Affordable remote-area power supply in the Philippines

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Abstract

The feasibility of photovoltaic (PV) systems for electrifying remote areas of the Philippines is discussed. In particular, a technical description is given of those PV systems that are appropriate to the needs of remote, but populated, rural areas and have been developed as part of the Philippine–German Solar Energy Project. Details are provided of a financing scheme, piloted by the Project on an unelectrified island, to make PV systems affordable to rural users. An analysis is presented of the potential of large-scale applications of PV systems in developing countries such as the Philippines, and a description is provided of current efforts to promote the use of such technology. A storage battery is identified as an essential component of a PV system. As a consequence, the wide use of PV systems will have a very significant impact on the market for storage batteries in countries embarking on PV-utilization programmes. It is clear, therefore, that battery manufacturers should take an interest in future developments in PV applications.

Photovoltaic systems in the Philippines

In 1981, the Federal Republic of Germany (through its German Agency for Technical Assistance (GTZ)) and the Republic of the Philippines (through its Ministry of Energy, now Office of Energy Affairs (OEA)) signed an agreement to implement the Philippine–German Solar Energy Project (PGSEP). Under PGSEP, the two countries agreed to undertake jointly a solar energy research project on photovoltaic (PV) applications in the Philippines. The objectives of the project were:

- to determine the technical feasibility of operating a PV power plant to supply the electric power needs of a typical rural village;
- to determine the technical feasibility of using PV technology for small rural applications;
- to develop local expertise in PV technology.

Field research and testing were carried out mainly in Bulacan, a province located just north of Manila. A field laboratory was established in the town of Dona Remedios Trinidad which is 30 km (or 1-h drive) away from the metropolis. The place proved to be an ideal site for field research because, despite the close proximity to Manila, the local conditions approximated to those of rural communities that were targetted for PV applications.

The first phase of the project involved the installations, operation and testing of a centralized, 13.3 kWp, PV power-plant. This facility provided electricity to a small agricutural village consisting of 60 households. Although the operation of the plant was proven to be technically feasible, it was, however, considered to be uneconomical given the high investment cost. Thus, such a centralized system was not recommended

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for wider implementation. After five years of field testing, the centralized PV plant was dismantled.

The second phase of the project focused on the development of small and decentralized PV systems that would be viable for rural applications. Among the systems designed, operated and tested successfully were:

- solar home systems
- communal battery-charging stations
- remote-area power supply for telecommunication facilities

This work proved that solar-powered home systems and battery-charging stations could reliably provide electricity in many rural areas of the country and had good technical viability and economic competitivenes compared with conventional and traditional sources of rural power.

The last phase of the PGSEP involved demonstration of the utilization of solar home systems and battery-charging stations for rural electrification on a commercial scale. A town, located on Burias Island, was chosen for the commercial-scale application of the small PV systems. Solar home systems were sold to individual houses on an amortized basis. The systems were designed to generate electricity for lighting and for powering small electrical appliances (e.g., radios and d.c. television sets). The objective of the demonstration project was to prove that the use of PV systems in remote rural electrification schemes could be a more economic and desirable option to grid extension and/or to the operation of small diesel-generator sets.

The positive results obtained from the above demonstration project have encouraged the Philippines, through its Office of Energy Affairs, to draw up a programme for promoting the use of solar home systems and battery-charging stations in unelectrified villages of the country.

Photovoltaic technology

The basic building block of a PV system is the solar cell. The latter can be made from various semiconductor materials. These are treated with special additives to bring about photosensitivity. When photons (i.e., particles of energy in sunlight) hit the surface of a solar cell, electrons are released and generate a flow of electricity. To complete the device, conductive layers are added to the top and bottom of the solar cell to collect the electricity and carry it to the load, i.e., the system that is to be powered. Almost all the PV cells that are presently available in the market are made from crystalline silicon.

Typically, cells are connected together to provide practical electrical voltage and power output levels. This group of cells is then packaged in a special protective enclosure called a 'module'. The voltage and power outputs of the module depend on the size of the cells used.

To provide the voltage (or power) required by many common applications, several modules are connected together. This module grouping is known as a 'panel'. Several panels can also be interconnected to give even higher voltage or power ratings. This grouping is referred to as an 'array'. To complete a functional solar-power system, power conditioning electronics and a battery bank are added. An inverter can also be included for a.c. applications [1].

Taking into consideration the above, the solar home system developed by the PGSEP is capable of generating an independent power supply adequate to meet the basic electricity requirements of single households found in typical rural villages of developing countries such as the Philippines. A regular solar home system consists of a single panel (~ 50 Wp), a 12 V/100 A h battery, a battery control unit, a voltage regulator for radio and television receivers, two 20 W fluorescent lights (with 12 d.c. ballasts), a 10 W incandescent bulb, frames and cables (Fig. 1). The installation of these systems takes only a day and a half. The PV panels convert solar radiation into electricity and store this in the batteries to provide electricity during the night time. On average, the system is expected to produce 180 W h/day. This is sufficient for three hours operation of the fluorescent lights and the black-and-white d.c. television set, four hours operation of the radio, and two hours operation of the incandescent bulb.

The PV panel is the most expensive component of the solar house system; it is more than half the total cost. On the other hand, the PV panel can last for 20 years while the other components of the system, especially the batteries that are the second most costly item, have to be replaced every three to four years. Notwithstanding this depreciating factor, economic studies have shown that home systems can still be competitive with conventional energy systems, particularly with small diesel-generator sets. Also, solar home systems can, in the long run, provide cost savings to those households that use kerosene pressure lamps for lighting and dry-cells for radios and casette players.

Solar home systems have demonstrated the following further advantages when compared with grid extension and operation of small diesel-generator sets.

(i) Unlike the situation in centralized power plants, a highly organized institution with managers, administrators and technicians is not required.

(ii) A solar home system is immediately available – unlike power plants that take some time to be planned, constructed and commissioned and also require the pooling together of large investment funds involving many agencies.

(iii) Distribution lines and electric meters (with significant lessening of project cost viability in areas of low population density) that are essential in grid extension are dispensed with, each house is equipped with its own solar system.

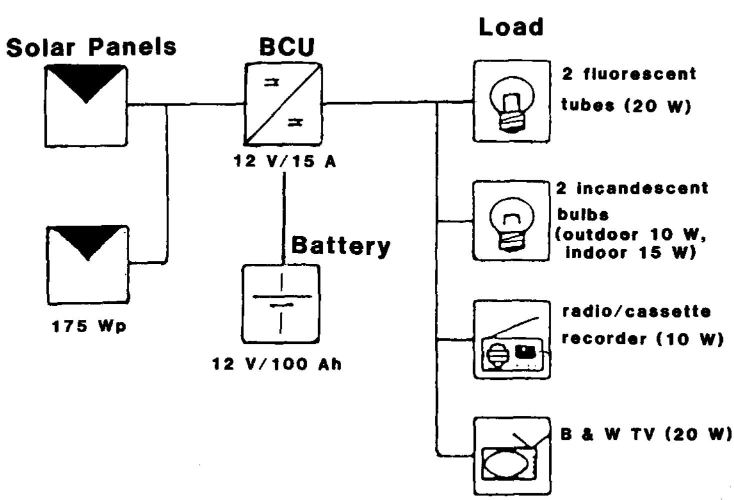

Fig. 1. Schematic diagram of a solar home system.

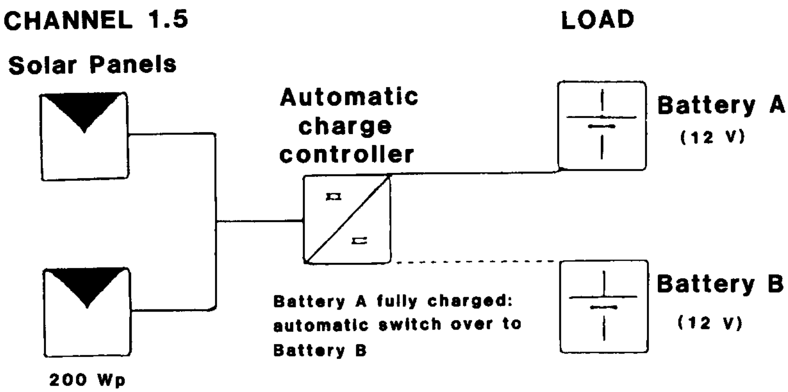

Fig. 2. Schematic diagram of a battery-charging station.

(iv) Compared with diesel-generator sets, a PV system does not generate environmental pollution and noise as no moving parts are involved.

(v) The PV system has a low-maintenance cost and practically no operating cost, as it runs on free 'fuel' from the sun.

A solar home system has a drawback. As earlier mentioned, the cost of the PV panels, which is half of the total system cost, may prove unaffordable to many families. Thus, solar-powered battery-charging stations have been developed (Fig. 2).

With this system, the rural households have the option not to buy the PV panels. Instead, they simply procure lead/acid batteries and have them recharged at a communally-owned solar- powered battery-charging station. The use of this system, however, means diminished electricity supply. Such charging stations have been tested by the PGSEP in country locations. A 1 kWp solar-powered lead/acid battery-charging station can service around 40 households on the basis of a weekly recharging cycle for each battery. Apart from the array of PV panels, the station requires a shelter for the charge regulation and safety equipment required for charging and handling of the lead/acid batteries.

In both types of PV systems, the use of local components, not only to minimize costs but also to develop the country's capability to produce and manufacture the systems locally, has been maximized in the project. Thus, only the PV panels are at present imported, whereas the other components (i.e., batteries, electronic control units, and d.c. loads) are produced locally. This has helped in reducing drastically the cost of the whole system and has further enhanced the competitiveness of PV systems, as demonstrated by the Burias Island electrification project.

Burias Island PV rural electrification project

Burias Island is located near the central part of the Philippine archipelago (Fig. 3). It is one of the three islands that comprises the province of Masbate and has a population of approximately 100 000. There are two towns on the island: San Pascual, in the north, and Claveria, in the south. The former was chosen as the site for the pilot PV rural electrification programme.

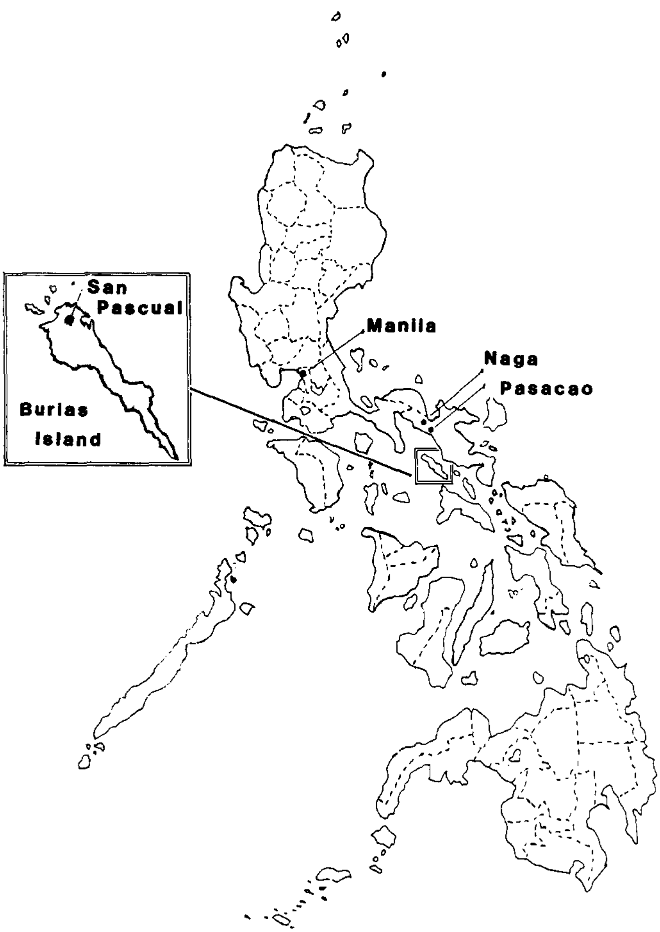

Fig. 3. Map of the Philippines showing location of Burias Island.

San Pascual can be reached by a three-hour boat ride from the town of Pasacao, which is on the Island of Luzon. Pasacao, itself, is a thirty-minute jeep ride away from Naga City, an urban centre in the southern part of Luzon Island. Naga City is accessible from Manila either by plane, which takes 45 min, or by bus in 10 h.

Farming, fishing and cattle raising are the chief industries of San Pascual. The crops are coconut, corn and rice. The sea surrounding the island is considered to be one of the richest fishing grounds of the country. A few groups of the population are either engaged in commercial activities or employed in local government agencies as employees or teachers.

Few infrastructures exist on Burias Island. A very rough road connects the two towns, but most of the outlying villages can be reached only by boat rides along the island's shoreline. During the months of monsoonal rains, transportation and communications between the Island and Pasacao can be cut off for weeks.

With regard to energy sources on the island, kerosene is used for lighting, either in wick lamps or in the more efficient pressure lamps. Many families have transistor radios and cassette recorders that are powered by dry cells. Kerosene and dry cells are brought in from Pasacao and are therefore more expensive on the Island. Wood is need as a fuel for cooking in all households.

Using PGSEP data obtained in the field laboratories at Bulacan, a study was conducted to determine the feasibility of using PV systems as options for electric power supply on Burias Island [2]. The options evaluated were:

(i) installation of a 16-km sea cable from the nearest point on Luzon Island to Burias and distribution lines to the different villages;

(ii) installation of a 600-kW diesel-generator set on the Island and distribution lines to the different villages;

(iii) installation of solar home systems and battery-charging stations.

Results of the economic computations and evaluation studies have shown that the use of solar home systems and solar-powered battery-charging stations is the most economical option for the people of Burias Island, given the current and near-term predicted levels of electricity consumption (Fig. 4). It was assumed that the electricity would be used mainly in providing household electricity needs, e.g., lighting, especially at night time. Even with the erection of a ricemill or an ice plant on the island, technical and economic evaluation studies have indicated that the sea-cable system and the centrally-operated diesel-generator set are less desirable options. The best approach is to have a mixed-energy supply system, i.e., diesel-generator sets to supply power to the rice mill and the ice plant and PV systems to supply power to the households.

An analysis was also made on the present energy expenditures by the people for lighting and operation of radios and cassette recorders. Based on expenses incurred in buying kerosene for lighting and dry cells to power radios and cassette recorders the survey found out that:

(i) a small segment of the population, at most 10% of the total households, can pay for solar home systems in cash;

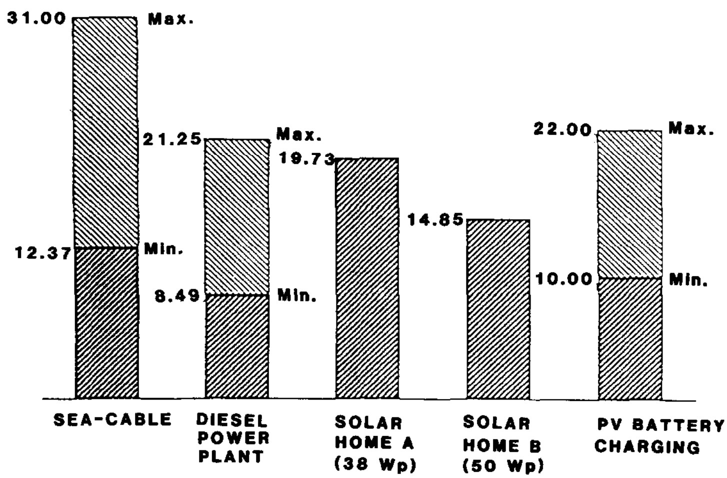

Fig. 4. Cost comparison of electricity-supply systems for Burias Island. Note: prices are in Philippine pesos (P 28.00=US$ 1.00).

(ii) the next 20 to 60% of the population can procure the systems if a financing scheme (say, 20 to 30% downpayment) and an amortization period (at least three years for the balance of the amount) can be available to them;

(iii) the remainder who cannot afford a solar home system can procure batteries that can be recharged in solar-powered battery-charging stations.

On the basis of these findings, the institutional mechanisms for the introduction of PV systems on Burias Island were laid out. Several months before, a PV-powered vaccine refrigerator was installed in the town centre. This served both as a cold-storage facility for the municipal clinic and as a public demonstration of the benefits to be gained from PV technology. Shortly after, 11 of the most affluent families in town, including that of the mayor, became interested in PV energy supplies and later bought their own solar home systems. As a result, the PV vaccine refrigerator and the first 11 solar home systems served as demonstration projects to the community and encouraged more households to consider solar home systems as an alternative solution to electricity needs. Through these initial efforts, PV technologies were promoted and brought to the awareness of most of the people living on Burias Island.

The first 11 solar home systems were made available and sold to the community through the PGSEP. When interest in PV systems increased, however, and demand for solar home systems grew to as much as 400 to 500 households, the Project was not in a position to handle the marketing and distribution of solar home systems to satisfy the increased demand. It was at this point that a sociologist from the Project staff conferred with the community leaders of the Island to discuss mechanisms by which solar home systems could be brought in and sold to interested buyers at prices that were generally affordable. It was recommended that the process should be operated by the townspeople themselves. This was to assure continuity of Project operations, even after the Project had been completed, and to instill the value of self-reliance among the Island people.

The PGSEP staff and the Island people agreed on the following strategy.

(i) The community was to organize itself into a cooperative to be called the 'San Pascual, Masbate Solar Power Cooperative'. This would supervise and promote the electrification of the Island through PV systems.

(ii) The cooperative would be responsible for bringing in solar home systems from distributors in Manila and for selling them at amortized prices to its members.

(iii) The cooperative would be responsible for the installation of the systems and collection of downpayments and fees for loans or purchases of the new systems.

(iv) The cooperative, with assistance provided by PGSEP staff, and with the endorsement of OEA officials, apply for a loan to the Development Bank of the Philippines (DBP) to finance its operation.

(v) The project would train local technicians to be employed by the cooperative to service the needs of its members.

(vi) The cooperative would be engaged in income-generating activities, e.g., operating battery-charging stations, electronic repair shops, and would make available to members spare parts for PV systems.

With assistance from the PGSEP staff, a project loan proposal was prepared and submitted by the cooperative to the DBP to partially finance 66% of the total cost needed to purchase 100 solar home systems. Money was borrowed at a 13% interest rate and was passed on to members at 16%. The OEA contributed around 9% of the cash requirement of the cooperative, while the members themselves put up the balance (25% of the total amount). The total amount that the cooperative was able to raise was 1 149 500 pesos (US$ 41 100).

With technical assistance from PGSEP staff, the cooperative developed a financial assistance scheme for its members to purchase PV systems. Using socio-economic data obtained from the survey conducted on the Island, buyers were asked to pay 25% of the system cost upon installation. It was arranged that the balance was to be paid over a three-year period at an interest rate of 16% per annum. The price of a solar home system at that time (around US$ 411) allowed families that were consuming kerosene and dry cell (at least US$ 9.80 per month) to buy PV systems through this scheme. For those who could not afford to buy a solar home system, the cooperative installed a 1.8 kWp battery-charging station.

Studies conducted by the OEA later showed that households using solar home systems were generally satisfied with the quality of service and found the price affordable. They realized that solar home systems were more economical than using kerosene lamps and dry cells. The PV systems provided better lighting and this allowed the population to extend their daytime activities.

There were problems encountered such as battery failures, and short lifetime of ballast, electronic control units and lamps. Nevertheless, the number of individual defects with the components was minimal and was primarily due to improper use and/or poor quality of components. System sizing appeared adequate. Users became cognizant of the limitation of the systems during 'sunless days' and many users learned to manage their loads to maximize use of their solar home systems.

In the last two years, the Burias Island project has became popular with may other island communities and remote upland villages. Many have requested assistance from the OEA to implement a project similar to that on Burias Island. Currently, two other areas have already initiated similar activities with help from the National Electrification Administration (NEA), the agency responsible for implementing rural electrification programmes. The German Agency for Technical Assistance is again collaborating with the NEA in this work.

The OEA has identified an extensive demand for PV systems in the Philippines and is currently planning a programme to bring such facilities to potential users and to achieve significant and widespread use of PV technology throughout the country.

Potential demand for PV systems in the Philippines

The Philippine energy programme involves three government agencies; the OEA, the NEA and the National Power Corporation (NPC). The OEA has the mandate to oversee the overall planning and implementation of the country's energy programme. Under guidance from the OEA, the Non-Conventional Resources Division (NCRD) has been given the task of developing and disseminating the applications of non-conventional energy systems, which include PV systems. The NPC is responsible for electricity generation while the NEA administors the distribution of electricity in rural areas through the organization of rural electricity cooperatives.

The Philippines is an archipelago consisting of more than 7100 islands. Power-generating plants exists only in the 27 largest and most densely populated islands. Even in these islands, however, electricity is not available in areas of low population. The NPC is presently targetting the electrification of a further 60 islands. After this, no conventional energy-based electrification programme has been planned for the remaining 2000 or more populated islands.

Despite the tremendous strides achieved by the NEA in bringing electricity to island rural areas, a large number of households still do not have access to electricity.

Many of these households are in communities located in remote upland villages and isolated coastral areas where population densities are low. The extension of distribution lines to these areas is costly. It is thus estimated that around 47% of the 12 million households in the Philippines do not have access to electricity. These households are located in small islands and in the remote upland villages and difficult-to-access coastal areas of the larger islands.

The use of kerosene lamps is incovenient and may even pose a fire hazard, while use of disposable batteries is expensive for the units have very short lifetimes. Bringing electricity through the grid, or installing small diesel-generator sets, to the presently unelectrified areas promises to be very expensive and difficult to maintain. The use of these systems are generally hampered by unreliable and expensive fuel supplies, lack of technical know-how on maintenance, and scarcity of spare parts. Because of these factors, there is a great demand for small decentralized power systems (ranging from a few watts to several kilowatts) in many remote areas of the country.

The NCRD, for example, has identified around 300 smaller islands having a land area of more than one square kilometre and a population that would constitute a large village. Such areas are, in principle, expensive to electrify with diesel-generator sets because of low population densities (in the range of 300 to 3000 households) and low levels of electricity requirement (e.g., electricity is used only during the night, particularly for household lighting purposes). Photovoltaic systems offer one of the most viable options for bringing electricity to these smaller islands.

Today, there are still around 13 667 villages that are unelectrified. At present prices, it is estimated that connecting individual houses in these villages to the grid may cost up to US$ 660. This is almost equal to the current cost of the cheapest solar home system, estimated at US$ 650.

It is, therefore, unelectrified households located in small island communities, remote upland villages and isolated coastal areas that are the potential users of PV systems, solar home systems and solar-powered battery-charging stations. From extrapolation of data obtained from the Philippine National Statistics Office, it is estimated that there are between 5.5 to 6.0 million households that are potential users of PV systems. Even if only 10% (i.e., estimated percentage of unelectrified households that can pay for solar home systems in cash) is targetted to use PV systems within the next five years, a very sizable market requiring 275 MW of PV panels would emerge. This demand amounts to almost ten times the current world production of PV panels. For battery manufacturers, such a programme would mean increased revenue as at least 1.1 million lead/acid batteries, designed specifically for solar home systems, would be needed (based on the assumption of at least one battery for each PV system).

The Burias Island Electrification Project has provided a model on how to implement a PV rural electrification programme. From the lessons learned from such a model, a nationwide programme is being prepared to introduce PV systems in an affordable manner to many of the country's unelectrified households. For rural households, there appears to be no other option that can provide better and cheaper electricity.

The 'FINESSE' Programme

The Energy Sector Management Assistance Program (ESMAP) of the World Bank is currently assisting the Philippines to conduct a study that will develop schemes wherein financing can be made accessible to small-scale energy users of renewable energy and energy conservation technologies. This study was called 'Financing Energy

Services for Small-Scale Energy Users', or FINESSE. The work recognized the fact that many renewable energy and energy conservation technologies are proving to be more techno-economically viable than conventional energy systems, but that their dissemination is hampered by lack of institutional support, in particular access to financing. The FINESSE study covers not only the Philippines but three other south-east Asian countries, namely, Indonesia, Malaysia and Thailand.

In addition to proposing financing programmes, the FINESSE study also has to recommend additional technical assistance programmes to address other current institutional limitations considered as barriers to the wider use of renewable energy technologies. These barriers include:

(i) lack of familiarity with the technology by potential users;

(ii) subsidized prices of conventional energy systems;

(iii) inadequate in-country distribution network to provide and service energy products;

(iv) inadequate labour and skilled personnel to plan and undertake projects.

The Philippine study is nearing completion and was presented to the World Bank, the Asian Development Bank, and other international financing institutions in October 1991 in Kuala Lumpur, Malaysia. The purpose of this meeting was to solicit financial support from these organizations. Among the renewable energy technologies expected to be covered by a possible FINESSE programme are photovoltaic systems. The study proposes finance for the implementation of the following three types of solar home system:

Type I. For lighting and operation of small radios (requiring one 30 to 36 Wp panel and one 12 V/70 A h battery).

Type II. For lighting and operation of small radios and black-and-white television sets (requiring one 50 to 70 Wp panel and one 12 V/100 A h battery).

Type III. For lighting and operation of small radios, black-and-white TV sets, and refrigerators (requiring six 50 Wp panels and three 12 V/100 A h storage batteries).

The study suggests a five-year commercialization programme that will involve the installation of 250 units of Type I, 690 units of Type II, and 1740 units of Type III. The programme will require only a modest number of lead/acid batteries, namely, 250 units of 12 V/70 A h batteries and 4170 units of 12 V/100 A h batteries. If, however, the programme proves successful, with all the incentives and support essential for the dissemination of this technology in place and with the financing expected to expand, the potential number of users can be very substantial: the upper limit of the market is around 5.4 million households. The number is still sizeable even if it is assumed that only 30% of these households can afford to acquire their own solar home systems.

The programme will follow closely along the lines of the Burias Island PV electrification programme. Rural Electric Cooperatives, under NEA or even private companies, are being identified as distributors of the PV systems. Battery manufacturers, may also adopt this role because they already have a national distribution network that reaches almost all the major towns in the country.

The FINESSE programme also proposes the installation of battery-charging stations in 6000 of the 13 000 unelectrified villages of the country. This is to be achieved within a five-year period. On the average, a village consists of 60 to 100 households.

Funding is also being requested for other remote-area PV applications. These include the supply of power to institutional users such as telecommunications facilities. For the latter, the system size ranges from 1 to 3 kWp (note, a pilot 1.8 kWp system uses 24 2 V/250 A h batteries).

Conclusions

In general, bringing electricity to rural areas is achieved by extending the grid or by installing small petroleum-fuelled generator sets. In most cases, however, such methods are not reliable and are expensive. Experience in the Philippines has shown that one possible option is the application of PV systems. Not only are such systems technically viable, but they are also economically feasible (in the long run), reliable, environmentally-safe and sustainable. A rural PV electrification programme is particularly suitable for countries such as the Philippines where access to remote, but populated, rural areas is difficult.

A PV-based rural electrification programme should receive the same support, incentive and assistance as a conventional energy-based rural electrification programme. If PV systems are allowed to compete with conventional energy systems on an equal footing (i.e., both with/without subsidies), the solar option has the advantage, even if economic parameters alone are used in evaluating and comparing the two systems. As such, a large number of potential users awaits PV systems.

Given that the second most important and expensive component of a PV system is the battery, the widespread use of PV systems will clearly have a very significant impact on the battery industry. As such, the battery industry should maintain a watching brief in this area and, as has happened in the Philippines, should even become involved in the development and promotion of PV systems. In fact, it is commonly argued that the key to the faster dissemination of PV technologies lies not only in the development of more efficient PV panels but also in the commercialization of cheaper, maintenance-free batteries with longer lifetimes for solar energy systems.

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