ACCELERATING SUSTAINABLE PV MARKET DEVELOPMENT

Anil Cabraal, Mac Cosgrove-Davies and Loretta Schaeffer
Asia Alternative Energy Program (ASTAE), The World Bank, Washington, D.C.

ABSTRACT

The Asia Alternative Energy Program (ASTAE) is a World Bank-donor initiative to support renewable energy and end energy efficiency investments in Asia. This article summarizes ASTAE's review of solar home system programs experience in Indonesia, Sri Lanka, the Philippines and the Dominican Republic. Successful PV market development for rural electrification requires removal of financial and institutional barriers. The authors emphasize the need to overcome the initial cost barrier of solar home systems, establish responsive and sustainable infrastructure and ensure quality products and services. The article also identifies the economic niche for PV use in comparison to traditional options, such as kerosene lanterns and extension of the grid. Major obstacles to the diffusion of off-grid electrication via PV are discussed, along with recommended solutions and best practices. The authors have sought to apply these recommendations in design of the Bank-assisted Sri Lanka Services Delivery Project.

INTRODUCTION

Nearly twenty years ago, the World Bank began to finance renewable energy projects, motivated by the high oil prices and energy crisis of the 1970's. The collapse of oil prices in 1985/96 soon undercut this initiative. Since 1990, however, technological improvements, cost reductions, and environmental concerns have all reinforced interest in renewable energy investments by the Bank and its clients. Currently, the World Bank actively seeks to mainstream alternative energy options for sustainable energy development as a means to address environmental concerns and mitigate greenhouse gas emissions.

In 1992, the Bank and donor partners including the Netherlands, the US DOE, the UNDP, and others, established the Asia Alternative Energy Program (ASTAE) to help prepare renewable energy and energy efficiency components for Bank-supported operations in Asia. The Program is currently engaged in solar home system and other PV activities in India, Indonesia, Sri Lanka, the Philippines, China, Bangladesh and the Lao PDR. This article is based on ASTAE's field experience over the past five years in solar photovoltaic project identification, preparation and implementation. It also reflects ASTAE's in-depth review of solar home system experiences in Indonesia, Sri Lanka, the Philippines and the Dominican Republic which are incorporated in the World Bank Technical Paper #324, "Best Practices for Photovoltaic Household Electrification Programs."[*]

Experience across the developing world confirms the technical reliability of photovoltaic (PV) systems in a variety of settings. Under the right conditions, solar home systems can offer lighting and other services to large numbers of households that are poorly served by existing energy sources or have no service at all. There is an important economic niche for such systems within rural electrification programs. PV systems are an effective complement to grid-based power, which is often too costly for sparsely settled and remote areas. For such rural conditions, fuel-independent, modular solar home systems can offer the most economical means to provide lighting and power for small appliances.

Field investigations of solar home system household electrification in Indonesia, Sri Lanka, the Dominican Republic, and the Philippines demonstrate that program success is possible with a variety of technical, financial and institutional arrangements. However all successful PV household electrification programs must overcome the high first cost of solar home systems, establish sustainable infrastructure, provide quality products and service, and ensure appropriate support from governments and donors. This article focuses on these essential conditions for successful PV market development and the specific design of two projects in Indonesia and Sri Lanka which are currently receiving financial support from the World Bank and the Global Environment Facility (GEF).

OVERCOMING THE FIRST COST BARRIER

Solar home systems use renewable energy and are self-contained generation and distribution systems. They consequently have low operating and maintenance costs in comparison to fossil fuel alternatives. Thus, the initial capital cost of a solar home system is very high in proportion to its total

[*] This article draws heavily on the finding of this technical paper as well as the project design details contained in the World Bank's staff appraisal reports for the Indonesian Solar Home System project and for the Sri Lanka Energy Services Delivery Project. The authors express appreciation to Jas Singh and Jon Exel for their help in preparing the text of this article.

life-cycle costs[1] (typically more than 75 percent). The purchase price of solar home systems range from $100 (10 Watts peak [Wp], China) to $1,400 (53 Wp, Kenya). For many low- and middle-income rural households, the purchase price of a solar home system represents almost one year's income. The price of solar home systems is one of the greatest barriers to ownership among rural populations, especially given the virtual absence of credit. Although outright cash purchase of solar home systems does occur, only the wealthiest of rural consumers have this option. In the Philippines, it is estimated that only 10 percent of potential purchasers can pay cash, while 20-60 percent could afford to buy a system on credit, depending on payment conditions and terms.

From the point of view of the potential user, the key issue is the affordability of the PV system in relation to its perceived value. While many beneficiaries of rural electrification receive subsidies, PV users are generally expected to pay for most of the costs of their systems. The barriers that constrain the purchase of solar home systems include:

- ***High capital costs*** and lack of access to credit make solar home systems too expensive for many rural households;
- ***High transactions costs*** arise in purchase or servicing of solar home systems due to limited supply, sales outlets, technicians and financing infrastructure in rural areas;
- ***Market distortions*** often increase the price of solar home systems relative to alternatives. These include:
  - import duties, tariffs, and taxes; and
  - subsidies for kerosene and grid-based service to rural consumers.

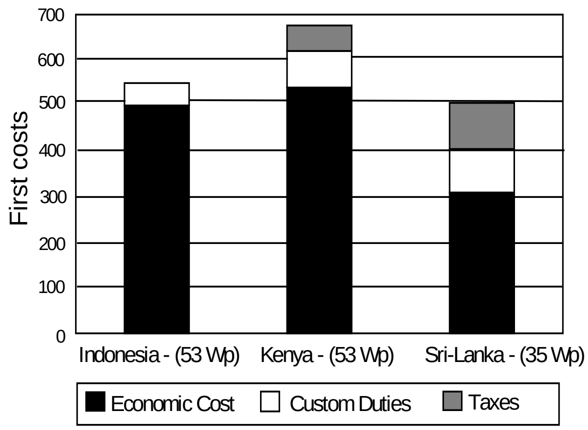
Term Credit and Affordable Payment Schemes. Affordable and accessible financing is a major consideration in the design of any PV program due to the high first costs of solar home systems. Affordability can be increased by providing households with term credit through local dealers or the banking system or by leasing or energy service company (ESCO) arrangements. The inability of borrowers to offer adequate security or collateral for the loan is a major constraint to offering term credit. Some approaches to overcome this problem include using the PV module as part-security, seed capital funds, loan guarantees, supplier credits, or equity investments on debt financing assistance from the Government. Pricing and repayment arrangements should capture households' ability and willingness to pay. For example, evidence suggests that consumer willingness and capacity to pay is influenced more by the size of the down payment for solar home systems than by the number or the size of the monthly payments. Flexible payment schemes may be needed for households with irregular income streams.

High Transactions Costs. Since the PV home system industry is in the early stages of market development, it is difficult for sales and service networks to reach the economies of scale that would allow for price reductions. The Indonesia experience clearly illustrates how economies of scale can affect the production, sales and servicing of PV systems. A solar home system in West Java (where annual sales are in the thousands) is 50 percent cheaper than in Lampung, Sumatra (where sales are in the hundreds). The combined effect on prices of a small market and limited competition is also seen in Kenya, where the total installed price of a 53-Wp system is $1,378, compared with an estimated financial cost of $670, based on competitive prices plus taxes and duties. The costs of solar home systems should fall as markets mature, sales and support networks develop and competition grows. Using existing durable goods, sales and service outlets could help reduce these overhead costs. However, as experience in Sri Lanka shows, unless the margins offered to such rural outlets are sufficiently high – they will not have much incentive to support solar home system sales.

Tax and Duty Structures. Governments should rationalize duty and tax structures, if they discriminate against PV development. Relatively high import duties and other taxes (particularly on PV modules) can severely limit the potential for commercially viable, market-driven solar home system programs. Duties and taxes on PV system components raise the financial costs of solar home systems. At the same time, subsidies for rural grid service or for kerosene often lower the cost of competing energy options to well below their economic value. In Sri Lanka, import duties added about $2.50/Wp to the cost of a PV module in 1993/94 (see Fig. 1). In 1994, India levied import duties of 45 percent on PV equipment and as much as 300 percent on solar lanterns. Such pricing policies can also distort cost comparisons between PV and grid services. Indonesia, for example, levies a 10 percent VAT on all goods and imposes import duties on PV modules, while subsidizing rural grid service (see Fig. 2). Duties on electronic components are particularly harmful to the PV system market, since suppliers are tempted to substitute locally-made inadequate or poor-quality battery charge controllers or to dispense with controllers altogether.

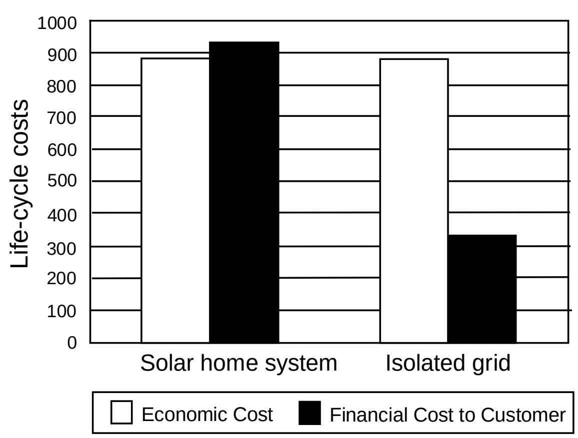
[1] Life cycle cost is the amortized annual cost of a system including capital, installation, operating and maintenance costs measured over a 25 year lifetime.

Fig. 1. The Impact of Duties and Taxes on the Initial Cost of a Solar Home System in Indonesia, Kenya and Sri Lanka (in 1993 dollars).



Grants and Subsidies. A judicious use of grants and subsidies can help implement household PV programs. To assure sustainable programs, such assistance should be used to build market infrastructure through planning, promotion, training, feasibility studies, quality assurance and similar activities, or as limited equity to reduce the capital costs of a project. The use of grants or subsidies to cover operating costs is dangerous and could undermine the long-term sustainability of a PV electrification program.

Fig. 2. Comparison of the Economic and Financial Costs of PV- and Grid-Based Service in a 250 Household Village in Indonesia (in 1993 dollars).



ESTABLISHING RESPONSIVE AND SUSTAINABLE INFRASTRUCTURE

Institutional Structure. No single institutional arrangement is appropriate for every country. Successful PV household electrification programs have been implemented under a variety of have been Possible alternatives include:

- ***Energy Service Companies (ESCOs).*** Electric utilities, cooperatives, non-governmental organizations and private companies can operate as ESCOs which buy solar PV systems in bulk, install solar home systems, retain ownership and bill for services;
- ***Leasing or Hire-Purchase Arrangements***. An intermediary (a private company, cooperative, or NGO) retains ownership of solar home systems until they are paid for by customers over a period of time; the intermediary often utilizes seed money from government or donor grants to establish a revolving fund to buy the first PV systems; and
- ***Cash or Credit Sales to Consumers***. Banks and dealers provide short-term financing at market rates to help consumers finance solar home systems. Existing organizations are used whenever possible to avoid the problems associated with creating and staffing new institutions.

ESCO models allow for the most affordable payment schemes, and can thus reach a larger customer base than other credit delivery schemes. A local or regional electric utility or a distribution company can serve as an ESCO. With a large custom base, the ESCO can obtain economies of scale in procurement and in the delivery of support services, make product standardization and quality assurance easier, and facilitate battery recycling. While the ESCO model is an attractive concept, its long-term viability requires business management skills and technical capabilities that may be limited in rural areas. The ESCO model also carries greater commercial risk due to the longer cost-recovery period.

The more market-oriented PV system financing through leasing and consumer sales works well in areas in which an existing marketing and financing infrastructure is already established. Commercial marketing channels, firmly rooted in the private sector, can offer services in a competitive and efficient manner. These commercial markets may be more responsive to consumer requirements and can offer a broader array of products than ESCOs.

Financial Sustainability. PV programs must be operated as businesses. They should generate revenues sufficient to recover capital investment, service debt, pay for administrative and support services, cover payment defaults and, in the case of for-profit operations, provide satisfactory returns for investors. In the past, the fees charged under many donor- and government-sponsored programs were set at levels comparable to the monthly cost of kerosene for low-income households. This was based on the assumption that rural consumers have a very limited capacity to pay. Such PV programs are intrinsically *unsustainable* over the long term. Experience shows that consumers are often willing and able to pay more for highly valued services than has previously been assumed. To ensure sustainability, PV programs should:

(a) set prices to allow for full cost recovery;
(b) select only consumers with a willingness and ability to pay;
(c) ensure that consumer expectations are in line with the energy services to be provided;
(d) maintain high product quality and responsive services;
(e) establish effective fee collection methods and enforce regulations to "shut off" service for nonpayment;
(f) adopt simplified administrative procedures; and
(g) select and retain quality staff.

Effective Management and Support Services. A successful PV program needs well-qualified managers and technicians. Local recruitment is advisable since people from the community who are known and trusted are more effective than workers from a central agency located outside the area. This, however, will often necessitate extensive training. Managers need to be proficient in business, marketing, and financial operations and to have access to information, technical assistance and ongoing training to update their skills. Adequate salaries and benefits are also required to retain qualified managers in rural areas. In addition, technicians must be trained (and given periodic refresher courses) in order to assure responsive repair and maintenance services – an often underemphasized aspect of PV programs. Technicians also need appropriate tools and transportation as well as locally available supplies of spare parts.

PROVIDING QUALITY PRODUCTS AND SERVICES

Technical Quality. The long-term sustainability of a PV program depends on well-designed products (including proper assembly and installation procedures) that meet consumers' expectations and capacity to pay. Only field-tested systems should be used in a PV electrification program. If untested PV systems are introduced and fail, the credibility of PV as a viable energy source for rural consumers can be seriously undermined. Low-capacity, high-quality products should be offered to those potential customers with only a limited ability to pay. Costs should never be reduced by compromising system quality or by decreasing support services. Where low-cost systems must be used, customers need to be fully aware of and accept a limited level of service. Large-volume procurements can also be used to help in the acquisition of high-quality products and to take advantage of bulk purchase discounts.

Consumer Awareness. User education is essential for PV program success. Information and training in simple maintenance and safe operating procedures should be targeted to those persons in the households who will have primary responsibility for the system. Users need to understand that good operating practices minimize recurring costs and enhance battery life.

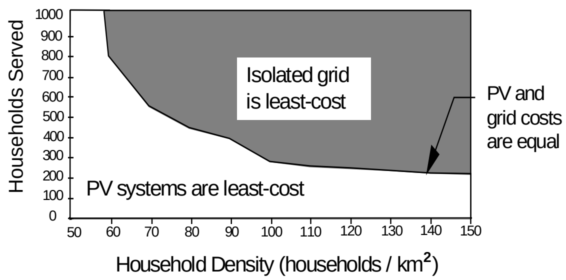
SOLAR HOME SYSTEMS VS. GRID-BASED POWER SUPPLY

Grid-based power supply and PV systems are not necessarily mutually exclusive options in delivering electricity services to rural areas. Grid-based power is the least-cost option for large concentrations of household or productive loads. It offers substantial economies of scale, owing to the large fixed-cost investment in distribution lines and generation facilities. However, grid solutions require a minimum threshold level of electricity demand and certain load densities to achieve these economies of scale. Deciding whether the grid or solar PV is the least-cost option for supplying electricity to rural areas requires attention to:

- Daily energy consumption of a household;
- Total number of households served;
- Number of households served per program service area (in km^2);
- Number and power requirements of productive loads; and
- Load growth.

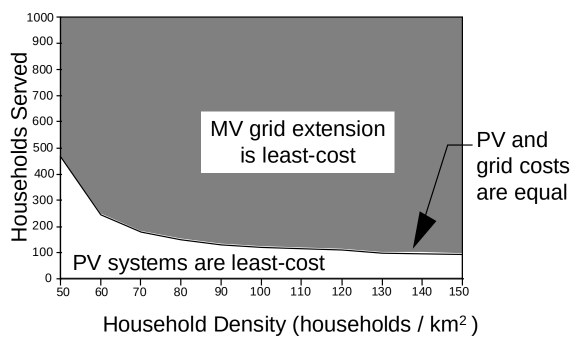
Figures 3,4 and 5 identify the "break-even" thresholds for grid-based and solar home systems for Indonesian communities with up to 1,000 households and household densities ranging from 50-150 households per km^2. The break-even point at which grid-based power supply and PV systems are equally cost-effective in these three scenarios depends on the size and density of the specific load to be served as well as the distance from low- (LV) and medium- (MV) voltage lines. This analysis considers both the isolated grid and central grid extension as grid-based power supply options. The central grid extension provides power to households from a distribution network connected to the central grid via a MV or LV line, while the isolated grid is composed of diesel genset powerstations in the range of 3 to 2000 kW serving households via limited electrical distribution system. Key assumptions for the economic analysis can be found in Annex 1.

Fig.3. Isolated Village.



A key concept introduced in this analysis is "Equivalency of Service," which assumes that households receive comparable levels of service from both PV and grid-based arrangements corresponding to 6 hours of task lighting (10 W fluorescent tube or 40 W incandescent bulb), 8 hours of area lighting (6 W fluorescent tube or 25 W incandescent bulb) and 60 Wh of other loads per day. In Indonesia, experience shows that these service levels are achieved by rural households using 15 kWh per month from the grid. It is also assumed that there are no productive loads and no load growth. These analyses are based on grid service and PV systems cost data for Indonesia.

Fig. 4. Village Located 5 km from MV Line.



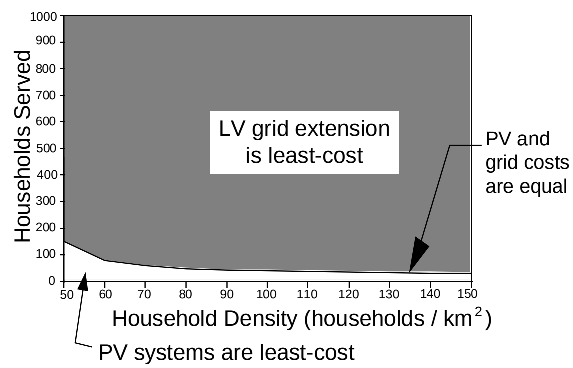
The break-even curve in each graph traces the line along which the levelized costs are the same for either PV household systems or grid-based power, given specific combinations of load (household connections) and load density (household connections per km^2). PV electrification is the least-cost option below the line and grid-supply is the least-cost option above the line. For example, an isolated diesel-powered grid is the least-cost option for a village with 400 household connections and 100 households per km^2 (see Fig. 3). If this village had half the number of household connections and a lower household connection density (for instance, 65/km^2), PV household systems would be the least-cost choice.

Figure 3 highlights an economic niche for PV home systems in small, sparsely settled, isolated communities. Here, solar homes systems are less expensive than either kerosene and batteries or grid-based power. This is true for villages of widely varying sizes and household densities. Typically, PV household systems are the least-cost option for villages with fewer than 200 connections.

Figure 4 highlights a second economic niche for solar home systems: in communities near (5 km or less) an existing MV line, PV systems are the least-cost option, if few households are to be served. Typically, PV household systems are the least-cost option for villages up to 5 km from the grid but with fewer than 100 connections.

Figure 5 defines a third economic niche for PV service in villages located near an LV line (3 km). Grid extension is normally the least-cost option for such settlements. However, PV systems are the least-cost option, if fewer than 50 households are to be connected. Often, these sparsely settled communities are passed over in the rural electrification process and remain unelectrified pockets locked inside electrified regions.

Fig. 5. Village Located 3 km from LV Line.



In summary, PV home systems are economically the lower-cost option, compared with grid-based service, if the average incremental cost of grid service is greater than $8.25 per month per household. This rule applies at a service level equivalent to 8 hours of area and 6 hours of task lighting (plus 60 Wh of other services daily), assuming a cost of $500 per 50 Wp solar home system. If the level of service is doubled, PV systems are economically the least-cost option when the average incremental cost of grid service is greater than $13.75 per month per household.

Similar least/cost analyses can be made for solar lanterns, solar battery charging stations and hybrid systems. The World Bank seeks to develop them and other renewable energy options within a cost effective environmentally sustainable energy strategy.

THE ROLE OF GOVERNMENTS AND DONORS

It is difficult for a new and somewhat marginal solar home system industry to make substantial investments in retail and service networks. Assistance from government and donor agencies can help build the necessary infrastructure to accelerate development. Such support can include:

- Supporting and conducting least-cost rural energy planning that includes PV system options;
- Making investment capital available for solar home system programs;
- Encouraging the commercial banking sector and financing agencies to finance PV home systems on reasonable terms by offering support mechanisms such as refinancing arrangements;
- Supporting promotional campaigns for PV household systems among rural households;
- Removing regulatory barriers that limit competition among energy service providers; and
- Offering training and technical assistance to help establish retail and service networks.

Grid-based electricity has been the mainstay of rural electrification efforts. However, the increasingly high cost of serving isolated and remote communities burdens government budgets. A large proportion of rural needs for household lighting and small power requirements can be met by solar home systems at a lower economic cost than grid service. In locations where PV household electrification is the economically viable option, governments must explicitly consider and encourage solar home system diffusion in lieu of grid extension. Political reluctance to specify areas unlikely to be served by electricity grids within 5-10 years raises unrealistic expectations among consumers. This expectation dampens efforts to market PV systems. Consumers are reluctant to purchase what is perceived to be only a short-term solution. Instead, explicit government support of solar home system programs for isolated, or remote villages, or unserved portions of electrified communities can help PV meet low load demands and prevent uneconomic extension of the rural electrification grid. Private sector participation in such programs should also be encouraged.

A multimodal approach to rural electrification considers PV systems along with other options to complement grid extension. The choice of technology should be based on consumer needs, economic viability, technical and institutional capabilities and consumers' willingness and ability to pay for the service. The approach chosen should allow for energy service delivery through a range of public and private sector institutions, as well as local cooperatives and NGOs.

The key role of government is to guarantee an appropriate institutional and regulatory environment. As noted earlier, governments should rationalize duty and tax structures as well as incentive or subsidy programs to reduce market distortions and facilitate access to credit. Other governmental functions include the setting of technical standards, monitoring and overseeing programs and disseminating information on PV technology and the performance of solar home systems. By investing directly in PV equipment as part of education, health and other social programs, governments can also play an important role in establishing the infrastructure needed to sustain PV systems.

Donor support for PV programs requires coordination with government programs, local organizations, other donor agencies and private sector stakeholders. Donor agencies can help in technology transfer and in financing investments in PV systems as part of rural electrification and rural development projects. The World Bank (and other multilateral banks) should actively promote a multimodal approach to rural electrification. The Bank can advise its clients on how to create the necessary enabling environment and help them explicitly consider PV systems and other off-grid options within Bank-supported projects; strengthen government's ability to identify and assess rural energy options; and make available financial resources to prepare and implement such projects.

There are currently two World Bank/GEF-assisted projects under implementation to support solar home system programs, the Indonesia Solar Home Systems (SHS) and the Sri Lanka Energy Services Delivery (ESD) Projects. Both projects were designed to overcome the principal constraints to solar home system market development, namely: (a) the high initial cost and the limited availability for term financing; (b) lack of information at the household level; and (c) undeveloped supply and service networks.

The SHS Project will assist the Government of Indonesia (GOI) to provide electricity services using solar home systems to about 200,000 households in West Java, South Sulawesi and Lampung provinces. The households targeted are in areas where the electric utility (PLN) grid service is not expected for at least three years or where it is uneconomic for PLN to provide such service. On January 28, 1997 the World Bank/GEF approved a $20 million loan and $24.3 million grant for the project. The GOI will utilize the Bank's/GEF's funds and provide credit to commercial banks who in turn will make loans to solar home system dealers - mostly small businesses. Because few rural households can pay for solar home systems on a cash basis, dealers will provide credit installment plans. Customers are expected to make a downpayment of about $75 to $100 dollars per program. The GEF will also provide a grant of $100 per solar home system. In order to make monthly installment payments affordable to a sizable segment of the population, the dealers would offer loans of about four years, with the actual length of the loan to be determined by the dealers.

On March 18th, 1997 the World Bank/GEF approved $30.1 million in loans and grants to the Government of Sri Lanka (GOSL) to support an Energy Services Delivery (ESD) Project. The $24.2 million International Development Association (IDA) credit and the $5.9 million Global Environmental Facility (GEF) grant will support three components of the project: (i) an ESD Credit Program, funding private renewable energy initiatives for approximately $49.0 million; (ii) a Pilot Wind Farm for approximately $3.8 million; and (iii) a Capacity Building component for approximately $2.6 million. The Credit Program's PV component will provide medium and long-term financing to private developer, NGOs, and community cooperatives for household electrification. The GOSL will utilize the Bank's/GEF's funds and provide credit to Participating Credit Institutions (PCIs) who in turn will make loans to the above mentioned parties. PCIs will determine the loan requirements in agreement with their clients. Sub-loans maturities are limited to 10 years, including a 2-year grace, and will not exceed the useful economic life of the equipment financed. The Credit Program reserves $5.0 million plus $3.8 million GEF grant for off-grid projects, including solar home systems and village hydro schemes. Grant co-financing is available through PCIs to developers of off-grid PV, and is limited to $100 per system with a module rating of not less than 30W. In addition project preparation grant funds are available to help subborrowers' engage consultants to prepare feasibility studies, business plans and PCIloan documentation. The Administrative Program of the Credit Program will also use grant funds for off grid project promotion, solar home system design verification, consumer education and a consumer protection facility. The Credit Program is expected to support projected sales of about 37,000 systems over a five-year period are indicated.

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Annex 1
Key Assumptions for Economic Analysis of Rural Residential Energy Systems
Indonesia Example

Solar Home Systems

Effective Sun-hours	3.5 hrs/day
Size Solar Home System	50 Wp
System Cost	$500
Module Lifetime	10 years
Module Replac. Cost	$300/panel
Battery Lifetime	3 years
Battery Cost	$50
Bulb Lifetime	1 year
Bulb Replacement Cost	$3.50

Kerosene/Battery

Battery Capacity	70 Ah, 12V
Battery Cost	$45
Battery Lifetime	2 years
Recharge Cost	$1/charge
Petromax Cost	$15
Petromax Life	4 years
Petromax SFC	0.06 l/h
Wick Lantern Cost	$5
Wick Lantern SFC	0.04 l/h
Kerosene Cost	$0.19/l
Kerosene Cost	$0.19/l

Isolated Grid

Diesel Capacity Cost	$625/kW (220 kW) to $1780/kW ($\leq$ 20kW)
Diesel Engine SFC	0.3 l/kWh
Diesel Fuel Cost	$0.19/l
Lube Oil Consumption	0.0030 l/kWh
Lube Oil Cost	$1.41/l
Overhaul Cost	$1875 (≤ 20 kW) to $28,830 (220 kW)
Overhaul Period	18,000 operating hours

Central Grid Extension

LRMC of Supply	$0.063/kWh
MV Line Costs	$9825/km installed
LV Line Costs	$5085/km installed
Load Coincidence Factor	80%

Distribution Grid
(for Isolated/Central Grid Systems)

Distribution Line Req.	5 km/km^2 service area
Power Factor	0.8
Distribution Losses	10%
LV Line Costs	$5085/km installed
LV Line per Transformer	4 km/transformer
Transformer Cost	$3415/trans. installed
Connection/Wiring Cost	$68/customer

General

Discount Rate	12%
Productive Load Capacity Factor	17%