesia. Decentralized diesel-based rural electric power delivery loses money; substantial and growing subsidies are required because the national residential electricity tariff does not even cover the fuel price component of decentralized diesel-based power generation. In 1991 the national operating cost subsidy for the two lowest residential tariffs (R1 and R2) was the equivalent of a half billion U.S. dollars. Diesel fuel oil prices are also subsidized, with the price of diesel fuel the same at Pertamina (the national oil company) terminals throughout Indonesia.

PLN has pursued a traditional approach to rural electrification, one that reflects the willingness and ability of the Government of Indonesia to subsidize most of the costs as part of a larger policy to support social equity and economic development in rural regions. The PLN model for electrification of remote communities has the following characteristics:

- Based on the traditional utility paradigm of "build and grow".
- Serves only 20-30% of the households in a community.
- Very low household energy consumption (typical 500-800 Whrs per day).
- Small diesel plants are typically operated at less than 20% capacity.
- 12 hour power (6 PM to 6 am) prevents daytime use of electricity for rural industry.
- Dependent on cost and supply of diesel fuel and skilled operators.
- Harmful to the environment, both local and global.
- Not commercially viable.
- Requires subsidy of 80%.
- "More for operating costs- "Hidden equity" used for capital equipment procurement.
- Costly to expand coverage and increasingly difficult to fund or finance.

PLN is operating under three conflicting mandates regarding rural electrification: expansion of rural electric services, minimization of operating losses, and becoming profitable under privatization. The first mandate is to electrify as many unelectrified communities as possible (extensive electrification). This mandate is in response to Government policies that support widespread rural social and economic development. Electricity is seen as an essential ingredient of social equity and rural development, and there is widespread demand by unelectrified rural communities to obtain electricity services as soon as possible.

The second mandate is for PLN to reduce and minimize its operating losses, which means limiting the number of customers. The number of connections is very effectively limited by PLN in these rural communities through the charge of a utility connection fee (typically Rp 90,000), which is more than most rural households can afford as a lump sum payment.

The third mandate, which reflects the announced[1] intention of the Government to privatize PLN, is the requirement for PLN to achieve financial viability as a private sector company. PLN is now a *PERSERO*, a government-owned company that is expected to operate on commercially

[1] The Ministry of Mines and Energy announced in August 1994 that the status of PLN had changed to a "PERSERO," or wholly government owned company with a requirement to become commercially viable. It is expected that the previous practice of capitalization of new equipment for rural electrification through funds supplied by the Ministry of Finance (largely from bilateral and multilateral aid and lending) to PLN at no cost will no longer be possible.

profitable terms, and to be sufficiently viable that it can sell shares in the international financial marketplace.

These mandates cannot be simultaneously achieved under PLN's present model and practices for off-grid rural electrification. A new model for sustainable, financially viable, large-scale rural electrification is needed in Indonesia if most of the rural population of the country is to have affordable access to electricity.

2.2. ACHIEVING THE MANDATES: THE SEARCH FOR ALTERNATIVES

As a result of this feasibility study, a new commercial model or framework for investment in and implementation of off-grid rural electrification that meets the tests of financial and operational sustainability. The new model also supports social and economic development needs, by tripling the number of connections and by providing 24 hour power, and supports local and global environmental goals by using renewable energy.

The principal motivation for the development of this framework has been the need to establish commercial operations that can become profitable in a reasonable time and which can yield sustainable long-term returns on investment while serving the enormous need and demand for basic rural electricity services. This is a formidable challenge. We believe that it can be met in politically, socially, economically, and environmentally sustainable ways.

3. REQUIREMENTS FOR SUSTAINABLE LARGE-SCALE ELECTRIFICATION OF OFF-GRID COMMUNITIES

There are no small communities in the Eastern Islands in which PLN provides 24 hour power. In fact, the only communities in the Eastern Islands that have 24 hour power are electrified by renewable energy-based hybrid power systems (two on Nusa Penida and one on Bonto). There are few if any daytime loads in such communities, due to the absence of electrically-powered economically productive activities. After electrification by PLN, daytime operation of a small diesel genset at perhaps 10% of full load would be extremely wasteful in terms of the incremental costs of additional on-site labor, fuel used at low efficiency, increased maintenance, and a decrease in generator life by 50%. Of course the absence of daytime power precludes investments in productive activities that would require such power. This is a vicious cycle, one which PLN and the Government of Indonesia in general would like to break, so that the benefits of 24-hour entry-level electrification can be brought to most of the rural population in a financially and economically justifiable and sustainable manner.

Without access to 24-hour electricity, communities cannot hope to attract either public, private, or NGO/PVO investments in socially and economically productive activities. Because renewable energy-based hybrid power plants incur no additional labor penalty and virtually no fuel use or efficiency penalties for 24-hour operation, they offer the potential for supporting investments in economically productive activities. In many of the communities visited on the Pangkajene Islands, boat builders, artisans, and others were using power from small privately owned generators, at extremely high unit costs per kWh. These individual private investments, expensive as they are, justified by those who make them on the basis of the perceived opportunity to increase their economic productivity.

4. OFF-GRID RURAL ELECTRIFICATION - THE CHALLENGE AND THE OPPORTUNITY

The challenge is to find sustainable ways to provide millions of rural inhabitants with access to electricity on an non-subsidized basis. The principal problem is that the present PLN technology and the PLN approach to generation, distribution, and sales of electricity in rural communities requires a subsidy of 80% or more of the costs of service. The opportunity is to introduce new technology and new commercial models to lower costs, reduce dependency on fossil fuels, increase coverage and revenues, and, over time, eliminate subsidies

4.1. GOI'S OBJECTIVE

GOI's objective is to establish a commercially and environmentally sustainable means of providing rural populations in Indonesia with electricity services that meet both their priority needs and their ability to pay. This can be achieved by simultaneously:

- Using a new, commercial model for rural electrification.
- Changing the technology used for power generation.
- Changing the technology for distribution and sales of electricity.
- Changing the ownership and financing model for rural electrification.

4.2. OPPORTUNITIES FOR IMPROVING THE COMMERCIAL VIABILITY OF ELECTRIFICATION OF OFF-GRID RURAL COMMUNITIES

No single measure can transform the present approach to rural electrification of off-grid communities to one that is commercially viable and sustainable. However, there is a set of measures which, when taken together, can reduce operating costs and increase revenue to the point where rural electrification can become commercially sustainable within three to five years, and substantially reduce the present subsidy requirements for new electrification of off-grid communities.

Reduction in Operating Costs

Operating costs can be reduced through several measures, including:

1. Reduction of the amount of diesel fuel required to produce a kWh of electricity.
2. Reduction of labor requirements for operation and maintenance.
3. Improvement in the match between electricity service and demand.
4. Increased efficiency of electricity production, delivery, and use.

Diesel fuel use can be reduced significantly through the use of renewable energy-based hybrid power systems in place of stand-alone PLTD units. Hybrid power systems increase diesel genset operating efficiency by operating the diesel units at rated capacity for short periods, and use renewable energy inputs to generate up to 85% of the electricity.

Site-based labor for power system operation and management can be eliminated through automated plant operation using computer controls and remote monitoring, coupled with regional operation and maintenance service centers. Hybrid power units are designed to operate in this fashion, and do not require on-site operators. The integrated diesel gensets will last for 20 years or more without replacement.

The investment in the power system can be optimized by determining the priority needs for electricity in a community and providing a modular power system to meet those needs at an affordable price.

Increase in Revenues

Revenues can be increased ten-fold through increasing the number of consumers, and by changing to an on-demand market-based method of selling electricity services.

The number of consumers can be increased from the typical range of 20-30% of potential customers (as found with small communities currently electrified with PLN diesels) to virtually 100% connection, through elimination of the lump-sum connection fee. Field surveys[2] provide strong evidence that the PLN connection fee is the single greatest deterrent to connection, and if there were no hookup charge most people would connect to the community power system. The financial analysis conducted for this feasibility study demonstrates that collection of a connection fee does not materially change the highly negative net present value (NPV) for a PLTD investment.

5. THE DETERMINATION OF MARKET-BASED FEES FOR ELECTRICITY SERVICES

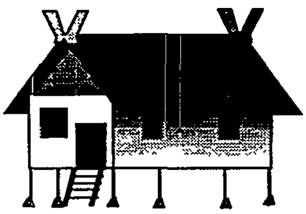
5.1. MEASURING THE WILLINGNESS AND ABILITY TO PAY FOR ELECTRICITY SERVICES

People purchase electricity for the services it can provide, especially lighting and entertainment. When electricity is not available, people purchase fuels and batteries (Figure 1), often at premium prices relative to the level of services the fuels can provide. Typically fuels and batteries are purchased incrementally, when people have the money available. No charge is made for access to purchase, although local middlemen often mark up the prices as much as local conditions can bear. The actual payments made for fuel and batteries provide a direct measure of the willingness and ability of rural people to pay for highly valued energy-based services.

[2] Field surveys were conducted by a joint field team in several regions of Indonesia. These surveys have revealed that the present PLN hookup fee presents a barrier to electricity service to virtually all low income and most medium income households in PLTD-equipped villages.

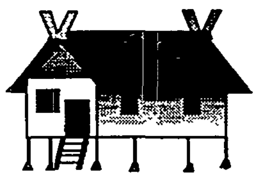
Payments for Energy Services

High Income
(15%)



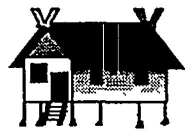
	Daily	Monthly
Kerosene :	800	24,000
Other:	600	18,000
	1,400	42,000
Electricity :	1,000	30,000
30 kWhrs/Month		

Medium Income
(60%)



	Daily	Monthly
Kerosene :	300	9,000
Other:	300	9,000
	600	18,000
Electricity :	500	15,000
15 kWHrs/Month		

Low Income
(25%)



	Daily	Monthly
Kerosene :	150	4,500
Other:	100	3,000
	250	7,500
Electricity :	150	4,500
4.5 kWHrs/Month		

Figure 1

As shown in Figure 1, rural Indonesian households without access to electricity routinely pay between Rp 7,500 and Rp 42,000 and more for fuels, dry cells, and battery charging. This established pattern of payments is used as the basis for the design of a market-based fee structure for electricity services. The market-based fees permit provision of electricity-based services that are both superior to and far more flexible than the same level of services that are now provided by fuels and batteries. In other words, for the same monthly expenditures that households are now making, they can have access to electricity at a consumption level that will permit superior service.

5.2 PATTERNS OF ENERGY PURCHASES FOR LIGHTING AND ENTERTAINMENT

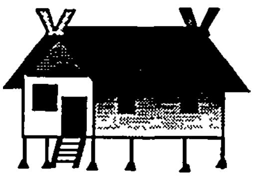
Throughout rural Indonesia, people without access to electricity routinely purchase kerosene for basic household lighting. They also purchase dry cell batteries for use in radios and audio cassette players, and often have an automobile battery that runs a small black and white television set. This battery is recharged at a local battery charging station. For these basic energy services, not including cooking, rural households typically pay between Rp 4,500 and Rp 25,000 per month for kerosene alone, depending on the size and wealth of the household. Payment for other energy sources, primarily dry cells and automotive battery charging services, ranges from Rp 3,000 per month for lower income households to as much as Rp 18,000 per month for higher income households. In these communities:

- Kerosene is purchased by the bottle (3/4 liter).
- Automobile batteries are purchased as needed and charged as needed, for television, VCRs, radios, and public address systems, when funds are available.
- Dry cell batteries are purchased as needed for radios and cassette players.
- The consumer pays local market prices and rates.

In the unelectrified Pangkajene Islands (South Sulawesi), the typical household pays Rp 18,000 per month for kerosene and batteries (Figure 2). If electricity were available, 500 Wh/day would provide the same TV and radio/ cassette services and twelve times the light as measured

Today, the typical household in the Pangkajene Islands pays the equivalent of 3,000 Rp per kilowatt-hour for energy services:

Medium Income
(60%)



Energy Use	Rupiah Daily	Rupiah Monthly
Kerosene :	300	9,000
Other:	300	9,000
	600	18,000

Kerosene For Lighting: 300 Rp/Day = .75 Liter = 4 Lamps @1000 Lmhrs*

Other: 300 Rp/Day (Battery for TV and radio)**

600 Rp/Day for 200 Whrs or 3,000 Rp/kWhr

With 500 watt-hours of electricity, the consumer receives 12 times the light plus TV and radio:

4 Lights	= 12,000 Lmhrs	For 500 Rp/Day = 1,000 Rp/kWhr
TV (B&W)	= 6 hours	
Radio/Cassette	= 2 hours	

* Equal to 120 Whrs of electricity
** Equal to 80 Whrs of electricity

Figure 2

in brightness (over the same period of time as the kerosene lanterns are used). These households are typically paying the equivalent of Rp 3,000 (US$ 1.50) per kWh of electricity, for services inferior to those provided from a local microgrid!

5.3. TYPICAL HOUSEHOLD USES OF ELECTRICITY

In PLN-electrified communities, there are high barriers to access to electricity, but attractive prices for the purchase of electricity once a potential customer becomes connected to the power system. In these communities:

- Electricity is purchased by the month on a uniform tariff basis.
- The consumer pays a one-time Rp 90,000 connection fee to the PLN plus a similar amount

for basic house wiring.
- The consumer pays highly subsidized below-market rates for electricity which are typically one-third to one-fourth of the cost of energy services from kerosene and batteries.

Rural households that have R1 electricity service pay a typical monthly fee of between Rp 3,500 and Rp 4,500. This PLN-provided level of service is 450 VA, and in principle can supply 450 Wh of electricity per hour, or about 5.5 kWh/day assuming 12-hour power from 6 p.m. to 6 a.m. the following morning.

In spite of the potential to use as much as 5.5 kWh/day of electricity, most households in 14 small eastern island communities connected to PLN diesel-based community power systems actually consume between 400 and 800 Wh per day. At present there are no financial incentives

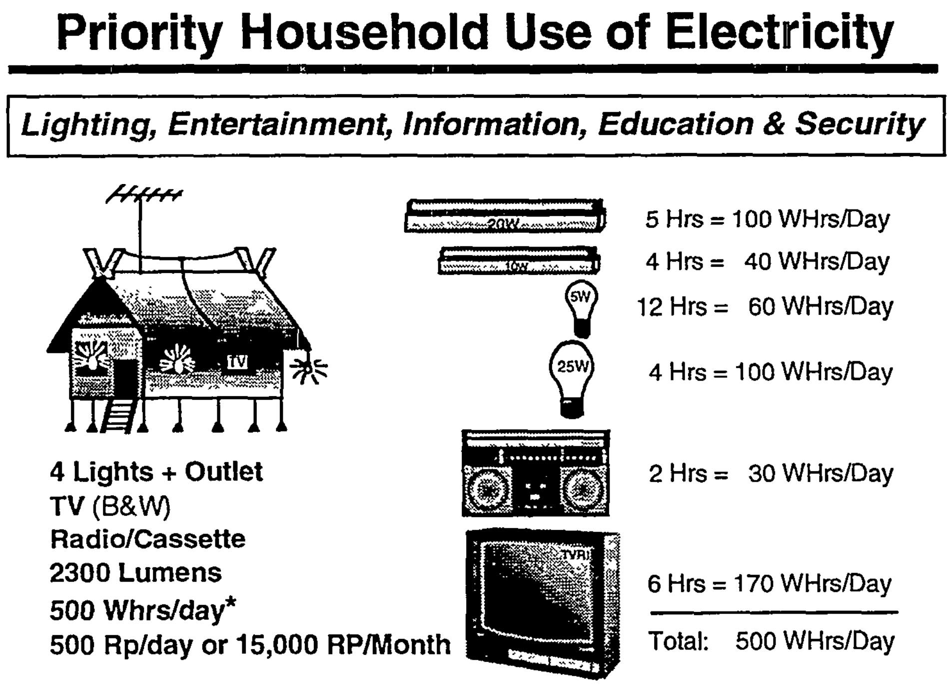


Figure 3

for efficient end use of electricity, since the PLN R1 tariff is far below market rates and the equivalent cost of kerosene. Typical electricity uses are shown in Figure 3. In this example, the consumption of 500 Wh/day provides six hours of television (black & white), two hours of radio/cassette, and use of four lights over a twelve hour period.

Those households that would use only a few hundred watt-hours per day, primarily or exclusively for lighting, are usually not connected to the local microgrid because they cannot afford the up front PLN connection fee of Rp 90,000. Because of this barrier, they purchase inferior lighting services through the use of kerosene, and pay as much per month (or more) than electrified households on the R1 tariff.

5.4. KEROSENE LANTERNS AND ELECTRIC LIGHTING

The basic lighting needs of a rural household are typically met through the use of two or three kerosene wick lanterns, and use roughly one-half liter to three-quarters of a liter of kerosene daily. Fuel for this lighting service costs Rp 150 - 200 per day. The present market price of kerosene in the eastern islands of Indonesia is Rp 380-400/liter (August 1994). This price is approximately 40% below international, non-subsidized prices. Many households consume 1 or more liters per day, and use pressurized kerosene lanterns.

Kerosene lanterns are not a high-quality source of light. A typical wick lantern has a brightness of about 35 lumens[3]. A 20 watt fluorescent tube lamp, widely available throughout Indonesia, produces 1300 lumens and is 37 times brighter. Moreover kerosene lanterns are dangerous. Many serious and sometimes fatal fires are caused by accidents and carelessness in the use of kerosene, and the pressurized lanterns occasionally explode, sometimes with deadly consequences.

5.5. THE COSTS OF ELECTRICITY-BASED EQUIVALENT ENERGY SERVICES

The lighting services (Figure 4) provided by two to three kerosene wick lanterns, using 0.50 to 0.75 liters of fuel daily, at a cost of Rp 150 - 200 per day, could be provided in a superior manner by electricity. One 20 watt fluorescent tube lamp, one 25 watt incandescent lamp, and one 5 watt incandescent lamp, and would require 150 Wh/day. Based on demonstrated

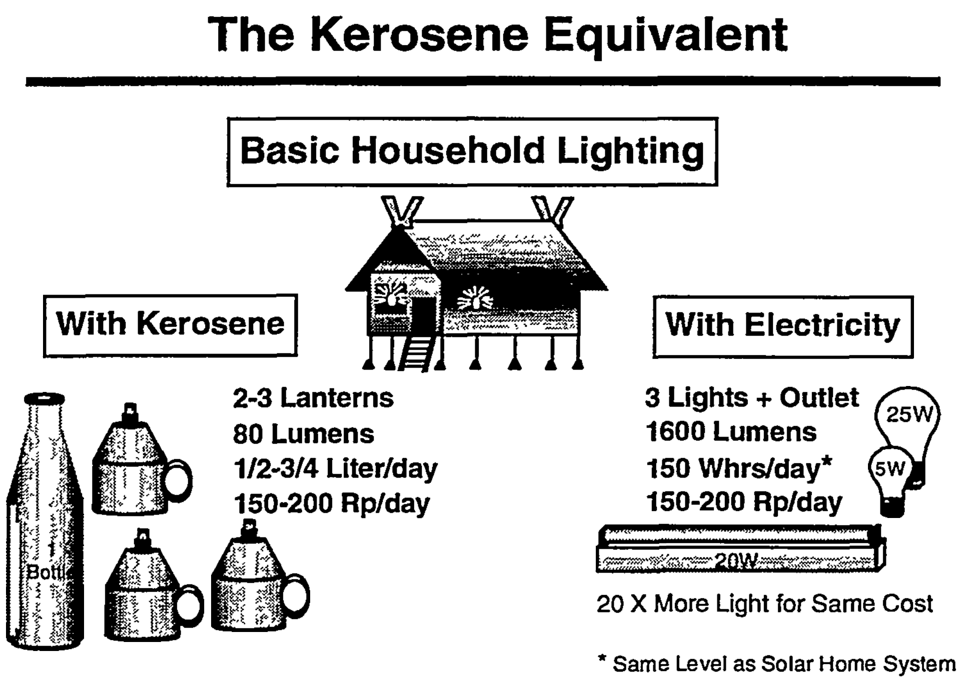


Figure 4

[3] A *lumen* is a measure of brightness or luminosity as perceived by the human eye. An ordinary candle has a luminosity of about 13 lumens.

willingness and ability to pay, this electricity-based service could be supplied for Rp 150 - 200/ day (Rp 4,500 - 6,000 per month).

This is the same level of electricity supply (150 Wh/day) provided by the photovoltaic solar home lighting systems now in use in rural Indonesia. However, the service from PV home lighting systems is inferior to that of a community microgrid. PV home lighting systems provide little or no electricity during periods of low sunlight, AC power is typically not available, and electricity supply from these systems is far less reliable than electricity from a professionally managed central microgrid. Households are charged a flat monthly fee from Rp 7,500 - 10,000 per month for ten years for a basic PV home lighting system, at an effective price in excess of Rp 2,000 (US$ 1.10) per kWh, or 15 times the typical cost of PLN R1 services.

Although the monthly payment is for the purchase of the PV system rather than a charge for electricity service, in effect the consumer is paying a very expensive flat rate for a variable and extremely limited service. Moreover, during the ten year period the 12VDC battery will have to be replaced up to 4 times at a cost of Rp 50,000 per battery.

6. NEW TECHNOLOGY AND A NEW COMMERCIAL MODEL FOR DECENTRALIZED RURAL ELECTRIC POWER DELIVERY

A new approach to providing electricity to off-grid communities using decentralized renewable energy-based power generation technologies has been developed in collaboration with BPPT and PLN. This new approach combines advanced power generation technology with an on-demand market-based system for selling electricity based on the demonstrated willingness and ability of rural Indonesians to pay for specific energy services such as lighting and entertainment (radio, cassette, television). In this approach, electricity is supplied and sold on demand, as needed, priced at market rates, and with no barriers to access (i.e. connection fees).

The objective of the new commercial model is to provide high-value electricity to services to all households in off-grid rural communities in a commercially sustainable manner. The objective will be achieved through implementation of the following measures:

- Maximizing connections, not consumption.
- Matching the level of services to each consumer's needs and ability to pay.
- Providing electricity service to all, not just the wealthiest.
- Pricing electricity on the basis of value and the consumer's willingness and ability to pay, not on the basis of uniform tariff rates.
- Use of a flexible, on-demand electricity purchase system (just likekerosene is purchased) not a monthly payment requirement.
- Selection of the most efficient least-cost power generation technology.
- Focusing on commercial sustainability rather than quotas.
- Concentrating on consumer service and system operation.

The combination of new technology and a new commercial model for serving rural communities with electricity is characterized by the following features:

1. Prime diesel power generation is eliminated, cutting labor requirements for operation and maintenance by over 70%.
2. Renewable energy-based power generation systems reduce the diesel fuel component of electricity production by 60 - 80%, and reduce associated carbon dioxide emissions by the same amount.
3. A connection rate of virtually 100% of potential electricity customers is assured through elimination of all connection fees.
4. The level of electricity service provided to each customer is matched to the ability and willingness of consumers to pay.
5. Revenues are increased ten-fold over those for PLTD-equipped communities with PLN tariff rates. This is achieved by:
    - Sale of electricity as a commodity, on demand (like kerosene).
    - Use of market-based fees rather than mandated tariffs.
    - Three-to five-fold increase in the number of connections in each newly-electrified community (from 20-30% in the traditional PLN approach to 90-100%).

6.1 COMMODITY-BASED SALES OF ELECTRICITY FOR RURAL POWER DELIVERY

In the new commercial model, guaranteed access to electricity will be available to all households whenever they want it and in any amount desired, depending on their needs and available funds. Increments of electricity service will be sold as disposable magnetic cards by community shops (warungs and kiosks). Each household will be connected at no charge to the community microgrid, and will have an electronic prepayment meter that "dispenses" electricity service based on the amount of electricity that has been purchased and "stored" in the meter. Virtually all consumers have the financial means to obtain basic lighting and entertainment services, and have the flexibility to buy and use as much electricity as they wish, subject to a peak power limit of 450VA.

The basic electricity service that can be provided at a cost equal to a typical bill for R1 consumers (Rp 4,500/month) will be equivalent to that provided by a solar home power system, except that the availability of electricity will not be subject to the weather, or to the frequent technical difficulties that many people have with the individual PV home power systems. This basic electricity service primarily lighting is priced in the new commercial model according to the cost of obtaining an equivalent service from purchase of kerosene. In this approach, all traditional metering and billing are eliminated, and the prepayment system assures virtually 100% revenue collection for the utility, and in advance of electricity use.

Energy Purchases in Rural Communities

Energy commodities such as kerosene and dry cells are purchased as needed, when money is available, and are fully used. Kerosene is not thrown away and batteries are used until they are discharged. (Their haphazard disposal is a growing environmental problem throughout Indonesia). Automotive batteries are recharged when they need it. There are powerful financial incentives for people to conserve valuable commodities. Low and medium income families in the eastern islands typically buy priority commodities when money becomes available, and are rarely able to make purchases on a monthly basis, because savings are rarely accrued in these households.

Making Electricity Available Like Other Commodities

Electricity usually is not perceived as a commodity. It has no tangible physical presence like liquid and solid fuels or like batteries. And, in the PLN model, it is provided on the basis of a monthly tariff.

If electricity services were available as a commodity that could be purchased in the amounts desired, at any time, just like kerosene or dry cells, rural households would be able to purchase the electricity services they want and are willing and able to pay for. There would be little waste in such a system. This requires new technology and systems of selling and dispensing electricity services.

The Desa Power Meter - a Tool for Commodity-based Sale of Electricity

A significant component of the new commercial model is the use of value-based fees for electricity services. Electricity will be sold in the same way that access to telephone service is paid for and kerosene fuel is purchased. Electricity services will be provided through the use of an on-demand dispenser, i.e. an electronic prepayment meter. Disposable magnetic *Desa Power Cards* similar to the Indonesian phone card would be sold by local merchants to community residents with values priced at multiples of the "kerosene equivalent" of the lighting services being purchased.

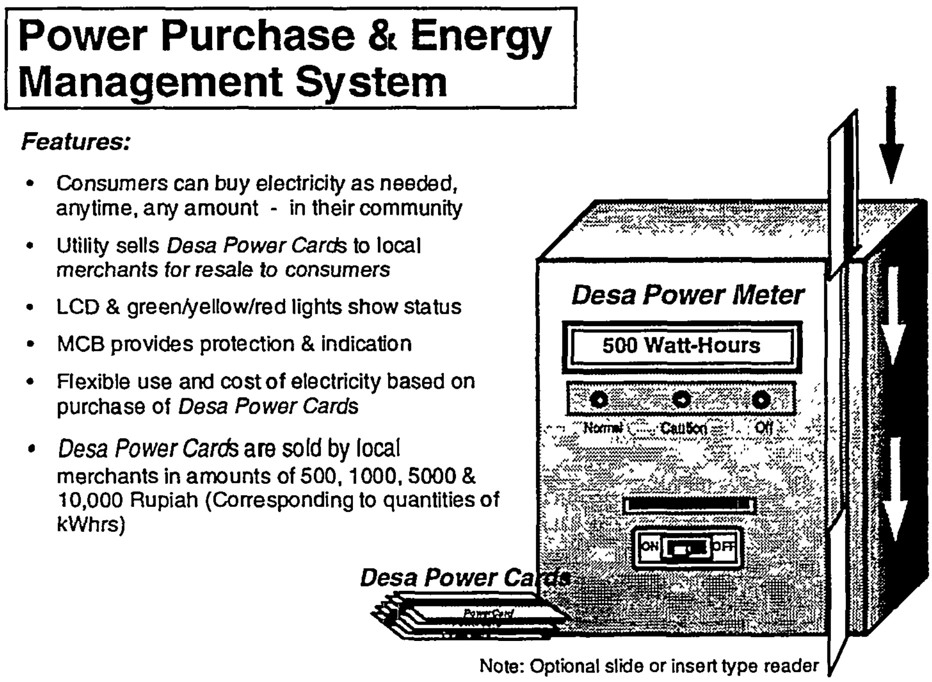


Figure 5

A power purchase and energy management system has been developed (Figure 5) to meet the challenge of providing electricity services on a prepaid commodity basis to rural households. Unlike other prepayment meters, which are designed for typical high levels of urban electricity services, and which are technically unsuitable and too expensive for rural community use the "Desa Power Meter" is designed to operate when service levels are only a few hundred watt-hours per day. The meter will be used in conjunction with renewable energy hybrid based electrification projects, beginning with the Eastern Islands Pilot Project.

In the implementation of these project, the local utility, whether public or private, will sell disposable magnetic strip *Desa Power Cards* to local merchants for resale to consumers. Each consumer would have a Power Meter in line with the service drop. Consumers will purchase electricity as needed, any time, and in any amount, in their community. These would be sold in amounts of 500, 1,000, 5,000, and 10,000 Rupiah, corresponding to specific quantities of kilowatt hours. The meter has an illuminated status display and signals to show how much service remains. The peak power draw would be limited by a mini-circuit breaker, and the meter would turn the power off after the final increment of credit had been used.

7. FINANCIAL ANALYSIS OF INVESTMENTS IN DECENTRALIZED DIESEL AND HYBRID POWER GENERATION SYSTEMS[4] FOR OFF-GRID RURAL ELECTRIFICATION

7.1. SUMMARY

An assessment was made of the financial performance of alternative investments in small-scale decentralized power systems for off-grid communities in Indonesia. The costs and benefits were calculated for two technology and policy options — the present PLN approach using small, dedicated diesel gensets (2X20 kWe) and a uniform highly subsidized national tariff structure, and renewable energy-based hybrid power systems operating under a new commercial model employing market-based fees for electricity services. A specific goal was to identify the circumstances under which off-grid rural electrification of small communities (100 to 150 households) could be technically, financially, and environmentally sustainable. The analysis was conducted using the full capital and operating costs for both PLTD *(Pembangkit Listrik Tenaga Diesel)* diesel power units and for hybrid power plants. The results are:

1. Hybrid power systems, designed to meet the priority energy requirements of a rural community of 200 to 400 households, with no hookup fees, and revenues based on kerosene equivalent market-rate fees, generate a *positive Net Present Value (NPV) under all financing conditions,* with the most favorable returns under typical World Bank financing terms and conditions for rural electrification projects in Indonesia.
2. With renewable energy-based hybrid power plants used in place of PLTDs, but with the present PLN electricity pricing structure, the required total subsidy (based on a negative net present value) would be reduced by one-third in the case of commercial rate financing, and

[4] This chapter was written to be used as a free-standing document. Consequently it includes, in summary form, some material that appears elsewhere in the Feasibility Study documents.

by almost two-thirds for World Bank financing. However, *under no circumstances is the net present value of the investment positive.*

3. The introduction of market-based fees for electricity could reduce the total required subsidy (capital cost and operations) for rural PLTD units by as much as 75%. However, *the investment in diesel-based power generation for small rural communities would still not be profitable.*
4. Of all options considered, the present model of diesel-based off-grid rural electrification is financially and environmentally *least-attractive.* Furthermore, the conventional PLN model limits electricity services to the few relatively wealthy members of a community, and inhibits investments in productive activities and in social services that would require daytime or full-time power. This approach is not a viable option for bringing electricity to the tens of thousands of unelectrified off-grid communities in the Eastern Islands of Indonesia.

7.2 INTRODUCTION

A financial analysis model was developed that permits detailed micro-economic (financial) analysis of alternative investments in small-scale decentralized power systems for off-grid communities in Indonesia. The model uses standard discounted cash flow analysis methods to calculate the annualized financial costs and benefits of each power system. The analysis specifically calculates and compares the financial performance of investments in conventional, small isolated diesel gensets (PLTDs), as implemented by PLN, and in 's renewable energy hybrid power generation units, to supply off-grid communities in the Eastern Islands of Indonesia with high-quality electricity services.

The analysis incorporates detailed PLN-supplied information and data on the *full capital and operating costs* for small (20 kWe and 40 kWe) conventional diesel gensets (PLTDs) used by PLN for its isolated rural power generation units. It also includes comprehensive data for the capital and operating costs of hybrid power plants, based on commercial experience. The analytical model was developed as an *Excel* spreadsheet; the model structure, data requirements, assumptions, and outputs are described and illustrated below. The selection of the most suitable hybrid power system, determination of likely community electricity demands, and the establishment of a fee structure for electricity services that is viable for both consumers and suppliers, requires an iterative mix of judgment and calculation. A major challenge in this work has been the determination of the *preferred least-cost technical and institutional options* for off-grid community electrification, and development of detailed and validated data for cost and performance for these options, especially for the conventional PLTD diesel power units as implemented by PLN.

7.3. MODEL OBJECTIVES AND REQUIREMENTS

The financial analysis model was developed as a flexible tool to evaluate the financial performance of investments in specific off-grid power systems suitable for the majority of Indonesia's off-grid communities, particularly in the Eastern Islands. The model was designed to be both *transparent yet comprehensive* in its treatment of technical, operational, economic, and financial parameters, *realistic* in capturing the conditions encountered in off-grid rural communities in the Eastern Islands, and *flexible* in use. It was designed to permit *rapid trade-off analysis* among various technical, operational, cost, and financial conditions, and to be easily updated in terms of input data, required outputs, and additional calculations. The model permits detailed specification of all power system and power distribution system capital and operating costs, operating modes, and efficiencies. The model allows comparative analyses using different financial parameters including financing terms and rates, project accounting life, discount rate, general inflation, fuel price escalation, as well as subsidies and capital cost buy downs, if any. The model calculates several measures of investment performance for both debt and equity financing, including Net Present Value (NPV), the Internal Rate of Return (IRR), and the Life-Cycle Cost (LCC) and First-year Cost (FYC) of electricity under a set of technical, cost, and financial specifications for the power system. The model can also calculate the external subsidy required, if any, to achieve a specified IRR under various revenue conditions, including standard PLN rural household tariffs and market-based electricity fees.

7.4. MODEL STRUCTURE AND IMPLEMENTATION

The financial model contains several submodels and data bases that automate the preparation of much of the input data for the financial analysis component of the model. The model is presented (Table 7-1) in a multi-page printout that arrays both input data and calculation results.

Table 7-1
SUMMARY OF THE FINANCIAL MODEL

Spreadsheet Page	Type	Contents
1	Summary of Analysis Results	• Power system performance • Characterization of target community & level of electricity services • Capital and life-cycle costs • Financial/economic assumptions • Financial performance
2	Input	• Power system and community load technical and cost data • Financial/economic assumptions • Contributions by energy type
3	Results	**Cost and Financial Performance** • Financial performance (NPV, IRR) • Summary income statement • Life-cycle costs (total, annual) • LCC/kWh components for capital, fuel, and non-fuel O&M
4	Results	**Power System Performance** • Electricity production, consumption, and distribution • Contributions by energy type • Diesel operation, fuel use • Power system performance
5	Input	**Capital Equipment and O&M Cost Workup Tables**
6	Input	**Community Electricity Demand Estimates** • Daily energy and peak load, individual and aggregate for household, community, and commercial loads • Connection schedule and tariffs/fees
7	Results	**Income Statement for Project Life**
8	Worksheet	• LCC/kWh by year for project life • Energy and fuel use by year
9	Worksheet	**Present Value Table; O&M Costs, Payback Period**

7.5. INPUT DATA REQUIREMENTS AND ASSUMPTIONS

All of the inputs to the financial analysis component of the model are in financial form. These inputs include the values of expenses, revenues, and financial parameters. Expenses and revenues are arrayed in the project income statement, typically on an annual basis. Once the income statement data are complete and the financial parameters are specified, the calculation of the financial performance indicators and other relevant financial data is straightforward.

Expenses include the initial capital cost of the installed and fully functional system, the year-by-year capital and operating costs of the full power system, and other expenses such as any taxes, permits, fees, licenses, insurance premiums, debt service payments, and leases.

Revenues include all sources of income, including fees paid by power system customers, and any payments by others, such as copayments by a government agency, credits, or grants.

Financial parameters include the debt and equity components of the investment, required rate of return on equity, debt repayment terms and conditions, and financial rates including the discount rate, inflation rate, and projected escalation in fuel prices, labor costs, and equipment that must be replaced over the life of the project. Other relevant parameters include applicable taxes and the rules and schedules for depreciation of capital equipment.

7.5.1 Technical data

Technical data (Table 7-2) for equipment specifications and performance are required as input to the technical model. Some of the input data are first calculated in submodels (e.g., diesel fuel consumption, peak watts and daily energy for categories of rural households, etc.). Examples of such calculations are the average effective heat rate for the diesel generator (kWh/liter of diesel fuel), the relative contributions of diesel and renewable energy sources to the total annual energy demand, and the annual diesel genset running time for the hybrid power system.

Table 7-2
Required Technical Data and Typical Examples
Sarrapo Lompo, Full Connections, 24-hour Power

Category	PLTD (2x20 kWe)	Model 25 Hybrid	Notes
Peak capacity	20 kW	26 kW	
Maximum electricity production	480 kWh/day	525 kWh/day	Full capacity
Diesel contribution	145 kWh/day	105 kWh/day	
Renewable energy contribution	none	38 kWh/day	PV only
Total energy production	145 kWh/day	142 kWh/day	Meets priority needs
Diesel run time	8,760 h/yr	1,916 h/yr	Hybrid is 80% less
Diesel fuel use	28,820 l/yr	11,689 l/yr	Hybrid is 60% less
Effective diesel fuel efficiency	0.99 kWh/l	4.45 kWh/l	Hybrid is 4.5 times better

7.5.2 Cost data

The principal cost data required for the analysis includes capital costs, non fuel fixed and variable operation and maintenance costs, and fuel costs. Examples are presented below. These data are arrayed on page 2 of the model spreadsheet printout.

Table 7-3
Required Cost Data and Typical Examples (U.S. $)

Capital Costs	PLTD (2x20 kWe)	Hybrid	Notes
Power system	25,677	122,529	PLTD data - PLN
Site/civil works	24,195	3,400	PLTD data - PLN
Transport to site	1,000	3,500	PLTD estimate
Commissioning	1,000	2,000	PLTD estimate
Distribution/revenue system	28,357	31,675	Includes service drops and meters
Operation and Maintenance Costs			
O&M repair labor	11,429/yr	4,524/yr	Hybrid is 60% less
General O&M supplies	2,625/yr	950/yr	Hybrid is 63% less
Minor overhauls (diesel)	1,200/yr	600/2 yrs	
Major overhauls (diesel)	3,150/3 yrs	1,500/6 yrs	
Diesel genset replacement	35,677/9 yrs	N/A	Hybrid genset not replaced
Battery replacement	N/A	12,000/6 yrs	
Diesel fuel price	0.25/liter	0.25/liter	6.1 liter/hr full load fuel consumption rate

7.5.3 Financial data

Required financial data input include general financial parameters applicable to all technical options and the financial data for a specific investment. Financial data of the latter type include the loan amount and any operating cost subsidies or capital cost buy downs.

Table 7-4
Financial Parameters and Typical Values Used in the Financial Model

Parameter	Base Case Values	Notes
Discount rate	12.0%/year	
General inflation	7.0%/year	
Fuel price escalation	2.0%/year	This implies a *decrease* in the real cost of diesel fuel, which is probably unrealistic.
Project accounting life	20 years	
Debt financing (rate, years, grace period)		
• Commercial	8%, 8-yr, no grace	
• World Bank (a)	8%, 20-yr, 6-yr grace	
• World Bank (b)	8%, 20-yr, no grace	
• World Bank/GEF	8%, 20-yr, 6-yr grace	GEF grant for 30% capital cost buy down
• Concessional	3%, 20-yr, 5-yr grace	
Consumer payment basis		See electricity fee table below for details of the two fee structures
• PLN rural tariff	R1, R2 residential	
• Market-based fees	Kerosene equivalent	

The specification of the two fee structures used in the analysis appears in Table 7-5. The market-based fees reflect surveys of what households in off-grid communities in Indonesia appear willing and able to pay based on monthly payments for kerosene, dry cell batteries, and automotive batteries plus charging services that would provide the same lighting and entertainment services as those provided by the specified electricity services. In the case of lighting, the services provided by electricity are vastly superior to those provided by all types of kerosene lanterns and/or 12V batteries.

A central feature of the market-based fee structure is that the consumers in the lowest electricity usage category would pay the same amount for electricity as they currently pay for kerosene and essentially the same as if they had PLN electricity service. Surveys of PLN-electrified villages have shown that the typical customer uses about 700-800 Wh/day, and that with education and demand-side management (financial incentives), this could be reduced to about 500 Wh/day.

Virtually all low-income and most medium-income potential customers presently are unable to hook up to PLN electricity services due to the unaffordable high (for them) connection fee. Based on surveys of what these low-income households pay for basic lighting and entertainment services from kerosene and batteries, these same services could be provided in a superior manner with electricity at essentially the same monthly cost. This corresponds to the T1 category used here, which provides an average of 200 Wh/day of electricity, primarily for basic lighting and entertainment services.

Table 7-5
Monthly Cumulative Payments with Market-based Fees and PLN Tariffs (US $)

Fee designation (usage)	PLN tariffs	Cumulative Monthly Market-based fees
T1 Low Income	2.14 R1	2.85
T2 Medium Income	2.14 R1	7.14
T3 High Income	3.00 R1	11.41
T4 (3 kWh/day) (commercial)	9.00 R2	28.57
Connection fee (one-time)	43.00 Fee	None

7.6. OUTPUT CALCULATIONS

The calculated financial parameters include the *Net Present Value (NPV)*, the *Internal Rate of Return (IRR)*, and the *Life-Cycle Cost (LCC)* and *First-Year Cost (FYC)* of electricity production and electricity supply.

7.6.1 Net Present Value and Internal Rate of Return

When all of the capital costs of the project are provided as debt, with specified terms and repayment schedule, the model calculates the NPV and IRR on the basis of actual project cash flows. The cash flows include annual payments toward the project capital cost, rather than a single first-year payment. In this case, particularly when a grace period is involved, there may be several years of positive cash flow before there are years of negative cash flow, if any. The calculation of the NPV is indifferent to the signs of the numbers in the stream of payments that under consideration. Each of these numbers is discounted to first-year values using the discount rate specified in the input section of the model, and the discounted cash flows are summed.

The calculation of an IRR involves determining the discount rate that makes the NPV of the project equal to zero. In order for there to be a calculable IRR, the cash flow under consideration must include both positive and negative numbers, in a suitable distribution. The first-year cash flow does not have to be negative.

Calculations of both the NPV and an IRR for a system requires consideration of both costs and revenues on an annual basis. If the objective of the investment is to achieve a hurdle rate of 12% IRR, an additional subsidy-based revenue stream may be required. In the case of small PLTD installations, a subsidy of over 80% is required to achieve this level of IRR.

7.6.2 Costs of Electricity Production and Supply

The Life-cycle Cost (LCC) of electricity is the present value of all costs over the life of the project, divided by the total number of kWh produced during that period. The First-Year Cost (FYC) of electricity is the average cost of production during the initial year of operation; it is the total first-year cost (including any first-year debt service and capital recovery on the initial investment, but not including the initial sunk costs) divided by the total number of kWh produced that year. Because there will be some technical losses between the power plant output and the end-use consumption, the cost of delivered energy will be equal to the cost of produced energy divided by (1 + fractional average loss). The technical losses projected for a small compact community such as Sarrapo Lompo are under 10%.

7.7. SPECIFICATION OF THE CASES FOR FINANCIAL ANALYSIS

Almost 60 different cases were analyzed. These cases represent combinations of technology choice, hours of operation, percentage of potential customers actually connected to the community microgrid, fee basis for electricity services, and the terms and conditions of financing. The factors that were combined to create these 60 cases are summarized in Table 7-6.

7.7.1 Selection of the Representative Community

The community of Sarrapo Lompo in the Pangkajene Islands of South Sulawesi was selected for the base case. Sarrapo Lompo is one of eight Pangkajene Island communities mapped and surveyed by the study team, and is characteristic in population, socio/economic features, and community layout of most of the island communities in this region. The community has a population of 1,135 people, with 227 households. The community also has a clinic, three schools, a church, and a government office. There are fifteen commercial enterprises that would be candidates for electrification, including three stores that require refrigerators, eight

Table 7-6
SCENARIOS FOR THE FINANCIAL ANALYSIS

- Three demand/supply technology conditions
  - Low and high demand, PLTD 2x20 kWe
  - Low demand, Model 15 hybrid
  - High demand, Model 25 hybrid
- Two electricity availability conditions
  - 12-hour power
  - 24-hour power
- Five financing conditions
  - Commercial (8,8,0)
  - World Bank (8,20,5)
  - World Bank (8,20,5) with 30% capital grant
  - World Bank (8,20,0)
  - Concessional (3,20,6)
- Two revenue specifications
  - PLN rural tariffs
  - Market-based electricity fees (kerosene equivalent)

other small stores, one tailor, two boat builders, and one workshop (see page 6 of model printout).

7.7.2 Energy-demand Scenarios

It was assumed that the island would be electrified using either a PLTD or PV/diesel hybrid power unit. A low-voltage power distribution system would be the community microgrid, and four scenarios were considered for estimating electricity demand. These were (1) 77 households and 6 community and commercial connections with 12-hour power (from 18:00 to 06:00), (2) the same, but with 24-hour power, (3) all 227 households, 7 community loads (including a set of 25 street/path lights), and 15 commercial customers, with 12-hour power, and (4) all 227 households, 7 community loads (including a set of 25 street/path lights), and 15 commercial customers, with 24-hour power.

The first two electricity demand scenarios assume that the usual PLN connection fee is required, and that, based on widespread experience in small rural or island communities, only 20% to 30% of the customers can afford to connect. The second two scenarios, reflecting the new commercial model presented earlier in this report, assume that there are *no connection fees* and that virtually all potential consumers actually connect to the power system.

7.7.3 Power Generation Options

To evaluate the financial performance of a diesel-based power system, it was assumed for both demand scenarios that two 20 kWe diesel gensets and associated facilities would be installed and operated according to PLN rural electrification standards. For evaluation of hybrid systems, a Model 15 hybrid unit was specified for the low-demand scenario and a Model 25 hybrid unit was specified for the high-demand case.

7.7.4 Financing Terms and Conditions

Several options for financing the investments in the power system were considered. These include (1) commercial or near-commercial rate financing of 8%/year, 8-year term, and no grace period, (2) World Bank rural electric power lending at 8%, 20 years, and with a 5-year grace period, (3) World Bank lending with a 30% capital cost buy down for the renewable energy plants (only) provided by a grant from the GEF[5], (4) World Bank debt financing with no grant component and no grace period, and (5) concessional financing at 3%/year, 20 year term, and 6-year grace period. These span the range of debt financing likely to be available in the foreseeable future.

7.7.5 Customer-based Revenue

Two cases were assumed for revenue from the customers. These were (1) the present PLN tariffs that would apply to this community (e.g. R1 and R2 for residential users), and (2) a market-based fee (Table 7-5) for electricity service based on demonstrated willingness and ability of rural Indonesians of similar socio-economic characteristics to pay for equivalent energy services.

7.7.6 Calculated Values

The net present value, the internal rate of return, and the life-cycle and first-year costs of electricity production were calculated for each of the cases. Each set of values was calculated for each combination of demand level, supply options, financing conditions, and revenue specifications. In all cases the analysis is conducted on a *financial basis.*

7.7.7 Economic Factors not Considered in the Analysis

A macro-economic analysis for the proposed large-scale renewable energy-based electrification of off-grid communities in Indonesia was beyond the scope of this study. However, an economic analysis would be useful in assisting the Government of Indonesia, the World Bank and Asian Development Bank, and bilateral development assistance agencies to evaluate the proposed new approach to rural electric power delivery from a national economic perspective. Some of the relevant economic factors (e.g. subsidies) are good candidates for internalization. Once internalized, they could be accounted for in the micro-economic (financial) analysis of the proposed private/public-sector venture now being developed.

These economic factors include the costs and benefits associated with or imputed to (1) diesel

[5] The Global Environment Facility (GEF) has received a $2 billion replenishment commitment from the participating donor countries; roughly half of this will be made available as grants to buy down the costs of commercializing and implementing low-carbon and no-carbon renewable energy supply options that have the potential for sustainable large-scale replication and diffusion. The Eastern Island Pilot Project meets virtually all of the GEF qualification conditions for grant co-financing.

and kerosene fuel requirements and shadow prices for fuel imports, (2) fuel price risk premiums for underestimation of future real costs of diesel fuel, (3) fuel and electricity subsidies and the value of their reduction and eventual elimination, (4) economic and equity-based social development linked with electrification, (5) economic development consequences ascribed to availability and use of electricity, and (6) environmental attributes of technical alternatives (local and global; GEF considerations).

7.8. RESULTS OF THE FINANCIAL ANALYSIS

7.8.1 Summary

The principal results of the analysis are:

- Investments in hybrid power systems, with 100% connection of all potential customers, no hookup fees. and revenues based on viable market-rate fees, generate *positive Net Present Values NPVs under all financing conditions,* with the most favorable returns obtained under World Bank-equivalent financing terms and conditions.
- With renewable energy-based hybrid power plants used in place of PLTDs, but with the present PLN electricity pricing structure, the required total subsidy (negative net present value) would be reduced by one-third in the case of commercial rate financing, and by almost two-thirds for World Bank financing. However, *under no circumstances* is the net present value (NPV) of the investment positive.
- The introduction of market-based fees for electricity could reduce the total required subsidy (capital cost and operations) for rural PLTD units by as much as 75%. However, *the investment would still not be profitable.*
- Of all options considered, the present approach to off-grid rural electrification is the *least-attractive and most uneconomic,* limits electricity services to the few relatively wealthy members of a community, and inhibits investments in productive activities and social services that would require daytime or full-time power. This approach is not a viable option for bringing electricity to the tens of thousands of unelectrified off-grid communities in the Eastern Islands of the country.

7.8.2 Presentation and Interpretation of the Results of the Analysis

The following case examples are presented:

- PV/diesel hybrid for a fully-electrified community.
- PLTD for a fully-electrified community.
- PLTD for a partially electrified community (PLN model).
- PV/diesel hybrid for a partially electrified community.

The net present value of the investments and the life-cycle and first-year costs of electricity production were calculated for the five selected financing options, and for both PLN-based tariffs and market-based fees for electricity services.

Investment in a Model 25 PV/Diesel Hybrid for a Fully-Electrified Community

Table 7-7 and Figures 7-1 and 7-2 present the results of the analysis for an investment in a hybrid unit to support 249 connections. With *market-based service fees for electricity,* based on the demonstrated willingness and ability of the potential customers to pay for the electricity services provided in this scenario, the NPV of the investment is positive under all financing terms and conditions. The most favorable NPV results from World Bank financing with a GEF grant component.

Table 7-7
Net Present Value and Cost of Electricity
Decentralized Model 25 PV/Diesel Hybrid Power Plant
Sarrapo Lompo, 24-hour power, 249 connections (227 households)

Financing Conditions	Net Present Value	
	PLN Rates	Commercial Rates
Commercial [8%, 8 yrs, no grace]	-177,006	**+10,364**
World Bank [8%, 20-yr, 6-yr grace]	-93,500	**+93,869**
World Bank [8%, 20-yr, no grace]	-158,069	**+29,301**
World Bank w/GEF 30% buy-down	-71,178	**+116,192**
Soft loan [3%, 20-yr, 5-yr grace]	-78,231	**+109,139**

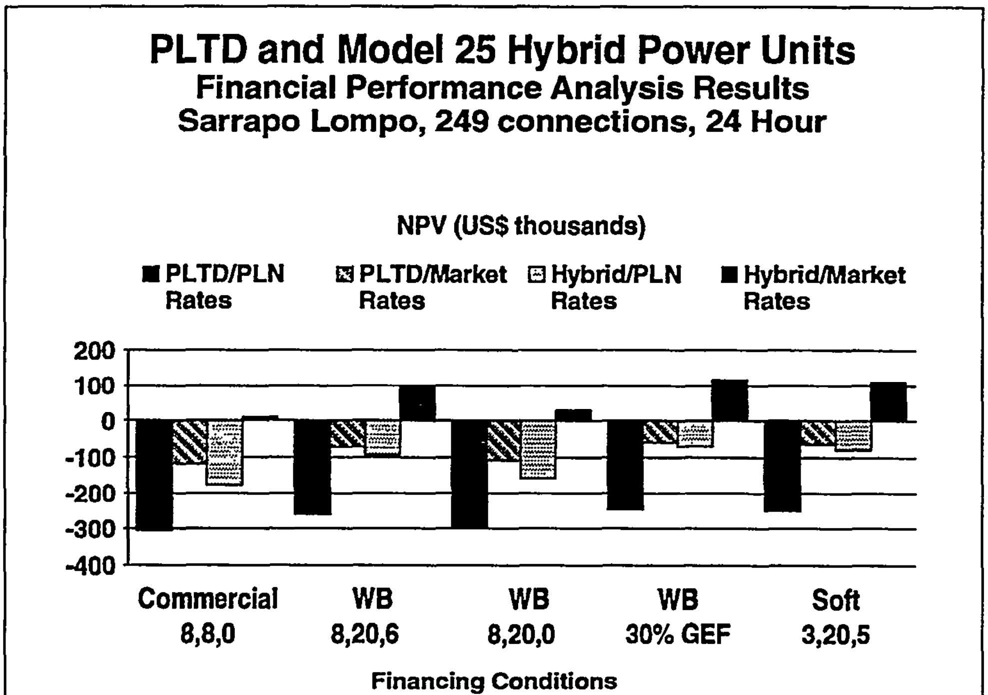


Figure 7-1

Even with connection of virtually all potential customers, the NPV of the investment is *negative if PLN tariff rates are used* as the basis for revenue, even under the most favorable financing terms and conditions (World Bank financing with a GEF grant component).

The variations in the NPV of the investment and in the LCC of electricity production are significant among the various financing alternatives used. In these calculations, the reduction in electricity costs and increases in NPV with a 30% GEF buy down of a conventional World Bank loan are significant. However, the most important commercial impacts of a GEF capital cost buy down will be increased near-term profitability of the investments in community power systems and greater availability of working capital for the proposed joint venture company.

Investment in a PLTD Power Plant for a Fully-Electrified Community

Table 7-8 and Figures 7-1 and 7-2 summarize the performance of an investment in a PLTD (and also in a PV/diesel hybrid) for a fully-electrified community.

The NPV of the PLTD power system investment ranges between a negative $250,000 and a negative $300,000. Availability of concessional financing with a six-year grace period or World Bank financing including a 30% capital cost buy down would be insufficient to reduce the NPV by more than about 15% from its value under market-rate financing. World Bank/GEF financing would not be available in this case. Even under the market-based service fees that characterize the new commercial model (and which results in a positive NPV for the power system investment using a Model 25 hybrid unit), the PLTD-based investment has a negative rate of return. However, the NPV under the most favorable financing conditions (World Bank with GEF 30% grant) is a negative $60,000. If conventional PLTD installations were financed using the electricity service fees for the new commercial model, the NPV of the required Government of Indonesia subsidy would be reduced by about seventy-five percent.

Table 7-8
Net Present Value
Decentralized PLTD Diesel Unit (2 x 20 kWe)
Sarrapo Lompo, 24-hour power, 249 connections (227 households)

	Net Present Value	
	PLN Rates	Commercial Rates
Commercial [8%, 8 yrs, no grace]	-305,688	-118,318
World Bank [8%, 20-yr, 6-yr grace]	-259,493	-72,123
World Bank w/GEF 30% buy-down	-247,144	-59,774
World Bank [8%, 20-yr, no grace]	-295,212	-107,842
Soft loan [3%, 20-yr, 5-yr grace]	-251,045	-63,676
Commercial (12-hour power)	-301,057	-132,330
World Bank (12-hour power)	-254,861	-86,134

Notes for Table 7-8
a) In the 12-hour power scenarios it is assumed that there are no commercial loads but that all of the 227 households are connected. Both required kWh production and revenues are appropriately reduced from the 24-hour operation scenario.
b) The PLN rates include the standard connection fee of Rp 90,000 ($45) per household.
c) Financial parameters are 14% discount rate, 7% inflation, and 2% fuel price escalation.
d) The World Bank loan terms with a 30% GEF capital cost buy down are 8%, 20 years, and 6 years grace period.

Net Present Value of Investments in Isolated PLTD Power Units

The net present value of investments in an isolated PLTD for a compact village (Sarrapo Lompo) was computed for the five debt financing terms and conditions, and for both PLN tariff-based rates and the market-based rates of the new commercial model. *The World Bank/Global Environment Facility (GEF) financing case is not applicable to investments in PLTDs, but has been included for completeness.* The standard PLN approach (12-hour power, World Bank Financing) is shown in bold. It is assumed in this analysis that the capital required for the PLTD plant is an equity investment on the part of PLN, and that the investment must generate an adequate return on equity.

In this example the standard PLN practice of charging a connection fee of Rp 90,000 limits the number of connections to 30% or in this case at 77 households. For the case of 24-hour power, 6 community/commercial loads are added due to the availability of daytime power. In the community of Sarrapo Lompo there is a total of 227 households and 22 community/commercial loads.

8. SUMMARY: THE NEW COMMERCIAL MODEL

The new model for sustainable electrification of rural off-grid communities in Indonesia is based (Figure 6) on the principal of "enoughness and sustainability", a concept articulated by Carl Weinberg[6]. This principal assumes that the most appropriate electricity service, both in rural and urban communities, should be a match of the consumer's need for service and ability pay with the power system's level of service and cost of supply (Figure 7).

New Model for Sustainable Electrification of Rural Communities is Based on:

Enoughness & Sustainability

Not The Traditional Utility Model of

Build & Grow

Figure 6

In the traditional utility model of build and grow (Figure 6), large investments are made in excess capacity which, in rural regions, is rarely used. The assumption has often been made that once electricity is available the demand for and purchase of electricity will grow rapidly, to justify the investment in initial excess capacity. In rural regions this rarely occurs. Consequently, it is more effective to use technologies that provide a level of service that matches the existing willingness and ability to pay and the demonstrated level of electricity

[6] Carl Weinberg is the former Director of Research for Pacific Gas and Electric Company in California, the world's largest investor-owned electric utility company.

services that the consumer will want immediately after hookup. The new technology for supply, distribution, and revenue collection meets these requirements in a cost-effective manner.

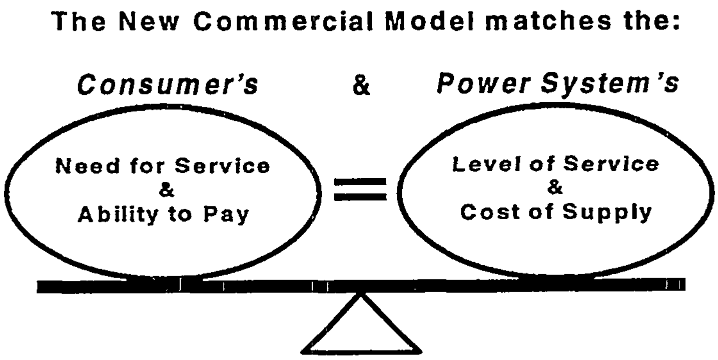


Figure 7

MX9900024

The Profitability of Photovoltaic Projects in Developing Countries

Philip W. Covell and Richard D. Hansen
Enersol Associates, Inc.
USA

ABSTRACT:

This paper shows that it is possible to recover costs and profit from photovoltaic projects, even in relatively poor countries. It explains three basic financial arrangements for full cost recovery used in several developing countries for solar home and business systems: self financing; term financing through equipment vendors, banks and non-governmental organizations; and leasing. It also describes potential sources of cost recovery (besides the end-users), including CO_2 offsets. Finally, it concludes that given the success of some projects, recent efforts toward market conditioning, and the effect of environmental concerns, there are good PV business opportunities for electric power utilities in developing countries.

This is an adapted and abbreviated version of a paper entitled "Full Cost Recovery in Photovoltaic Projects: Debunking the Myths about Equipment Subsidization. Much of the information has been drawn from the field experiences of Enersol Associates, Inc., a nonprofit organization specializing in PV project implementation; and SOLUZ, Inc., a Massachusetts based company affiliated with Industria Electrica Bella Vista, which operates a PV system leasing business in the Dominican Republic. Together, these organizations have facilitated the installation of over 5000 systems on a full cost recovery basis.

1. INTRODUCTION

Photovoltaic systems appear to be a logical solution for the overwhelming majority of rural people in the developing world, who after 100 years of gradual grid extension in their countries still depend on the Ray-O-Vac delivery truck for electrical distribution. The population is dispersed, the electrical demand is low, and the cost of conventional transmission and distribution is high. But adoption of photovoltaics in these areas has been slow. One might think that serving just 10% of the presently un-electrified homes in a tiny country like Honduras or the Dominican Republic with photovoltaics would not be an unreasonable expectation. Yet "solarizing" 10% of these people (about 40,000 homes) would be a major accomplishment. Even the roughly 40,000 installations in such a huge country as Mexico is a major achievement, and most of those were subsidized by the state and federal governments.

This may cause one to wonder if it is possible to recover the full costs of broadly-applied photovoltaic projects from relatively low-income end-users. Utilities are certainly wise to look before they leap into photovoltaic projects.

However, commercially-viable PV projects do exist, and this paper describes several business strategies that are currently achieving full cost recovery in projects consisting of decentralized, 20-to-100 watt photovoltaic systems which meet basic needs for lighting and limited home power. A utility-style PV equipment leasing project is described, as are some potential sources of cost recovery which may be of interest to utilities.

Three Financial Arrangements for full cost recovery

There is world-wide experience with several proven models for developing full cost recovery projects: cash purchases, term financing and leasing. Some may be more effective than others in certain countries or regions, or at certain stages in the growth of a local PV industry. In maturing markets such as in the Dominican Republic or Sri Lanka, several financial models may be used simultaneously, resulting in market penetration of over 50 percent in some communities.

1. Cash purchases (end user owns and self finances)

As people focus on the financing obstacles, it is easy to overlook the significance of cash sales. For example, roughly half of all systems installed in the Dominican Republic and Honduras are paid for in cash by the end users. Kenya is reported to have over 20,000 systems installed, nearly all of which were paid for in cash by the users without consumer financing.[1] More than 50% of the over 300,000 solar home and small business systems installed world-wide have been procured on a cash or very short-term (e.g. two to three months) basis.[2]

Cash sales are a good way to begin a project because they are practical even if no financing is available for consumer credit or leasing programs. They also occur at a slower pace than do financed installations, allowing newly-trained technicians to gain experience before larger scale investments in end-user credit and/or leasing are made.

Yet even as financing becomes available, planners should not underestimate the value of cash sales. It is reasonable to expect that in projects that feature full cost recovery, there is always a portion of the rural unelectrified population that can buy their systems outright will elect to do so in order to avoid household debt, finance charges, and the time and effort necessary to secure financing. This frees scarce financing capital for those customers who actually need it.

Businesses that cater to cash customers understand what full cost recovery entails. They know they must charge end users all equipment costs, transportation, warrantee costs, labor, overhead and profit in order to survive. Equipment costs include shipping, insurance, customs clearance,

---

[1] Van der Plas, Robert, "Lessons: Solar Energy Answer to Rural Power in Africa," World Bank, Industry and Energy Department, FPD Note No. 6, April 1994.

[2] Howley, Bill, personal conversation, 24 February 1995.

import duties, plus overhead and profit associated with importing and wholesaling. In competitive situations, private businesses generally operate with very modest overhead and profit margins.

People who purchase PV systems generally must pay a technician for maintenance and repairs beyond the warrantee provided by the vendor. Although some analysts have argued that leasing schemes that build in regular maintenance routines are necessary due to people's inability or unwillingness to make repairs to their systems, Enersol's experience does not support this view. Those who can pay for their systems in 24 to 36 months can usually afford the up-keep and will not allow their investment to remain idle for long. Formal maintenance agreements may be helpful in some cases, but technical success or failure is more often determined by the proximity of qualified technicians than by the type of maintenance agreement.

2. Term financing (end user purchases the system with credit from equipment vendor, "NGO" or bank)

Vendor Financing

A significant portion of domestic and small business PV installations around the world are financed directly by the vendors, usually for one to three months at market or slightly above market rates.[3] Rates are sometimes stated in US Dollars to avoid devaluation risks while covering the costs of capital, collection, default, overhead, and often deferred profit. However, few vendors have sufficient capital or administrative capacity to offer medium- or long-term credit, so other financial arrangements must be made to reach poorer elements of society.

Revolving Funds

One financing approach uses a revolving credit fund. Terms have typically ranged from one to three years with interest rates within a few percentage points of prevailing commercial rates. Although the end-user owns his or her own system and pays for maintenance as required (as with cash purchases), the system serves as collateral until the loan is paid off. The fund managers (often community development associations, agricultural co-ops and the like—often referred to as non-governmental organizations, or NGOs) pay the equipment vendor/installer for those services not covered by the down payment, and then receive periodic payments from the customer. In one rather efficient variation of this approach, ADESOL, an organization dedicated to the promotion and financing of photovoltaic systems in the Dominican Republic, allows some vendors to evaluate clients and authorize loans on its behalf. In this way, its credit operation is similar to sales financing schemes which have accelerated the growth of the US automotive industry since the 1920s.

Revolving funds are often initiated with donated capital, but some can be effectively expanded with debt financing. Finance costs charged to the end-user include those for vendor financing, with additional costs of marketing of the financial product and loan processing. The goal need

[3] In Honduras and the Dominican Republic, vendor-financed systems account for an estimated 25 percent of installations.

not be to subsidize credit, but simply to make it available, for it is often the lack of credit rather than its cost to the consumer that limits the sales of photovoltaic systems.

Commercial Banks, Loan Guarantees and The Fondo Solar

Commercial banks have not commonly provided credit for single home PV systems, and those banks that have provided loans directly to end-users (such as the Honduran Coffee Bank) have required salaried co-signers or mortgage guarantees (or both) that few rural people have. Furthermore, their location in urban areas and large towns has prevented many commercial banks from serving remote customers of PV systems.

Through its Fondo Solar, Enersol Associates has found that providing loan guarantees to NGOs can help solve this problem. With an initial grant from the Rockefeller Foundation, Enersol deposited $85,000 in a U.S. interest-bearing account in 1993, and later borrowed $30,000 from the International Fund for Renewable Energy and Energy Efficiency (IFREE). Using that fund as collateral, guarantees are provided to local banks in Honduras and the Dominican Republic for photovoltaic project loans, effectively shielding the banks from most risks. Meanwhile, Enersol is somewhat protected from currency related risks because the local banks, not Enersol, issue loans. Local banks have generally given preferential interest rates based on this guarantee, and some have shown a willingness to lend beyond the amount of the guarantee.

It is possible to guarantee local banks' retail loans to hundreds of end-users, or to guarantee "wholesale" loans to agencies that on-lend to the system buyers. Enersol chose the latter option for several reasons:

1) Community development, micro enterprise and agricultural NGOs, more than the commercial banks, had already developed an expertise in lending in remote rural areas.
2) Enersol already had good working relationships with several NGOs in financing PV systems.
3) It is easier for the guarantor (Enersol) to track the progress of a few bank loans to NGOs than hundreds of bank loans to end-users.

It is estimated that between 15 and 25 percent of the unelectrified population in Honduras and the Dominican Republic (between 120,000 and 200,000 homes) could afford systems financed through three-year financing. Fondo Solar resources are now totally committed, guaranteeing five loans to four NGOs in the two countries. Enersol is seeking other grants and loans to increase the Fondo Solar to $1 million, a level which could finance approximately 8000 systems in five years.[4]

3. Leasing (end user leases from Electric Power Utility, equipment supplier, NGO or other entity)

Many rural households that are unable or unwilling to invest the significant amount of capital required to purchase a single home PV system are willing to pay a monthly lease (or energy

[4] This assumes average $400 loans with three-year terms at interest rates that cover all (including capital) costs.

service) fee. This seems to be the preferred mechanism of electric power utilities because it mimics, in a decentralized manner, the business arrangement that utilities know best: collecting monthly fees for services it provides with its own capital equipment.

Two schemes for leasing remote home and business systems are described by the World Bank:[5] In one case, users pay a monthly fee for several (usually eight or more) years until they effectively pay for their systems, at which time they assume ownership of the systems. In the other scheme, the lessor or "energy service company" (ESCO) simply sells the energy service and never relinquishes ownership of the system. People can use the system for as long as they continue to pay for the service. In either case, the costs for system leasing are a combination of types of costs incurred by equipment vendors and financiers. However, because the financing is long term, a greater percentage of the population can afford the monthly payments. Ultimately, the users spend more money over time on leasing fees than they would by simply purchasing an equivalent system, but they do not need to accumulate capital for a down payment.

A significant level of market knowledge and organizational sophistication is required to manage a leasing operation efficiently. Utilities or other prospective lessors should either dedicate sufficient resources to defining the right product and business strategy, or contract an experienced PV leasing company to "build, operate and transfer" the decentralized power plant. Since margins are relatively small and only realized at a fairly healthy volume, there is little room for error.

Although most of the leasing programs known to the authors rely to some degree on subsidies to the end users, at least one developing country leasing program is achieving full cost recovery. The privately-financed Solar Electric Energy Delivery (SEED) project, managed by Soluz, Inc. and operated by Industria Electrica Bella Vista in the Dominican Republic, will soon complete its first 1000 installations and will ramp up to 5000 customers in 1996 and 1997.

Other Sources of cost Recovery

Obviously, revenue collection from PV end-users merits project managers' constant attention. However, there may be other sources of cost recovery besides the end-user. In the case of Enersol projects, some "one-time" costs associated with initial training and technical assistance are covered either by private sources motivated by the positive environmental impact or by U.S. government agencies aiming to improve environmental quality, promotion exports, or both.[6] This groundwork of project development is intended to build a track record of full cost recovery for equipment, delivery, and financing, effectively lowering the investment risk of scale-up activities.

[5] "Solar Photovoltaics: Best Practices for Household Electrification" (draft), The World Bank, Asia Alternative Energy Unit (ASTAE), October 1994.

[6] The US Department of Energy (mostly through Sandia National Laboratories) has been a primary contributor, as have numerous private foundations. The US Agency for International Development may partially support a $1.5 million project in the Dominican Republic and the US Environmental Protection Agency is considering a Cooperative Agreement with Enersol.

CO_2 Offsets and Joint Implementation

Another source which may become prominent in future projects are the fossil fuel-burning operations of electric power utilities. Because PV systems emit no CO_2 and usually replace kerosene lighting, many PV projects permanently reduce overall CO_2 emissions. Typical PV systems installed in the Dominican Republic and Honduras are estimated to offset up to 6 tons of CO_2 over their 20 year lifetime[7]. If companies responsible for significant CO_2 emissions (electric utilities, for example) are forced either to reduce their emissions or to fund other projects that capture or reduce emissions, PV projects could benefit. Furthermore, the March 1995 Conference of the Parties to the Climate Change Convention in Berlin adopted the concept of Joint Implementation, which would allow polluters in one country to meet their CO_2 emissions targets by funding offsetting projects in other countries. This would be especially beneficial in developing countries where a majority of the rural population uses kerosene lamps for lighting.

The PV project catalyzed by Enersol Associates in Honduras, for example, is one of seven projects approved for inclusion in the United States Initiative on Joint Implementation. Based on the size of the offset investment, the amount of CO_2 displacement from the Honduras project could range initially from thousands to tens of thousands of tons of CO_2, and eventually to hundreds of thousands of tons. If expanded to include other countries in the region, over the next several years "JI"-related solar-based rural electrification activities could potentially offset millions of tons of CO_2

CONCLUSION

Among the many PV projects internationally, there are a few based on cash sales, term financing and leasing that demonstrate the feasibility of full cost recovery from end-users. There are people who know how develop and manage profitable photovoltaic projects. There are also several regions where market conditioning with full-cost recovery projects have created opportunities for private or public investment in scale-up activities. These conditions are growing precisely at a period in history when environmental pressures are beginning to be reflected in energy economics and finance. This translates into opportunities for electric power utilities, and their potential new customers in developing countries, to profit from photovoltaic projects.

[7] Kaufman, Steven L., "Environmental Advantages of Solar-Based Rural Electrification" (draft), Enersol Associates, Inc., Somerville, MA. April, 1994.

MX9900025

The Gtz System Management Applied to Photovoltaic Rural Electrification Projects

Dr. Pablo Rosenthal - Brendel
Proper - Bolivia
Gtz - Cooperación Técnica de la República de Alemania

ABSTRACT

The GTZ (Federal Republic of Germany Technical Cooperation Society) has developed a general project design system, particularly for Renewable Energy, that systematically covers all aspects necessary in their planning and implementation, so that their effects are sustainable in the long run, and cover as well all the requirements of a determined diffusion. This is what they have called "System Management."

This methodology of project implementation can be described as capable of being applied to any action area, and has already proved and validated its efficiency in projects where it has been applied. The main reason for its use is based on the correction of previous experiences with projects that had a tendency towards one area of action alone, in a much too exclusive way — mainly the technological area — neglecting important aspects in the sustainability of technologies being introduced.

The experience of PROPER - Bolivia (Programa para la difusión de energías renovables), who has been applying this system to its projects, is being used as a methodological basis. PROPER started in 1991, and is programed to last until September or 1996.

Among the main components being described in the system's methodology, in the particular case of PHOTOVOLTAIC RURAL ELECTRIFICATION PROJECTS, stand out the areas of Technological Transference; Training; Diffusion; Financing; Energy Policy; Planning, Monitoring, and Evaluation; and Support and Follow-up to the supply and demand.

1. INTRODUCTION

Traditionally, projects of renewable energy carried out by the GTZ were centered around the development of specific aspect of them. For instance, one can mention the GTZ's SEP (Special Energy Program) Projects, which emphasized the technical aspect. These projects did not achieve the proposed results. From another point of view, projects that only emphasized social-cultural aspects, or formation of human resources, did not achieve the desired success either.

In the moment of their application with final users, technical projects of renewable energies developed failures since they did not consider the social-cultural component during the planning stage. Projects that emphasized the social, economic, and cultural components failed because of the inadequate development of equipment and technology elements. In both cases, they did not take into account the formation of human resources, energy policy, and financial elements that could provide sustainability. Thus, in the development of these projects, they did not contemplate adequately during their formulation and planning, a variety of aspects and topics that kept coming up, and that affected the achievement of the desired results to a greater or lesser degree. Experience showed that developing one single factor as a "key" element for the development of renewable energy did not work for sustainable projects.

In view of this situation, The GTZ took up as an objective the development of a new focus for the development of renewable energy projects. The result was the SYSTEM MANAGEMENT, whose methodological implementation started out gradually.

The GTZ is currently developing approximately 120 projects in the area of Energy. Among them are precise, regional, national and super regional projects that encompass practically all aspects of energy from different perspectives (technological development, energy planning, training and diffusion, etc.), but all of them revolve around renewable energy. Out of all of these projects, the Renewable Energy Diffusion Program in Bolivia, PROPER - Bolivia, is one of GTZ's first energy projects to totally apply the concept of SYSTEM MANAGEMENT. The description of the method's application in this case, and the results achieved so far with it, allow us to appreciate its effectiveness.

2. DEVELOPMENT

During PROPER's first phase (the orientation phase), orientation and planning in all aspects involved in PROPER's future work was done. The philosophy guiding these actions was that of finding the weakest and most necessary to strengthen points in the area of renewable energy in general, and particularly in the photovoltaic rural electrification area, attempting to set the long-term sustainability of these energy sources in Bolivia. During this first phase, work was intensive between February of 1991 and September of 1992. The areas of discussion, analysis and going deeper into its state, are the following:

Putting in order of priority of renewable energy sources to be developed:

Identifying the work areas with more implementation success probability, from the energy demand in the rural area, the duly evaluated potentials of renewable energy, the geographic zones and ecological systems existing in Bolivia, and finally, the state of the art of technology points of view. Fundamentally, the explored areas were: the solar area (photovoltaic and thermal), the hydraulic area (at the level of small and micro hydroelectric central stations) and aeolian area.

Technological Transference

Attempting to find the feasible, income-producing and possible application "niches" of the different renewable energy technologies, according to the rural energy demand, evaluating the quality of currently used equipment and materials, and finally, tracing the necessary lines of action to raise the current state of technology in the country.

Training and Formation of Human Resources

Identifying human resource training and formation institutions able to develop or incorporate renewable energy topics, diagnosing the current state of knowledge of renewable energy systems and technologies, preparing strategies to increase the knowledge and amount of people who can adequately handle the topic of renewable energy at different levels - from rural installers, through technical means, to engineer and higher training level personnel.

Diffusion

Quantifying and qualifying the existing information about renewable energy, detecting the existing gaps and the most urgent information necessities required at the level of technology users, suppliers and producers, rural development designers, decision-makers, and political authorities with the goal of defining future diffusion tasks to be carried out.

Financing

Surveying and analyzing financial entities of formal and informal nature at the national level, looking at their accessibility about the project's objective, creating databases, and even designing easy access and use software that is useful for entities and people interested in doing rural electrification projects with renewable energy.

Inter-institutional Coordination

Considering all the people involved with renewable energy, an intense activity of institutional relationship was also performed, involving the State, Regional Development Corporations, operative Rural Development (state and non-state) Institutions with real presence in the field, and other International Cooperation Agencies that were starting to work in this area. All the inter- institutional relationship activities were to create a favorable environment for the development of PROPER.

During this phase, the concept of sustainability of renewable energy in Bolivia was also being developed through the creation of an institutional network where all the different involved people actively participate. In this network, PROPER would initially play a catalyzing role, and later on it would slowly retreat until it disappeared at the end of the project.

Once the orientation phase finished in a satisfactory way, and enough information to make decisions gathered, the execution phase of PROPER - Bolivia got started (planned for four years, form September 1992 to September 1996), with the goal of achieving the following objective:

In the national market, the supply of good quality renewable energy technologies according to the users' needs satisfies the population's increasing demand, mainly in the rural areas of Cochabamba and Santa Cruz.

The objective stated above would be achieved through the four following results:

- Increase the efficient diffusion and promotion of the reach and use of renewable energy technologies.
- Increase the personnel trained and qualified in renewable energy technologies at the professional, technical, and small-business levels.
- Improve the technological supply of these systems, orienting them towards the needs of the rural and marginal urban population.
- Cause the increase of the demand of technological systems that use renewable energy technologies in the rural and marginal urban areas.

To achieve these goals, the Technical Assistance activities being developed in a global way are:

Diffusion and Promotion

In this area, work is being done in the production of information intended to strengthen the role of renewable energy in a rural energy context. To support this task, documentary videos about the real applications of renewable energy are being produced periodically. These documentaries are being transmitted on closed circuits (urban and rural), regular programming of TV channels of different zones in Bolivia, and even on some national networks under cooperation agreements. In the same way, mini programs are being produced to be transmitted on radio, since it is the communication medium with the most rural coverage.

Every semester, E&D (Regenerative Energy and Development) Magazine is published, with an average of 2500 copies printed of 7 edited issues so far, and a distribution that reaches an intended spectrum of the population (basically decision makers). This magazine will be distributed in Latin America starting this year. Supplements about renewable energy are published in the country's main newspapers (the last of them reached 150000 issues printed). Monthly, an average of a newspaper page of renewable energy news, provided by PROPER, is published. With these activities, PROPER intends a massive promotion of a collective conscience about the use of renewable energy and its applicability in the country.

As a mean to speed the information exchange, PROPER has formed CINER (Renewable Energy Information Center) that counts with a library specialized in the topic, and has provided hundreds of institutions with approximately 47000 pages of selected information.

In other types of diffusion activities, it supports the conduction of specialized seminars, as a mechanism to encourage the information and experience exchange between specialist groups and people who work in the field, seeking the strengthening of inter institutional coordination mechanisms, and of specialized work. To this date, national seminars on solar energy, renewable energy, energy and rural development, and an international seminar on renewable energy have taken place, as well as the VI Latin-American Meeting on Micro Hydroenergy, an event organized together with the Latin-American chapter of HIDRORED. An international seminar on solar energy is being organized for September of this year.

These and other campaigns are useful in informing the general population about the reach, uses and limitations of renewable energy technologies, but they also help in making decision taking personnel, designers, and political authorities aware of the importance of renewable resources as means to satisfy the rural energy demand.

Training and Formation

To support the training and formation of human resources, PROPER is working together with seven technical institutes and two universities that have officially included courses on solar energy to their curricula. At the moment, there are 75 duly qualified and trained professors that teach this topic in their respective institutions, providing not only the necessary knowledge, but also the necessary learning material.

PROPER does direct training of personnel of mediating institutions that carry out renewable energy projects, seeking the efficient implementation of such projects. In some cases, such professionals have traveled abroad to improve themselves through courses and stages of high level of feasibility.

To support the tasks of formation and training, it also edits technical texts on renewable energy (on maintenance, installation, and general knowledge). PROPER is aware that one can assure the sustainability of renewable energy in Bolivia only through adequate qualification of human resources that work with renewable resources.

Development of the Technological Supply

At the technological transference level, PROPER has promoted qualitative leaps in the renewable energy technology's market in Bolivia. Through the support of existing national enterprises, it has accomplished the manufacture of new products: a specially designed battery for solar use, technological transference for the production of ballasts, and regulators for photovoltaic equipment. In other area of work, it supports the joint-venture consolidation between national and foreign enterprises as another method of achieving technological innovation in the country.

To complete the circle, PROPER works together intensively with these enterprises to improve their pre and post-sale systems, the introduction of production quality control and the diversification of their products and services with the hope that they can efficiently respond to the market's demands.

Channeling of the Rural Demand

The central activities in this area are those of relating to project executing institutions to achieve the identification, formulation, and execution of real and feasible projects in the rural area. The institutional spectrum of executors includes Non-Government Organizations (NGOs), electrification companies, development corporations, and eventually, base organizations. In this sense, work has involved the improvement of local consultants, attempting to refine the concepts of management, organization, and social-economic evaluations in a way that is adequate to energy projects for the rural sector.

Similarly, PROPER coordinates tasks with financial agencies (state funds, bilateral and multilateral international cooperation such as USAID, Cooperation Ministry of the Netherlands, Inter-American Development Bank, Global Environment Facility, World Bank, European Union, etc.).

Just like in other countries, it verifies that there are enough resources to implement the projects, and the main misstatement is the non-existence of projects that are real, coherent, feasible and sustainable in time. However, it also works in the creation of a Renewable Energy Fund together with other government and cooperation agencies, as a mechanism to ensure the constant and expedient flow of financial resources.

These activities have allowed the drafting of the following table of projects:

TECHNOLOGY	**CAPACITY INSTALLED**	**BENEFICIARIES**	**INVESTMENT (thousands of $)**
<u>Projects carried out</u>			
Photovoltaic	6.25 kWp	125 families	114.5
Information			10.5
Micro - Hydro	5 kW	20 families	10.0
<u>Final Design Projects</u>			
Photovoltaic	65 kW	1,300 families	1040.0
Hydraulic	105 kW	570 families	266.0
Aeolian	15,000 kW	20,000 families	32,000.0
Thermal solar	6 m	930 families	16.6
<u>Pre-feasibility Projects</u>			
Hydraulic	54 kW	556 families	181.0
<u>Identified Projects</u>			
Photovoltaic and	587.1 kW		
Thermal solar	828 m	270,000 families	12,615.9
Hydraulic	1561 kW	4,730 families	3114.9
TOTAL	**17,288.9 kW**	**289,231 families**	**49,369.4**

Energy Policies

Traditionally, the state's policy on the energy sector has been oriented only towards conventional energy sources and their intensive application in the urban area. The rural area has always been considered in a declarative and marginal way. A clear proof of it are the failures of 20 years of rural electrification.

Nevertheless, in the recent past, PROPER has closely cooperated with the National Energy Secretary in the design of the Rural Energy Promotion Direction, a state institution responsible for rural energy planning and development considering renewable energy as strategic sources of energy. The Government has adopted the work developed, demanding a greater participation of PROPER in providing technical assistance.

Planning, Monitoring, and Evaluation

There is a unit specifically in charge of Planning, Monitoring, and Evaluation of activities related to the program development and application of the SYSTEM MANAGEMENT within PROPER. The multiple and diverse work areas, and the groups of institutions with a high level of heterogeneity meant relative sophistication in the planning, monitoring and evaluation methods being carried out.

The system itself is highly endowed by all media provided by computer science. There is a series of forms designed for recording activities, evaluating indicators, and planning and monitoring done bimonthly. Once a year, global planning and evaluation are done. The activities done in this field become determining in the feedback of the impact caused by the program, the adequate orientation, and strategic adjustments to be done in determined moments. Follow up of the renewable energy market development is done by this unit through the permanent monitoring of the supply and demand.

3. CONCLUSIONS

It was possible to validate the applicability of the SYSTEM MANAGEMENT for the management of projects in the energy field, particularly in photovoltaic energy projects for the rural area. This allows a permanent diffusion of this energy in Bolivia once PROPER is finished.

The sustainability of these activities is strengthened by the functioning of an institutional network; however, an attempt to consolidate it is being done, through the creation of a foundation or association dedicated to the promotion and diffusion of renewable energy.

An institutional network would group the most relevant people in the area, technology producing and supplying companies, sponsors, project executors, Government, information and documentation centers, etc. Thus, the range of activities developed by the program would have with this network, a specialized counterpart (an institution) for each work area.

Quality Issues for Solar Home Systems

Klaus Preiser
Fraunhofer-Institut für Solare Energiesysteme
Freiburg Germany

1. INTRODUCTION

Characterised by its simple system design, consisting of one or two PV modules, a charge controller, a battery (12/24 Volt) and the directly connected DC-appliances, the Solar Home Systems (SHS) are one of the best options to electrify small houses in remote rural areas. But being committed with rural electrification means for all involved organisations and persons to deal with new managerial and operational schemes. Besides organisational and infrastructural aspects and the necessary participation of the users in the planning and operating process, the quality of these systems plays a key role. The long term operating costs after installation, e.g. for maintenance and repair are often not taken into account. The uncertainty about the durability, the financing and the handling of PV systems can be identified as the main barriers for industries, utilities and the users to get involved in this new technology.

At the FhG-ISE we have analysed various electrification projects with PV in more than 20 countries. The results show among others that the photovoltaic module takes with about 40% the major part of the system costs in the first year including system installation. Considering the cumulative costs after 20 years however the part of the PV module decreases to 10-15%. The costs for battery replacement as well as the efforts for maintenance and repair become the most important factors. This fact is due to the high quality and reliability that has been achieved in the manufacturing of PV modules. While PV modules are highly standardised and worldwide validated certification procedures are established there are no equivalent measures available for the balance of system components (BOS), i.e. battery, charge controller, installation material and electrical appliances. But the quality of these components influences dramatically the satisfaction of the users and the installing and financing institutions. One faulty component like an electronic ballast for a fluorescent lamp or a bad charge controller causes failures in the desired energy service, that the users expect from their system. First recommendations for the quality improvement of Solar Home Systems and their components to achieve high reliable and less expensive operation have been elaborated at the Fraunhofer-Institut für Solare Energiesysteme (FhG-ISE). In the frame of various European research programmes we will develop quality criteria and testing methods for SHS and its different components together with other European PV research institutes and the PV industry. Together with local partners testing procedures adapted to the local capabilities and necessities can be elaborated for PV systems and the different components.

As an example for our experiences in the field of rural electrification a pilot project is presented that has been carried out in the frame of a cooperation with the Universidad Nacional de San