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DOE/NASA/20485-13
NASA TM-83035

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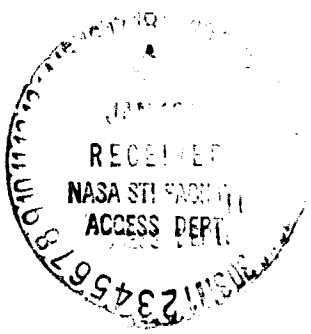

Work performed for
U.S. DEPARTMENT OF ENERGY
Conservation and Renewable Energy
Division of Photovoltaic Energy Systems

Prepared for
Sixteenth Photovoltaic Specialists Conference
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Under Interagency Agreement DE-AI01-79ET20485

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ABSTRACT

The NASA Lewis Research Center manages the Stand-Alone Applications Project for the U.S. DOE. During the 1980-81 program year, that project office sponsored three major studies to determine the worldwide market for stand-alone photovoltaic power systems in three specific segments of the rural sector. The three studies addressed the worldwide market for photovoltaic power systems for village power, cottage industry, and agricultural applications. The objectives of these studies were to:

- Assess the market potential for small stand-alone photovoltaic power system in specific application areas
- Identify technical, social and institutional barriers to PV utilization
- Identify funding sources available to potential users
- Recommend marketing strategies appropriate for each sector to American PV product manufacturers.

The studies were prepared on the basis of data gathered from domestic sources and from field trips to representative countries. This paper summarizes the results of these three studies. Both country-specific and sector-specific results are discussed, and broadly applicable barriers pertinent to international marketing of PV products are presented. Generic recommendations to American PV manufacturers of appropriate strategies for the international market in general are also made.

INTRODUCTION

Very early in the National Photovoltaics Program, it was realized that because of the widespread electrification of the United States and other developed countries, most of the initial market for terrestrial photovoltaic systems would be in the developing regions of the world. Such systems, it was reasoned, were more likely to be cost-competitive with alternative energy sources especially in rural areas. The basis for this thinking was the realization that the real cost of supplying small amounts of power dependably to remote areas is extremely high when one determines true cost for transmission line installation or generator installation, operation and maintenance.

The U.S. Department of Energy sponsored several activities designed to help the establishment of a strong, competitive American photovoltaics industry. One of these activities was to conduct assessments of the market for photovoltaics in several sectors. The responsibility for conduct of

market assessments for small stand-alone (i.e., non-grid connected) photovoltaic systems was assigned to the Stand-Alone Photovoltaic Systems Project Office managed by the NASA Lewis Research Center. In response to this assignment, that office issued contracts to three organizations to study the market for stand-alone photovoltaic systems in three specific rural sectors which were felt to be large potential markets. The markets studied were: (1) the rural village PV power market, (2) the cottage industry PV power market, and (3) the agricultural PV power market. The three organizations who conducted these studies under NASA-Lewis-managed contracts were Motorola, IIT Research Institute and DHR, Inc., respectively. These studies had four major objectives:

- To assess the market for stand-alone photovoltaic power systems in specific application areas
- To identify the technical, social and institutional barriers to widespread photovoltaic utilization
- To identify sources of financing for potential purchasers
- To recommend to American photovoltaic manufacturers strategies appropriate to marketing photovoltaics in the developing world.

These studies resulted in a series of reports (refs. 1 to 8) that were distributed to the American photovoltaics industry over the last 18 months. This paper briefly summarizes the results of these studies.

MARKET STUDY RESULTS

The Market for Photovoltaics for Rural Village Power

The market for photovoltaics in the developing world for remote village power systems was studied by Motorola (ref. 1). For the purposes of the study a remote village was defined to be:

"A grouping of up to 2000 people living in a remote area, but in close enough proximity to interact with each other on a daily basis."

The term remote as used in this definition implies that the village is located such that it cannot be supplied economically with central station utility power.

The methodology employed in this study had two major components: a literature search, and a series of in-country surveys. The literature search gathered pertinent information such as developing countries' rural electrification plans, utility rates and costs of power line extension, and performance and cost data of alternative forms of power generation such as diesel generators. The information gathered was used to determine the key regions and countries for further on-site investigation and to determine the approach to be used in the in-depth in-country surveys. The countries selected for the surveys were also selected so as to provide a representative cross section of the developing world. The criteria for selection included: (1) the country be located in or near the sun belt, (2) the country possess a possibly sizable market potential, and (3) the country

be accessable to U.S. marketers. Additionally, the countries chosen represented both the oil importing and oil exporting nations. The in-country visits accomplished the following objectives:

- o Gathered new data and validated data acquired during literature search
- o Acquainted local officials with present status and future plans of U.S. PV industry
- o Determined potential obstacles or barriers to PV market development
- o Assessed the degree of possible penetration of potential market

A total of 23 countries (table I) was surveyed and over 800 key people were contacted.

Village Power Study Conclusions. - In order to estimate the potential market for photovoltaics in the village power sector, the power requirements for representative remote villages were estimated. It was assumed that an average remote village population would consist of about 500 people living in 100 homes. Table II shows the assumptions made for village electrification. It was estimated that about 10.7 kWp per village would be required. Thus an average of 10 kWp per village was used for calculation purposes.

Based on the approximate number of unelectrified villages identified during the in-country survey, an extrapolation was made for the entire developing world. This extrapolation estimated a total of 2 million unelectrified villages. Multiplying 10 kWp per village by the 2 million unelectrified villages results in a total potential market of 20 000 MWp. This is probably a conservative estimate of the total village power potential, because the potential for replacement of diesel generators already installed in to a large number of villages was not included.

Assuming that the 20 000 MWp estimated potential is relatively accurate, the next question is, "How much of it can actually be achieved?" To answer this requires other important factors pertinent to international PV marketing be considered, such as availability of financing, existence of import restrictions, knowledge of photovoltaics in the developing world, and others. These can be thought of as the barriers to international PV marketing, and tend to be the same regardless whether the market being studied is the village power or the agricultural market. A discussion of these barriers to international PV marketing will be presented later.

When the barriers are considered, the achievable village power market in the near term (i.e., the next 10 years) was estimated to be not more than 5 percent (1 GWp) of the potential market. The primary reason for this somewhat pessimistic estimate is that moving a new technology into a market having limited financial resources and that is somewhat slow to accept new ideas will take time. The first 5 years of the period will be devoted to proving that photovoltaics is truly a viable alternative energy option. The last 5 years will be the beginning of the true commercial market.

However, even at this limited 5 percent market penetration, the 1 GWp real market represents a multi-billion dollar export market and that can provide a substantial portion of a significant production base.

Market for Photovoltaics for Cottage Industry Applications

The market for photovoltaics in the developing world in the cottage industry sector was studied by the IIT Research Institute (ref. 2). For the purposes of this study, cottage industries were defined as "small rural manufacturers, employing less than 50 people, producing consumer and simple products." It was known that stand-alone photovoltaic systems are not cost competitive with grid generated electricity; therefore, the study focused on rural areas of nonindustrialized countries, where commercial power is not available.

The approach employed for this study was to initially establish the existence of a potential market, to examine the economic advantages of a photovoltaic system as compared to alternative means of supplying electric power, to quantify the electric power needs of typical cottage industries, and to identify countries which appeared to represent early market opportunities.

Since data on cottage industries is extremely limited, especially in developing nations, it was necessary to take an in-depth look at the cottage industry sector of specific developing countries to determine how photovoltaics might "fit" in. Four countries were selected for this in-depth analysis -- the Philippines, Mexico, Morocco and Brazil. In-country field investigations were made in the Philippines and Mexico.

After estimating the potential market for cottage industry power systems, the next course of action was to determine the feasibility of attaining that potential or, in other words, to determine the real market for photovoltaic systems. The most significant factors which determine the real market for stand-alone photovoltaic systems in cottage industry applications were determined to be:

- Is the system affordable to the purchaser?
- Does the system demonstrate itself to be the best option for the purchaser over his current power source or the available alternatives?
- Will the system be accepted and utilized by the end-user?

Cottage Industry Study Conclusions. - The potential market is a theoretical estimate of the gross demand for small-scale decentralized sources of electric power for rural cottage industry applications. The underlying assumptions are that the rural producer desires electricity and that the purchaser can afford it. Factors considered in determining the potential market include: rural population, importance of manufacturing and cottage industry to the economy, the number of people engaged in fundamental industries and the power consumption of typical cottage industries. It was

also considered that: some rural industries are electrified or soon to be electrified by a grid network, in some areas hydro or wind power may be more appropriate, and some rural areas will have insufficient solar radiation for effectively utilizing photovoltaics. The remainder of the market is assumed to be the potential market for stand-alone photovoltaic systems, diesel-driven generator sets or gasoline-driven generator sets. Based on these factors, the potential market was found to be 70 000 megawatts.

The amount of this potential market that can be achieved in reality, however, appears to be very small, at least in the near term. The major reasons supporting this conclusion are that cottage industries, in general, are severely capital constrained and are not good candidates for loans or recipients of significant public sector support. Further, for many of the most economically significant cottage industries, the power levels required are high enough that stand-alone photovoltaic systems, at the system cost of $6-$13/Wp assumed in this study, may not be the most economical means of providing decentralized sources of electric power. For example, a barrel making operation was estimated to require a 30 kW photovoltaic system in order to fully electrify the "factory". Under the cost scenarios employed in this study, a diesel generator set was determined to be a better economic choice than photovoltaics in the near term. Only those applications requiring small amounts of electric power, such as lighting and small tools, would be viable. Collectively these applications amount to only a very small fraction of the potential market.

Market for Photovoltaics for Agricultural Applications

The market for photovoltaics in the agricultural sector was studied by DHR, Incorporated (refs. 3 to 8). This study was conducted in a manner similar to the other previously discussed studies. First, a domestic literature search was conducted to characterize the agricultural sector of developing countries and to develop an approach to be used during in-country visits conducted under the second part of the study. Five countries were selected for detailed in-country surveys: Nigeria, Morocco, Colombia, Mexico and the Philippines. These countries were selected on the basis of several factors including: economic importance of agricultural sector, energy situation, extent of electrification, solar resources, and geographic representation.

These surveys included a series of meetings with the country's energy, agriculture, economic, financial, business and policy experts to obtain current agricultural and energy development and policy data and an evaluation of factors important to introducing PV power systems into the agricultural sector. Site visits were made to obtain power requirements and energy use profile data for several agricultural applications. The information gathered provided a data base to characterize the environment in which PV systems would be marketed and used. Data on applications were used to identify cost-competitive end uses by year of competitiveness. An example of the cost-competitiveness end uses for a specific country, Mexico, is shown in table III. Similar end uses were identified for the other four countries in which the surveys were conducted.

The results obtained for the five countries surveyed in-depth were used to prepare a projection for the photovoltaic market in the agricultural sector worldwide. The methodology employed in that projection is detailed

in reference 8 and essentially involved quantifying the photovoltaics market on the basis of the factors which were determined to be the most important based on the in-country case studies: The estimates produced by the methodology, while useful in drawing broad conclusions, should, because of uncertainties in data accuracy, and the influence of nonquantifiable factors such as distrust of new technology, be treated as only first order estimates.

Agricultural Study Conclusions. - The study estimated that the real worldwide agricultural sector market ranges from 14 to 55 MWp between 1981 and 1986. These projections assumed that the DOE 1982 and 1986 cost goals for both modules and systems were achieved. Clearly significant delays in achieving the projected selling costs will cause reductions in the real market. The countries which are projected to account for over 90 percent of the regional market are shown in table IV.

In addition to the quantitative market estimates, the study made several conclusions regarding the technical and economic feasibility of stand-alone photovoltaic systems in the agricultural sector which are noted below.

- In the next 2 to 3 years only small power needs can be economically supplied by PV systems. They include battery charging, small field irrigation and livestock watering from shallow depths, small grinding mills and small produce coolers.

- By about 1985-86, PV applications requiring 4 to 6 kW of power will be economically feasible. The feasible applications expand to include irrigation and livestock watering from deeper wells, larger grinding/milling operations, produce coolers and freezers, and aquicultural uses.

- The relatively maintenance-free operation of PV systems may swing the balance in favor of PV systems and away from diesel and gasoline generators, even if PV power is more expensive, in countries which have poor equipment-servicing facilities.

- Except for livestock watering under open range conditions, the ability of PV systems to operate unattended is not a significant advantage in agriculture.

- In the next 4 to 5 years the ultimate purchaser of larger PV systems (through direct purchases or financing by development banks) in developing countries will be the government. Thus, PV must be shown to be economically feasible when compared to its nearest competitor.

- The private sector may be able to afford (through outright purchases or with commercial bank loans) small power systems since capital investment is much less.

- In countries where farmers are faced with high fuel prices, in 1982 a PV system will be cheaper to operate, on an annual cash flow basis, than a gasoline powered generator of about 1 kW.

- Although only small power needs can be economically served by PV systems in agricultural applications, the market is significant.

Barriers to International Photovoltaics Marketing

All of the studies identified barriers that must be overcome by American photovoltaic product manufacturers before successful international marketing in the developing world can be achieved. These barriers tend to be the same regardless of the application sector. The most significant barriers are summarized below.

- Lack of awareness of PV technology and its applicability is a major barrier to market development. Compounding the awareness problem is the attitude that photovoltaics is an "energy source of the future." This problem pervades all decision-making strata ranging from government officials, financiers, dealers and distributors, and users.

- Other than the oil-exporting nations, most potential customers have limited access to long-term financing. In addition, photovoltaics will most likely take a lower priority in the allocation of government long-term capital financing particularly if other renewable energy sources are judged to be economically superior.

- Many developing nations are establishing government energy policies that stress self-sufficiency. The import of U.S. photovoltaic systems may be viewed as contradictory to that policy.

- Consumer buying behavior in the developing nations is characterized by high discount rates and consequently very fast payoff times on investments. The high initial price of photovoltaic systems will not be appealing to potential purchasers unaccustomed to life-cycle cost decision making.

- Many nations subsidize domestic fuel costs. This has the effect of greatly restricting the market in the private sector when the decision to purchase photovoltaics in contrast to a conventional powered system will be made on a financial basis rather than an economic basis.

- German, French and Japanese photovoltaic companies, through demonstration projects supported by their governments and by aggressive marketing, are establishing a strong presence in many countries worldwide. Furthermore, some countries (e.g., Mexico, Brazil, India) are developing indigenous PV industries.

- The generally poor state of the world economy is severely affecting the ability of developing countries to carry out rural development plans which could have provided sources of financing for many photovoltaic sales. Additionally, many developing countries are imposing import restrictions, many of which may hinder photovoltaics marketing efforts. Also the very strong U.S. dollar relative to many developing countries' currency means increased cost of imported photovoltaic products to consumers.

Recommendations to American PV Manufacturers of Strategies for International Marketing

The three studies summarized in this paper made several strategy recommendations to the U.S. manufacturers who wish to market their products in the developing world to help overcome some of the barriers noted above. These recommendations are summarized below and should be considered generic suggestions to PV manufacturers and dealers based on field work. The actual market strategies employed would depend significantly on the market characteristics of the individual nations concerned.

Advertising/Information Dissemination. - A significant barrier to marketing photovoltaics abroad is the lack of information and awareness on the technical and economic advantages of PV systems. To effectively reach the potential customer and to create demand for PV products, demonstrations may be the single most effective tool. With low literacy rates in developing countries, information is often disseminated by word of mouth based on one person's experience.

Financing and Pricing. - Customer financing of PV purchases may be the most important factor in a developing country PV market. Low per capita income, the lack of available long-term capital in some countries, and the high cost of capital combine to severely restrict the ability of the customer to pay for a high first cost PV system. Some development banks will offer long-term loans at low interest rates but only for cost-effective PV systems. However, the total amount of money available may be small. Focusing marketing efforts on corporations or government agencies that have the money to buy PV systems will solve the financial problem, but the market may be limited.

Another approach in overcoming difficulties is leasing the PV equipment to the customer. Although leasing arrangements are generally not used in developing countries, there are some advantages of leasing that make it an attractive financial alternative. First, leasing a PV system will spread costs over a period of years. Second, leasing programs can be operated by a local distributor who would purchase systems from a U.S. manufacturer and in turn rent systems to users. Thus the user does not have to make a 20 year commitment, the U.S. PV manufacturer sells the PV panels outright, and the dealer realizes a substantial profit. Furthermore, it could be financed by short-term working capital loans which are easier for users to obtain.

Distribution and Service Infrastructure. - Dealers and distributors are an essential and costly component of any successful overseas marketing effort. In the case of photovoltaics, the market to date is too small to support an extensive distribution system within any developing country.

There are, however,a number of ways in which a distribution network could be established: (1) piggyback onto existing pumps, electrical generators, diesel and gasoline engine distributors; (2) establish a new exclusive dealership within a country with a local entrepreneur; and (3)

develop an exclusive distribution system within a country by the PV manufacturer.

Closely tied to the development of a distribution infrastructure is the necessity of offering the customer quick and quality service for all products sold plus maintaining adequate supplies to meet PV demand. As a marketing tool, service availability is exceptionally effective.

Product-Market Fit. - In offering PV systems to the Third World community, the PV manufacturer should initially offer small units that are economically and financially viable as compared to other alternative energy sources. Later as costs drop, the manufacturer may expand product lines to include larger power outputs, offering an entire line. It is critically important that complete systems as opposed to components be offered for sale. For example, a PV-powered pump should be produced for sale rather than a PV power supply for use with an electric pump.

Trade Relationships. - Finally, the PV manufacturer should be flexible in considering the benefits offered by a developing country in terms of tariffs, license, taxes, trade allowances, etc. In a virgin PV market and with possible heavy Japanese and European competition, the early loss of market share to competitors by not taking aggressive advantage of financial, tax and other incentives offered by a developing country may hinder market development later as competitors establish themselves in the marketplace.

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Table I - Countries Surveyed

Africa	Arab and Mideast
Senegal	Jordan
Ivory Coast	Egypt
Nigeria	Sudan
Cameroon	Yemen
Gabon	United Arab Emirates
Togo	Pakistan
Mali	
Tanzania	
Kenya	

Latin America	Southeast Asia
Mexico	Philippines
Brazil	Thailand
Peru	Malaysia
Colombia	Indonesia

Table II - TYPICAL VILLAGE POWER REQUIREMENTS

[Village size: 500 people, 100 homes]

FUNCTION	
Water Pumping	
Liters/person/day	50
Wh/day (5 hr/day)	4700 (1/2 hp)
Lighting - Indoor	
Lights/home	2
Wh/day (4 hr/day)	16 000
Lighting - Outdoor	
Lights/village	5
Wh/day (12 hr/day)	2400
Television	
Sets/village	20
Wh/day (4 hr/day)	1600
Refrigerators	
Refrigerators/village	10
Wh/day	10000
Grain Grinder	
Grain required/person	1 Kg
Wh/day	6000
Communications	
Emergency radio sets/village	1
Wh/day	400
TOTAL kWh/day	41.1
TOTAL kWp Required*	10.7

* - Based on sunlight equivalent of 5 hr of noonday sun.

TABLE III - SUMMARY OF APPLICATION ASSESSMENT FOR MEXICO

Feasible Agricultural Applications	Size, kWp	Year PV Can Compete
Cattle Watering	0.8	1982
Rural Potable Water	1.8	1984
Small Grain Loaders	2.0	1984
OTHER RURAL SECTOR PV APPLICATIONS		
Radio - Telephones	0.3	1982
Lighting	.3	1982
Educational TV and Tape Recorders	.3	1982
Private TV	.3	1982
Refrigerators	.3	1986
Irrigation	7 - 20.0	1986
Ice Making	73.0	1986
Crop Processing	10 - 300.0	1986

TABLE IV - COUNTRIES ACCOUNTING FOR 90 PERCENT OF MARKET IN EACH REGION

Asia and Australia	Europe, North Africa and Middle East
Australia	Egypt
India	Greece
New Zealand	Italy
Pakistan	Portugal
Philippines	Spain
Thailand	Yugoslavia
Sub-Sahara	**Central and South America**
Ghana	Argentina
Kenya	Brazil
Nigeria	Mexico
Mozambique	