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Market Assessment of Photovoltaic Power Systems for Agricultural Applications Worldwide

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A. Cabraal, D. Delasanta, and J. Rosen
DHR, Incorporated

and

J. Nolfi and R. Ulmer
ARD, Incorporated

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

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A. Cabraal, D. Delasanta, and J. Rosen
DHR, Incorporated
Washington, D.C.

and

J. Nolfi and R. Ulmer
ARD, Incorporated
Burlington, Vermont

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PREFACE

This report is last in the series investigating the market for photovoltaic power systems in agricultural applications worldwide. The other reports in the series were:

DOE/NASA/0180-1 CR-165286	Market Assessment of Photovoltaic Power Systems for Agricultural Applications in the Philippines. April 1981.
DOE/NASA/0180-2 CR-165441	Market Assessment of Photovoltaic Power Systems for Agricultural Applications in Nigeria. October 1981.
DOE/NASA/0180-3 CR-165477	Market Assessment of Photovoltaic Power Systems for Agricultural Applications in Mexico. July 1981.
DOE/NASA/0180-4 CR-165511	Market Assessment of Photovoltaic Power Systems for Agricultural Applications in Morocco. August 1981.
DOE/NASA/0180-5 CR-165524	Market Assessment of Photovoltaic Power System for Agricultural Applications in Colombia. November 1981.

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The study was performed for NASA by DHR, Incorporated, 1055 Thomas Jefferson Street, Suite 414, Washington, D.C. 20007, with Associates in Rural Development, Incorporated, 362 Main Street, Burlington, Vermont, 05402 as subcontractor. The project manager for the study was Dr. Anil Cabraal, DHR, Incorporated.

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FOR AGRICULTURAL APPLICATIONS WORLDWIDE

EXECUTIVE SUMMARY

Objectives

The Photovoltaic Stand-alone Applications Project Office at NASA Lewis Research Center in Cleveland, Ohio sponsored a series of studies evaluating the market for PV systems in several countries worldwide. These studies identified and characterized the agricultural sector market for PV in the Philippines, Mexico, Morocco, Nigeria and Colombia. The purpose of this report is to integrate the results and draw conclusions from the country case studies, and to attempt to extrapolate the results to other countries worldwide. This enables identifying and characterizing the critical variables influencing the market for PV in the agricultural sector of a country. This information is used to make strategic recommendations to the US PV industry to assist them in effectively marketing their product overseas.

Approach

The approach employed in this integrated analysis is to use information obtained during the case studies, supplemented by data from the World Bank, United Nations, Solar Energy Research Institute, Department of Energy, Department of Commerce and other published sources to determine:

- Important country characteristics that indicate whether a potential for PV sales for use in the agricultural sector exists
- Important market factors that indicate whether an appropriate marketing environment for selling PV to the agricultural sector exists
- The types of applications for which PV power is technically, economically and financially feasible
- Country-specific PV market size estimates
- Strategies that should aid the U.S. PV industry in effectively marketing systems in high potential countries

Major Conclusions

The following conclusions apply mainly to agricultural sector applications. However, the market-related conclusions encompass applications in all sectors. In general, countries with a high potential for stand-alone PV sales are characterized by having: adequate financing (capital-surplus countries and countries with high farmer income); high fuel prices (even some oil exporting countries have high fuel prices in rural areas); inadequate electrical service in rural areas; government commitment to alternative energy sources; poor engine maintenance facilities, and a large agricultural cash-economy.

This study estimates that the worldwide agricultural sector market potential ranges from 14MWp to 55 MWp between 1981 and 1986. If JPL cost goals cannot be met in the expected timeframe, and costs are exceeded by over 20 percent, the potential agricultural sector market could only be attained in the 1981-88 timeframe. Table 1 shows the countries which account for over 90% of the regional market.

Conclusions regarding technical and economic feasibility of stand-alone PV use in the agricultural sector are:

- In the next 2-3 years only small power needs can be economically supplied by PV. 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 4-6KW of power will be economically feasible. The feasible applications universe expand to include irrigation and livestock watering from deeper wells, larger grinding/milling operations, produce coolers and freezers, and aquacultural uses.
- The relatively maintenance-free operation of PV will swing the balance in favor of PV systems and away from diesel and gasoline generators, even if PV power is more expensive, in countries such as Nigeria which have poor equipment-servicing facilities. The other countries visited had adequate service facilities in the rural areas.
- Except for livestock watering under open range conditions, the ability of PV to operate unattended is not a significant advantage for use in agriculture.
- In the next 4-5 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 both economically and financially feasible when compared to its nearest competitor.
- The private sector may be able to afford (through outright purchases or using commercial bank loans) small power sources since the capital investment is much smaller.
- In countries where farmers are faced with high fuel prices, by 1982 a PV system will be cheaper to operate, on an annual cash flow basis, than a gasoline powered generator of about 1Kw.
- Although only small power needs can be economically served by PV in agricultural applications, the market is significant.
- It is most likely that the demand for PV in agriculture will be overshadowed by the larger market in applications such as rural services, telecommunications, signalling and TV. The market for PV powered TV is expected to be very large in many countries.

TABLE 1

Countries Accounting for 90% 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	

Technical and economic feasibility alone will not assure significant PV systems sales. There are several market-related factors which, in many cases, will be the driving forces influencing the magnitude of PV product sales. The major factors identified during the field visits and in subsequent investigations are:

- Lack of awareness of PV technology and its applicability is a major barrier to market development. Compounding the awareness problem is the attitude that PV is a "energy source of the future." This problem pervades all decision-making strata ranging from government officials, financiers, dealers and distributors, and users. Information dissemination through traditional and non-traditional advertising channels will be important in developing the market.

- Other than the oil-exporting nations, most farmers and agribusiness have limited access to long-term financing. In addition, PV 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. This implies that PV systems may have to be financed by the customer, the PV dealer or PV manufacturer.

- Energy surplus nations that subsidize their energy cost to the consumer will not have prime private sector PV markets. Feasible PV applications will most likely be 1KW or less in size and located in remote areas away from the grid. This increases marketing costs two ways. First, many more systems will have to be sold to justify a marketing position in this type of country. Second, potential buyers in remote locations are difficult to contact and inform, thereby increasing advertising and marketing costs. Sales to the public sector which would evaluate PV applications based on opportunity costs of competing fuels are equally feasible in both energy surplus and energy importing countries.

- Consumer buying behavior in the developing nations is characterized by high discount rates and consequently very fast payoff times on investments. PV's high initial price will not be appealing to small landholders unaccustomed to life-cycle cost decision making.

- German, French and Japanese PV companies, through demonstration projects supported by their governments and by marketing are establishing a strong presence in many countries worldwide. Furthermore, some countries (e.g., Mexico, Brazil, India) are developing indigenous PV industries. Lack of US presence at this nascent stage may preclude US companies' obtaining a significant market share later.

- The state of the conventional power equipment industry will have either a positive or negative effect on PV sales. In a country where PV systems are competitive with gasoline or diesel generators, a well developed conventional power equipment industry will provide the infrastructure with which to market PV. However, where PV is not cost-effective, its other advantages cannot adequately overcome the barriers of a strong conventional power equipment industry.

- Potential PV customers can range from government financed rural development projects, communications agencies, agribusinesses, cottage industries and medium sized landholders. Each market segment has an associated buying behavior and value system that the marketing strategy must reflect. Marketing costs are increased since buyers require complete systems as opposed to PV system components.

Strategic Recommendations

From the field visits, it is clear that American PV manufacturers or dealers of PV systems are developing a virgin market that requires innovative marketing tools and an aggressive market strategy. There are six components of a marketing strategy that are important in developing the international photovoltaic market: advertising and information dissemination; financing and pricing; product distribution; product-market fit; product or service availability, and trade relationships. Each of these components is described in greater detail below. Together they represent a comprehensive approach to marketing PV. The strategies outlined in this report 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 PV abroad is the lack of information and awareness on the technical and economic advantages of PV systems. Potential users of PV systems, government agencies, current diesel and gasoline engine users, etc., do not have a sense of what PV is and how it can be used. Exacerbating the problem is the inadequacy of information-transfer mechanisms in developing countries. Thus, the dissemination of product information in developing countries becomes a complicated and expensive task.

There have been a number of successful agricultural information dissemination programs operating in the developing countries. Most notable among these programs are those promoting the "green revolution" methods of increasing agricultural yields. Although mounting a similar information dissemination program by an individual company is prohibitive in terms of cost and time, an effective alternative may be an industry financed trade association whose objective is to promote PV use overseas. This association, through briefing of important government officials, advertising, demonstration, etc., would increase the general level of knowledge of PV within the country and help promote US manufactured PV systems. At the same time, the association could send back to subscribers both market information and opportunities.

For the individual company, brand name identification will be an important component of any marketing strategy. This association of name and product could be accomplished through dissemination of company literature, advertising and use of information media found within the country. To effectively reach the potential customer and, more importantly, create demand for the company's PV product, demonstrations of PV systems 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; the advantages of providing high profile demonstration units are considerable. First, demonstrations will show farmers the energy and cost saving advantages of PV. Second, demonstrations could disseminate information on where and from whom to buy PV equipment. As a final note, any information dissemination program should account for differences in values, economics and policy within a country. An information program based on an American or European audience may be less effective in a developing country.

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. There are a few solutions to this problem: Some development banks will offer long-term loans at low interest rates but only to 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 financing 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 PV system costs over a period of years. Second, leasing programs can be operated by a local distributor who would purchase panels from a US manufacturer and in turn rent the panels to farmers in the area. Thus the farmer does not have to make a 20 year commitment, the US 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. Not only are farmers more familiar with obtaining working capital loans, the amount of funds available is also much greater than long-term loan funds.

Pricing PV units is a complex task since PV is fundamentally different technically and economically from other energy alternatives such as gasoline and diesel generators. Additionally, many consumers in developing countries do not evaluate purchases on a life-cycle basis but instead opt for first costs or payback period in making investment decisions. Competition with other PV firms, as well as conventional energy prices, also figures into any pricing decision.

Obviously, the final decision on pricing will be based on conditions prevailing within a country at a particular time. It should be noted that one important component of price—dealer margins—could have a significant effect on a firm's competitiveness. Considering the high capital cost of PV, and because most dealers may carry PV systems as a secondary portion of their business, percentage dealer margins should be minimized.

Product Distribution

Dealers and distributors are an essential and costly component of any successful overseas marketing effort. In the case of PV, the market to date is too small to support an extensive distribution system within any developing country. For an individual company it is clearly out of the question. This does not imply, however, that a PV manufacturer should not try to develop an elementary distribution network within a country.

There are 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.

Of these three options, a piggyback option may be the most advantageous. The advantage of using existing systems are twofold. First, the costs of marketing the PV product would be greatly reduced by having the distribution infrastructure already in place. Second, the existing distribution network has a working knowledge of the marketplace. As a disadvantage, PV systems will be sold as a source of secondary income and may not be given priority by the sales people.

Options Two and Three have the major disadvantages in that they will be expensive to develop and initially less effective in reaching a large proportion of the marketplace population. However, the advantages are that the PV product will receive full attention of the sales people, and a dedicated distribution system to PV will begin. Option Two has an additional advantage over Option Three in that a local entrepreneur would bring to the venture knowledge about the marketplace. It should be mentioned that many countries do not allow foreign firms to participate in retail sales; however, most nations do allow foreign companies to participate in wholesale trade.

Product-Market Fit

In offering PV systems to the agricultural 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 should expand product lines to include larger power outputs. Offering an entire range of PV systems from the small to the large may be expensive both in terms of development and inventory. As a rule, PV will compete only in those markets in which it has a comparative advantage over other energy sources. 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.

There is also a tendency among new companies marketing new products to fit the customer behavior to the product. In developing countries there is less likelihood that traditional agricultural practices could be altered to fit the unique characteristics of PV systems. In marketing PV, the systems offered for sale should correspond to farming practice currently in use. As an example, consider the problems of selling a PV powered produce cooler to farmers unaccustomed to refrigerating vegetables: not only does the PV unit have to be sold to the farmer but also the produce cooler. This task would be made simpler if farmers are currently using these systems.

Product and Service Availability

Closely tied to the development of a distribution infrastructure are the problems 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. As an anecdote, after World War II an American manufacturer of diesel engines offered to service any large diesel sold anywhere in the Philippines. The goodwill (and surprise on seeing an American engineer so far from home) to this day has helped this company maintain its market there and become a household name in the Philippines. To generate similar goodwill, the American PV companies should try to offer a complete range of quick maintenance and repair services to all potential customers. Although costly, such service will generate a positive image of the PV industry as a whole and of a company in particular. The same can be said of having a ready supply of PV systems so customers do not have to wait for PV systems to be imported (often a process that takes months).

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 many cases, a manufacturer will forego some incentives offered by developing countries in order to maintain an equity position, protect a patent, 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 prevent significant market development later as competitors establish themselves in the marketplace.

MARKET ASSESSMENTS OF PHOTOVOLTAIC POWER SYSTEMS

FOR AGRICULTURAL APPLICATIONS WORLDWIDE

1.0 INTRODUCTION

1.1 Background

The United States National Photovoltaic (PV) Program was established by the U.S. Department of Energy (U.S. DOE) to advance PV power systems to the stage where they can contribute significantly to the U.S. energy requirements by the end of this decade. Ongoing research and development are directed at achieving major system cost reductions and field experience with PV power systems. The project is managed by the U.S. DOE and consists of several project offices, one of which is the Photovoltaic Stand-Alone Applications Project Office at NASA Lewis Research Center, Cleveland, Ohio. This project office has conducted international market assessments to ascertain whether stand-alone PV power systems can provide useful and economically productive power for various applications in developing countries during the next several years. This report is the last in the series of reports evaluating the potential for PV systems in agricultural applications. The other reports discussed the market for PV in the agricultural sectors of the Philippines, Mexico, Morocco, Nigeria and Colombia.

1.2 Objectives

This report integrates the results and draws conclusions from the country case studies and attempts to extrapolate the results to other countries worldwide. The principal purposes are:

(1) to identify and characterize the market for PV in the agricultural sector of a country, and

(2) to make strategic recommendations to the U.S. PV industry to help them effectively market their product overseas.

The purpose of the case studies was to identify applications with high PV sales potential in each case study country so that photovoltaic suppliers and distributors could develop appropriate marketing strategies. The market analysis provides the following essential information for each country.

- Level of interest, awareness and experience with PV power systems.
- Estimate of potential market size for PV power applications in the agriculture sector.

- Operating and cost characteristics of gasoline and diesel power systems that will compete with PV.
- Energy, agriculture and development goals, programs and policies which will influence PV sales.
- Appropriate financing mechanisms and capital available for PV system purchases.
- Investment climate for U.S. companies and appropriate methods for conducting business in the country.

The type of potential photovoltaic applications considered in this study are those requiring less than 15KW of power and operate in a stand-alone configuration without back-up power. These applications include: irrigation, rural water supply, post-harvest operations, food and fiber processing and storage, and livestock operations. An assessment of the market in the 1981-1986 is of most interest since after that, grid connected PV will become competitive and markets much greater than the market for stand-alone systems will emerge.

After the visit to the Philippines it also became apparent that non-agricultural applications may represent a significant PV market potential. Some of these are rural services, remote microwave and TV repeater stations and rural signalling applications. An attempt was made to gather information on such applications during the visits.

1.3 Approach

The approach used in this integrated analysis is to carefully evaluate the results obtained from the case studies to determine:

- Important country characteristics that indicate whether a potential for PV sales for use in the agricultural sector exists. These include: size and type of agricultural activity; dependence on imported petroleum, extent of rural electrification; level of solar insolation; financial capability of the farmer and the public sector; and extent of U.S. trade.

- Important market factors that indicate whether an appropriate marketing environment for selling PV to the agricultural sector exists. These include: availability of financing; energy prices in rural areas; energy and agriculture policy; attitudes, perception and PV information availability; business environmment; institutional factors and competition.

- The types of applications for which PV power is technically, economically and financially feasible.

The case study approach yielded detailed market data suitable for developing marketing strategies for the five countries visited. In examining other nations, case-study results are extrapolated to obtain PV market estimates in agricultural applications. It should be emphasized that the latter market estimates represent only orders-of-magnitude and should be treated as such. While they are adequate for indicating which countries are most favorable, a more in-depth market study must be conducted before attempting to penetrate that market. Additional data sources used include: the World Bank, United Nations, Solar Energy Research Institute, Department of Energy and Department of Commerce. Finally, based on the conclusions drawn from the analysis, strategic recommendations are made. These should be useul to the U.S. PV industry in developing appropriate marketing strategies.

1.4 Report Organization

Chapter 2 looks at the technical characteristics of selected PV agricultural applications, and examines the cost-competitiveness of PV in each. In Chapter 3, the analysis is extended to include market-related factors which can influence PV sales. Chapter 4 combines the learning from the previous chapters to present order-of-magnitude estimates of the market for remote stand-alone PV systems in agricultural applications worldwide. Finally, in Chapter 5, general conclusions are drawn for marketing PV worldwide. Included among these conclusions are strategic recommendations that U.S. companies will find useful in selecting countries in which to market PV systems and in actually setting up operations for selling their products.

2.0 COMPARATIVE ANALYSIS OF POTENTIAL PV APPLICATIONS IN THE CASE STUDY COUNTRIES

The purpose of this chapter is to conduct a comparative analysis of applications that were found to be technically and economically feasible in the case study countries. This information is then used to draw general conclusions applicable to other countries worldwide. The results would be useful to PV firms in selecting their products mix based on applications found to be technically and economically feasible.

The primary hypothesis behind the selection of potential stand-alone PV applications was that the fastest market penetration would take place in applications that do not have access to the electricity grid, where (1) commercial energy (diesel, gasoline) is currently in use; or (2) the government development plans expect a significant increase in the use of commercial energy for the applications in the near future. This is based on the rationale that farmers currently using mechanized power would be in a better position than a subsistence farmer to evaluate the relative benefits of PV systems and have access to greater financial resources. Furthermore, the social, cultural, and skill characteristics of farmers that had led them previously to become innovators and acceptors of new technologies will be applicable to photovoltaic systems.

During visits to the countries, a number of agricultural applications that could use PV power systems were identified. This identification was based on three major criteria:

- Potential Market Size
  - level of production, its importance in the country
  - extent of the use of an operation for production
  - extent of the current level of mechanization of the operation
  - remoteness from the grid in the 1981-86 timeframe.
- Technical Feasibility
  - load characteristics
  - energy demand profile
  - operating environment
- Economic Feasibility
  - PV system cost reduction expectations
  - cost of using diesel or gasoline alternatives for the same application

Based on the above criteria, a wide variety of agricultural applications were examined in each country. The power requirements ranged from 20W to about 12KW and operated in a stand-alone mode. They currently use batteries, diesel, or gasoline engines/generators.

After the pilot visit to the Philippines it became apparent that market potential for PV would be substantially greater in other remote applications such as telecommunications, potable water supply, radio and TV receivers, signalling and cathodic protection. Although these applications are not strictly speaking agricultural, during visits to the other countries, the above applications were also evaluated because they contribute to overall rural development. However, the focus of the study remained the agricultural sector.

The following sections describe the technical characteristics of selected applications; the cost competitiveness of PV systems in each application; other applications which represent a potentially large market for PV; and finally generalized conclusions extendable to other countries are made.

2.1 Technical Characteristics of Agricultural Applications

Table 2.1 compares the technical characteristics of several agricultural applications evaluated during the visits. The selection was based on the technical and market size criteria mentioned previously. Economic feasibility of the applications will be evaluated in the next section. Emphasis was placed on applications that require a year-round, reasonably steady source of energy. The following generic applications where PV power could be appropriate were evaluated:

- rechargeable batteries (lead-acid) are a common feature in remote areas of most countries. Cost of battery charging could be as high as $4/battery (Nigeria) or $3-4/battery (Morocco). Furthermore, transport of batteries into electrified towns or villages for recharging is inconvenient, entails significant costs, and the chance of battery damage is high. Equipment power requirements could range from 20-400W each.
- Outposts such as forestry stations, maintenance yards on large estates, or veternary centers require power for lights, water supply, transceivers, and refrigerators. The need for small amounts of power year-round makes it a feasible PV application. Typical power requirements are about 1-2KW.
- Grinding, milling or shelling operations are conducted in small villages or towns. Power requirements range from 2-12KW. The smaller machines are generally gasoline powered and the large are driven diesel engines. Usually, there is a need for power year-round with peaks occuring after harvest.
- Power requirements for livestock watering are determined by herd size, environmental conditions and pumping depth. Often diesel and gasoline pumpsets operate at around 50 percent of rated capacity due to the need for high starting power. PV powered electric pumps are well suited for livestock watering for the following reasons:

Table 2.1

COMPARISON OF CHARACTERISTICS OF SELECTED AGRICULTURAL APPLICATIONS

GENERIC APPLICATION	PHILIPPINES	MEXICO	NIGERIA	MOROCCO	COLOMBIA
Battery Charging	Audio-visual uses, transceivers, 20W to 400W* used 1-2 hours/day year round, charging requires transportaton to town at present, or a 400W gasoline generator are needed.	Projectors for agricultural extension agents use 400W gas generator, used 2 hrs./day. Agents always depart from stations in electrified locations.	Audio-visual equipment drawing 100W for 1-2 hours/day for use by agric. extension agents	Only non-agricultural applications	Limited Applications
Power Supply for remote locations	Forestry stations, maintenance yards (lights, water, supply, transceivers, refrigerator) 1-2KW gas generators used to 2 to 5 hours/day year-round.	Limited Applications	Veterinary units (refrigerators, freezers, water, lights) 800-1000W gasoline generators used year-round.	Limited Applications	Domestic uses (lights radio, water pumping) Rural health posts (lights, radio, water refrigerator, sterilizer) 1-3KW gas. generators used, 2-8kwh/day required.
Grinding/ Milling/ Shelling	2-11 KW diesel used 2-14 hours/day year round, although significant seasonal variation are present; corn grinding and rice milling are major uses	5-10 KW gasoline maize shellers used 6-8 hours per day during September to November only. 2-3KW gasoline maize mills used 2-3 hrs./day.	1.5 - 2KW gasoline grain grinders used 8-10 hours/day. May have to be movable from market to market. Year-round use.	9-12 KW diesel powered grain mills used 7-12 hours per day.	Mills (2KW) located in central Andean region fed by grid. Coffee depulping, 1-2KW gasoline and electric motors used.
Livestock Watering	Limited Applications	4.5-6 KW diesel pumps 5 hours/day at an average total dynamic head (TDH) of 55m (10-150m) range. Adequate for 300 herd of cattle.	Village and livestock water supply. 1.5-3KW of gas/diesel power for an average total dynamic heat of 10-15m. Pumped to 10-18 cubic meter tanks.	5-6KW diesel pumps - ground water depths 50-75m. 16 cubic meters of water required per day	Llanos region uses windmills or diesel pumps. Watering points for 300-400 head of cattle needed.
Irrigation	4-7.5 KW gas/diesel pumps - 4" diameter suction and 10-20 m TDH. Used mainly for rice. Average area = 6-8ha.	9-13KW diesel pumps - ground water depths 20-60 m. Used mainly for grains, fodder, fruits and vegetables. Average area = 4ha.	Manually watered at 20-30 liters per min. Used on 2-5 ha of fruits and vegetables. Required 7-8 months of the year.	5-6 KW diesel pumps-ground water depths 10-40m (15m average). Used for vegetables, fruits and forage crops. Area = 2-10ha	Most crops draw water from wells over 100m deep and requires 75KW pumps. Small fields, less than 10ha require 2-3KW gasoline pumps for 0.2-2 hrs/day during dry season.
Grain Handling	Limited Applications	2.2KW gasoline engine used 4-6 hours/day. Due to breakdown these are often replaced by 5 workers.	Limited Applications	Limited Applications	Limited Applications

*Power rating of equipment.

Table 2.1

COMPARISON OF CHARACTERISTICS OF SELECTED AGRICULTURAL APPLICATIONS
(Continued)

GENERIC APPLICATION	PHILIPPINES	MEXICO	NIGERIA	MOROCCO	COLOMBIA
Aquaculture	Hatcheries (lights, pumps, aerators) 1 KW gasoline generator used on average 18 hours/day year-round. Fish Farms (pumps) - 4 high volume low head, 7KW diesel pumps Average pond size - 20 ha Used 5 hours/day, 3 days/week and 2 hours/day additional during dry season.	Hatcheries - Located on grid. Fish and Shrimp culture does not require pumping and does not have any other power needs.	Great interest in developing inland fisheries. Power required for hatcheries and aerction.	Limited application	No applications were identified.
Salt Ponds Water Pumping	8-11KW diesel pumps 5 hours/day, year-round. Salt in dry season. Fish in rainy season. Pumps are low head high vol. - 6"-10" suction.	No applications were identified.	No applications were identified.	No applications were identified.	No applications were identified.
Ice Manufacture	11 KW diesel producing 1.5 mt of ice. Operates 24 hours/day, year-round.	Limited application.	5 KW ice plants producing 500-1000 kg ice/day for use by fishermen. Needed throughout the year.	Storage of fish in ice is not a common practice, although losses are high.	Limited application.
Produce Cooling/Drying/Refrigeration	Rice dryers using 1.5KW gasoline powered fan and rice-hull furnace. Used after harvest 4-8 days/ha/yr.	Butane refrigeration for food, drink, medicines etc. Requires 1kg/day of butane. Produce coolers L'mited application.	1-2KW gasoline powered fans for dryers for grain drying. Used 4-10 hours/day, 9 months of the year. Cooler Cooler (fruits, vegetables) 12-15 cubic meters cooler using 1-5KW gasoline engines. Used all year.	Butane refrigerators for storage of food and medicines are found in many rural locations.	Limited application
Power for Piggeries/ Poultry/Dairy	Piggeries 3KW power throughout the year - many located near grid or are attempting to use biogas electric generators.	Limited application - Dairy (260 animals) - 13 KW of power for pumps, refrigerators, bottling plants, etc. Located on grid. Poultry (5000 birds) 1.2 KW power. Located on grid. Pigs(40 sows) - 2.9KW for lighting heating and water. Located on grid.	Limited application	Limited application	Limited application

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- both water requirements and pump output increase with increasing insolation;
- no batteries are needed;
- an oversized motor is not needed since electric motors have better starting torque characteristics;
- does not have the maintenance and refueling problem associated with gasoline or diesel pumpsets located at remote waterpoints.

- PV power for irrigation has the same advantage as for livestock watering. However, there are disadvantages that make it less desirable for irrigation than for livestock watering.
  - much higher water requirements, necessitating larger PV arrays;
  - with a single crop per year irrigation supplements rainfall and power is required only 3-4 months of the year;
  - even with multi-cropping, powered irrigation is not needed year-round.
  - when water supply is from a central reservoir, water management practices could result in timing and length of water release to not coincide with the peak operating period of the PV pump.

  Thus, gasoline and diesel pumpsets offer operating flexibility that PV pumps do not have. However, a cost analysis, even under these disadvantageous conditions, may show PV powered irrigation to be cost-competitive with other alternatives. This issue is discussed in the next section.

- Grain movement using augers or elevators are used in many countries. However, opportunities for PV powered grain lifting equipment were evident only in Mexico.
- Hatcheries for the production of fish and shrimp have to be located near a suitable water supply. In the case of the Philippines most hatcheries do not have convenient access to the grid. However, in Mexico, almost all hatcheries have access to the grid. A reliable power source is essential.
- Small diesel or electric ice plants producing 0.5-1.5 MT/day of ice are being considered for use in fishing villages. Since the plants operate 24 hours/day, an equivalent PV powered unit would require a very large array and large number of batteries. Power system reliability is important but not as critical as in hatcheries.
- It is unlikely that grain-dryers would receive electricity from a fully dedicated PV array since it would only be needed after harvest. The most likely configuration would be grain dryers used in conjunction with a PV pump.
- Small refrigerators are likely to have greater use for rural households than for agricultural uses. Power is required year-round.
- PV powered produce coolers, particularly if crops are in limited production due to lack of storage or if losses are large, could have a significant demand. Power requirements for 12-50 cubic meter walk-in coolers range from 0.75-1.1KW. In many temperate and all tropical countries, power would be required year round.

2.2 Economic Analysis of Photovoltaic Applications in Agriculture

Technical feasibility alone will not ensure widespread use of PV systems in agriculture. They must also be less costly to operate than its competition. A variety of measures are used to compare the costs of two systems providing the same service. They include comparisons between: first costs, years to positive cash flow, annual cost, payback period and net present value life cycle costs. The first and second methods are often the methods employed by farmers and other entrepreneurs in a financially less sophisticated environment. In evaluating the competitiveness of PV systems vis-a-vis alternative power sources, net present value life cycle cost methodology is an appropriate method to be used. This method takes into account the stream of costs emanating from each investment and calculates the total cost of each investment through the life of the system. If financing for PV systems is from public sources, economic as well as a financial analysis may be needed. This is especially true if the governments receive funds from donors such as the World Bank, Asian Development Bank or the Inter-American Development Bank. These banks require loans to be evaluated in terms of their economic benefits to the nation (as opposed to evaluation based on the financial rewards to an individual). Briefly an economic analysis attempts to value the contributions made by a project to the country's basic socioeconomic objectives. In practice, an economic analysis involves the use of prices for goods and services that are free from marketplace distortions and reflect the real, economic value of a good. For example, the price of gasoline in the Philippines is $1.18 at the refinery outlet, but cost to the consumer is $2.42. The former price would be used in an economic analysis. A financial analysis, on the other hand, would use the cost to a consumer ($2.42/gallon). To a businessman, a financial analysis would be more appropriate. However, to a development planner an economic analysis would be more important.

Since PV systems are highly capital intensive and since most long-term loans emanate from development banks, PV systems require using an economic life cycle cost analysis. Financial life-cycle costing must also be conducted since, even if an investment is beneficial from a national perspective, very few individuals would invest in it unless it was personally profitable.

2.2.1 Cost Parameters Used in the Case Study Countries

Evaluating the competitiveness of PV systems was based on its cost in comparison to that of gasoline or diesel generators. The reason for the comparison was that if a farmer or a government agency is considering investing in PV, they must be shown that it is cheaper than familiar alternatives such as gasoline and diesel generators. Accepted life cycle costing principles were used to compare the costs of PV systems to its competitors in this study.

For cost comparisons of PV systems to alternatives the data include power and energy requirements, costs and characteristics of gasoline and diesel generators, cost of fuel, PV system costs, operation and maintenance costs, etc. The data were used to calculate the net present value life cycle costs of PV and the conventional alternative systems. Cost parameters used in the analysis is shown in Table 2.2. PV systems costs were based on JPL cost projection (Table 2.3). Life cycle cost computations were conducted for various years of installation to determine the year in which PV system costs become less than or equal to its competitors costs.

Since cost-competitiveness is critically important to market penetration, first year of cost-competitiveness information was used to calculate size of the PV market in each application for each country.

2.2.2 Cost Comparisons

Table 2.4 shows the peak power requirements and first year of cost-competitiveness for the applications shown in Table 2.1. In general, only applications requiring less than about 6KWp, are competitive with conventional power sources prior to 1986. There is however, significant differences between countries. This variability between countries is due to many reasons including:

- energy usage profile, and typical power needs
- fuel prices
- O&M costs for conventional power systems

For example, a reason for unfavorable conditions in Morocco is the large power requirements for agricultural uses. In Nigeria, due to poor engine maintenance facilities and high fuel prices in rural areas, PV systems become cost-competitive much sooner than in other countries. In the case of the Philippines, a financial analysis makes a PV system cost-competitive about 3-5 years earlier than an economic analysis. Thus, the private sector in the Philippines may be more inclined to invest in PV systems sooner than the government if financing was available. In the case of Mexico, the reverse is true.

TABLE 2.2

Parameters Used in the Economic Cost Comparisons

PARAMETER	PHILIPPINES	MEXICO	NIGERIA	MOROCCO	COLOMBIA
Discount Rate (%)	12	15	9-12	15	12
Analysis Life (years)	15	20	20	20	20
Fuel Cost - Gasoline ($/gallon) Diesel	1.18 1.18	0.46-2.38 0.16-1.15	1.15-2.15 0.90-1.90	3.10 1.65	0.88-2.25 0.70-1.75
Real Fuel Cost Escalation %	3	3	3	3	5
Life of Conventional System (years)	2-6	5-10	1-3	8-10	5-10
Labor Cost ($/hour)	1	0.625	2-4	1.25	2.00-3.00
Battery Life (years)	5	5	5	5	5

NOTE: The parameters used are representative of values typically used in each country for economic lifecycle cost analyses. Discount rates are given in real terms after factoring out inflation. Fuel prices in the Philippines are those at the refinery. In Mexico, the lower price is the subsidized price to the consumer; the higher price is the opportunity cost of fuel used in the economics analysis. In Nigeria and Colombia, the lower price reflects official fuel price and the higher ones are typical in remote areas. Labor costs assume that skilled labor located in a town would have to go to a site for major O&M work. Routine maintenance is done by farmers. Analysis life is only 15 years in the Philippines since bankers felt 20 years loans were not feasible.

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Table 2.3

Photovoltaic System Cost Assumptions (1980 dollars)

	1980	1982	1984	1986
PV system without batteries * ($/$W_p$)	17.17	8.05	5.96	3.87
Battery Costs ($/amp-hr)	1	1	1	1

* Source: JPL, "1980 Photovoltaic Systems Development Program Summary Document", Pasadena, California

TABLE 2.4

PEAK POWER REQUIREMENTS AND FIRST YEAR OF COST-COMPETITIVENESS OF SELECTED AGRICULTURAL APPLICATION

APPLICATION	PHILIPPINES		MEXICO		NIGERIA		MOROCCO		COLOMBIA	
	KWp	Year	KWp	Year	KWp	Year	KWp	Year	KWp	Year
Battery Charging	0.01-0.08	1980-81[a]	0.02	1980	0.06	1980[b]	-	-	-	-
Remote Power Supply	0.7-1.8	1981-86	-	-	2	1981-82	-	-	1.2-1.75	1982-83
Shelling/Grinding/Milling	1-40	1983-86+	3	1986+	2	1983-84[b]	10	1986+	0.48-0.68	1981-83
Livestock Watering	-	-	1.8	1982-84	6	1982-83	1	1985	0.34	1982
Irrigation	1.7-10	1984-86+	7	1986+	2.6	1982-84	3.3	1986+	Included in Remote Power Supply	
Grain Handling	-	-	2	1982	-	-	-	-	-	-
Aquaculture	5-15	1981-86	-	-	-	-	-	-	-	-
Salt Ponds Water Pumping	7	1984-86	-	-	-	-	-	-	-	-
Ice Manufacture	73	1986+	-	-	26	1986+[b]	-	-	-	-
Produce cooling/Drying/Refrigerating	-	1996+[c]	0.3	1986+	2-3.7	1981-82	0.6	1986	-	-
Power for Piggeries/Poultry/Dairy	-	-	-	-	-	-	-	-	-	-

a/ For the Philippines first year based on financial analysis and second on an economic analysis.

b/ Based on analysis of similarly powered equipment.

c/ Used in connection with irrigation only.

Other factors such as reliability, need for remote unattended operation, etc. were taken in account in the market penetration analyses for each country. These factors in some instances made PV more suitable than its alternative even though PV costs were higher.

Small power applications that are currently cost-effective are often within the purchasing ability of farmers. However, most farmers do not base decisions on a 20-year life cycle analysis. They are more inclined to base their decisions on an annual cash flow basis. Thus if a PV system is less expensive to operate than a conventional generator they would be interested in investing in PV. Table 2.5 shows a cash flow analysis example for Mexico, Philippines and Morocco. It shows the cost to an individual operating a 1KW gasoline generator to provide power 4 hours/day year-round. In Mexico, the gasoline generator costs are half that of the PV system. The major reason being the low cost of fuel. In the Philippines and Morocco, with fuel costs accounting for over 60% of total costs, the PV system is cheaper to operate. In the latter two countries not only is PV cheaper on a life-cycle cost basis, it requires a lower annual outlay of cash.

Note that the example assumed a steady energy demand of 4KWh/day, 365 days/year. If energy is required only intermittently throughout the year, then PV electricity may be more expensive than power from a gasoline generator. The conditions in Morocco and the Philippines are similar to those found in most low- and middle-income countries. Thus, this cash flow analysis result would be valid in many other countries worldwide.

In order to generalize the economic cost-competitiveness analysis conducted for each country, a sensitivity analysies was conducted to determine the relationship between the first year of cost-competitiveness, power requirements and insolation. The results are shown in Figure 2.1. The figure shows that prior to 1986 only PV systems less than 4KW in size are cheaper than gasoline and diesel generators on an economic life-cycle cost basis. This is true in most countries around the world, particularly those within 30 degrees south and 30 degrees north latitudes. As Table 2.6 shows this encompasses almost all developing countries in the world. The results were insensitive to a change in operating hours from 4 to 6 hours/day. The type of applications within a 4KW PV system size bound include: battery charging, transceivers, livestock watering, irrigation of small fields, small grinding/milling installations, produce coolers up to about $50m^3$ in capacity.

Table 2.5

Financial Analysis Example (1KW Generator)

1982 Average Annual Cost ($/Year)#

	Gasoline Generator	Percent Fuel Cost	PV
Mexico	1100	23	2200
Philippine	2250	62	2200
Morocco	2600	67	2200

#Includes loan and principal repayment, cost of fuel, and operation and maintenance costs.

Assumptions:

- o 23.2% interest rate*, 10% inflation, 13% fuel cost escalation*, $2/hour labor cost, 5 year life of gasoline engine, $9.74/Wp array cost in 1982 (1982 array cost in 1982 dollars), 20 year array life, $1/amp hr. storage, 3 days storage, 5 year battery life; 4Kwh/day demand, 0.3 gallon/hour gasoline consumption, gasoline cost-$0.46/gallon in Mexico, $2.50/gallon in the Philippines and $3.10/gallon in Morocco, generator costs $525.

*NOTE: Interest rate of 23.2% is equivalent to real interest rate of 12% when inflation of 10% is incorporated into it and 13% fuel escalation is equivalent to a real escalation rate of 3%. The above analysis does not incorporate taxes, depreciation, investment tax credits, etc., a later analysis (Chapter 5) gives a comparison of PV and gasoline systems taking into account the above mentioned factors.

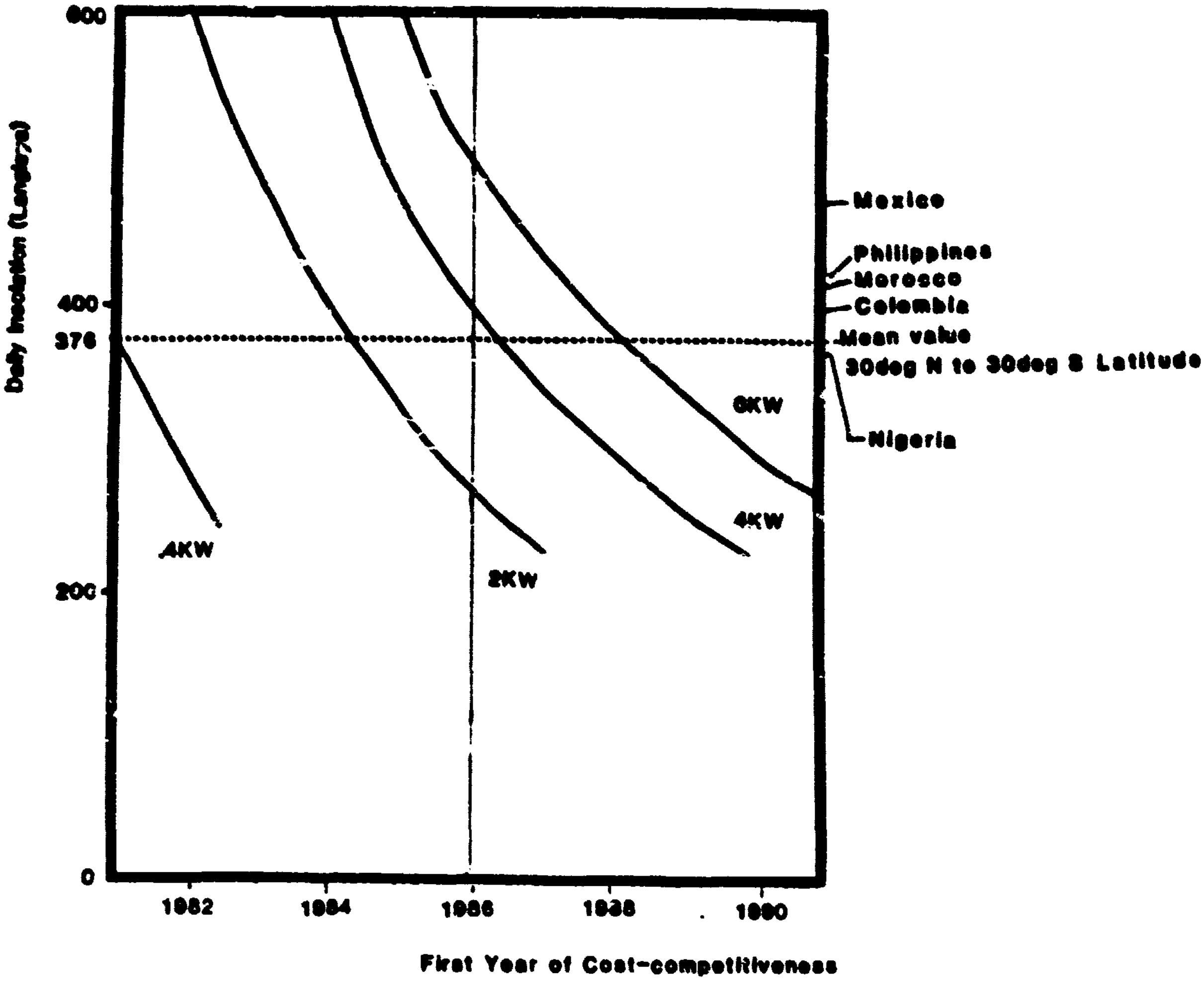

Figure 2.1

Relationship Between First Year of Cost-Competitiveness, Insolation and Power Requirements

Assumptions Used in Economic Analysis:

12% discount rate, 3% fuel escalation rate, 20 year array life, 5 year battery life, $1/amp-hour battery costs, 5 days storage, power required everyday for 4-6 hours/day, $2/day labor cost, JPL PV array cost projections, $1.15/gallon fuel costs in 1980, engine costs varying from $400 for 0.4 KW generator to $5000 for 6KW generator, life of engines vary 3000-5000 hours, gas/diesel O&M costs $0.25-0.40/hour of operation, fuel consumption 0.13-0.64 gallons/hour, all costs measured in real terms after discounting out inflation, all measurements in 1980 dollars.

Table 2.6

Countries and Regions with Significant Land Area

Outside 30°N and 30°S Latitude

Afghanistan	Japan
Argentina	Korea
Canada	New Zealand
Chile	Peoples Republic of China
China	Syria
Europe	Tunisia
Iran	Turkey
Iraq	United States
Israel	Uruguay

The above analysis was based on continuous need for energy throughout the year. If, however, energy is not required for an extended period of time (greater than the battery storage capacity) the electricity generated by the array has to be dissipated. Thus the cost per kilowatt-hour increases. A sensitivity analysis showed that if the array is unused for two months, the year of cost-competitiveness would be delayed by about one year. A three month period of no use would delay year of cost-competitiveness by two years. It should be borne in mind that Figure 2.1 was based on JPL PV array cost projections. Since attaining these goals are somewhat uncertain, a sensitivity analysis was conducted to determine the effect of increased array costs on cost-competitiveness of PV. A 10 percent cost increase did not delay year of cost-competitiveness. However, a 20 percent cost increase delayed year of cost-competitiveness by one to two years. This in effect reduces the size of the PV market that can be penetrated in the 1981-86. However, the total market size could be attained in a longer timeframe, such as 1981-88.

In conclusion, the case study and the generalized analysis showed that PV systems were more economical than conventional power sources for a variety of applications requiring less than 4-6 KW of power. In addition, in 1982, on an annual cash flow basis, PV systems were cheaper to operate than a 1KW gasoline generator in several of the case study countries.

2.3 Other Applications

After the pilot visit to the Philippines, it was decided that teams visiting the other countries would observe and investigate opportunities for PV in non-agricultural applications. However, the non-agricultural applications data collection and analysis effort would not be as in-depth as the agricultural sector applications. Table 2.7 shows the non-agricultural PV applications identified in Mexico, Morocco, Nigeria and Colombia. The types of applications in general have the following characteristics: low-power needs (mainly less than 1KW, but up to about 5KW), year-round energy demand, remote locations (7-10 Km from gird and poor access roads) and require high reliability.

2.4 Conclusions

The technical and economic evaluation of PV use in the agricultural sectors of the five countries found that:

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

Table 2.7
OTHER APPLICATIONS

APPLICATION	COMMENTS
MEXICO	
Rural potable water supply	4-22 KW pumps being considered. 95% in electrified areas. For 5 KW system PV will be competitive with diesel power by 1983.
Rural radio-telephones	Pilot PV project on-going.
Tape-recorders for schools	A project to introduce 4.5W_p battery chargers to 200 schools has been initiated.
TV	There should be a large demand for PV-TV. Current battery recharging costs are as high as $3-4/battery.
Telecommunication, signalling and measurement	Power for all types of equipment in remote locations is needed.
Cathodic protection	PV is being considered for use on the rapidly expanding oil pipeline network.
NIGERIA	
Power supplies for public buildings	PV may be feasible for replacing unreliable diesels as a power source for local government center and police stations.
Military communication stations	A need for highly reliable, fully integrated systems exist.
TV	Current power sources are batteries which are recharged weekly at a cost of about $4. PV-TV could be the largest market in Nigeria.
Television relay stations	Power requirements are about 1KW.
Repeater Stations	Power requirements range from 120-600W
Cathodic protection	The $1 billion dollar oil refinery and pipeline development plan coupled with the highly corrosive nature of the Nigerian coastal environment should create a substantial demand for PV powered cathodic protection devices.
Marine, airport and rail signals	$11 billion transport sector development plans should generate a significant demand for PV powered signalling devices.
MOROCCO	
TV	A market for small black and white TV's powered by a PV array of about 20W_p exists. Total market may be about 175 KW_p in next five years.
TV repeater station	Television directorate is interested in installing 40-50 PV powered stations over the next five years. Total market could be about 40KWp.
Microwave relay stations	State Ministry of Ports, Telephone and Telegraph has requested a price estimate for a PV installation capable of delivering 600W for 24 hours a day. A total of 20 relay stations are to be installed over the next five years. Market size will be about 36KWp.

Table 2.7
OTHER APPLICATIONS (Continued)

APPLICATION	COMMENTS
MOROCCO (con'td)	
Power for small railroad stations, signals, etc.	A near-term PV market for signal and warning lights at remote railway level crossings (250 W for 5 hour/day) and a longer-term market for railroad station power supply exists.
Marine Signalling	Lighthouses, radio beacons, jetty lights, and light buoys should present opportunities for PV
Airports	Remote airports require power for radio beacons, telephones, light, radio etc. could provide a market for PV.
Rural radio telephones	Already one PV powered unit is in operation (! W power, 8 hours/day). Forty units are currently located in areas with no grid power.
COLOMBIA	
Rural Health Posts	About 600 health posts current depend on 1-2KW gasoline generators. They are used 3-4 hours/day for lights, radio, refrigerator, sterilizer, etc. PV market size is about 50-90 KWp between 1981-86.
Rural Telephones	A tender for 2200 PV powered telephones will be issued in 1982 by the Telecommunication Authority. There is a small market for private communication systems. Market size is about 160-170 KWp between 1981-86.
Vaccine refrigerators	Small refrigerators are required for isolated regions. Currently not even kerosene refrigerators are used due to fuel delivery problems.
Domestic power supply	Power for domestic uses in large farms, ranches and for families needed. A PV market about 700-1100 KWp is expected between 1981-86.
PHILIPPINES	The Philippines study concentrated on agricultural activities. However, based on the Philippines 5 year development plan significant opportunities for PV sales will exist for use in: rural radio and TV, village potable water supply, microwave and relay stations, military communication, etc.

- By about 1985-86, PV applications requiring 4-6KW 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 aquacultural uses.
- A 20 percent increase in array costs would delay year of cost-competitiveness by about one to two years.
- The relatively maintenance free operation of PV will swing the balance in favor of PV systems and away from diesel and gasoline generators, even if PV power is more expensive, in countries such as Nigeria which have poor equipment servicing facilities. The other countries visited had adequate service facilities in the rural areas.
- Except for livestock watering under open range conditions, the ability of PV systems to operate unattended is not a significant advantage for PV use in agriculture.
- In the next 4-5 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 both economically and financially feasible when compared to its nearest competitor.
- The private sector may be able to afford (through outright purchases or using commercial bank loans) battery chargers or small power sources since the capital investment is much smaller.
- In countries where farmers are faced with high fuel prices, by 1982 a PV system will be cheaper to operate on an annual cash flow basis, than a gasoline powered generator of about 1KW.
- Although only small power needs can be economically served by PV in agricultural applications, the market is significant.
- It is most likely that the demand for PV in agriculture will be overshadowed by the larger market in applications such as, rural services, telecommunications, signalling and TV. The market for PV powered TV is expected to be very large in many countries.
- A delay of one to two years in attaining cost-competitiveness could significantly affect the size of the PV market in the 1981-86 timeframe.

3.0 IMPORTANT MARKET FACTORS

This section delineates the major market-related factors which influence the magnitude of PV sales in foreign markets. Its primary purpose is to serve as a general guide to the PV manufacturer, relating the factors which he must evaluate prior to deciding whether to enter a foreign market.

Based on our five on-site country investigations, we have identified the following major market factors:

- attitudes and information availability
- availability of financing
- energy pricing
- energy/agricultural policy
- business and trade environment
- distribution network
- competitive environment
- trading status with U.S.

These factors, though set out as separate influences, are not mutually exclusive. For example, the level of awareness of PV technology will not only help determine whether a farmer will purchase PV-powered equipment, but will also affect his ability to secure financing for such a purchase.

In the discussion below, examples are extracted from the detailed data gathered in the case-study countries to explain each of these factors. For the rest of the countries, we have had to rely upon aggregate data drawn from such sources as The World Bank, The Solar Energy Research Institute, the U.S. Department of Commerce and the U.S. Department of Energy. While these aggregate data serve as a useful benchmark, any manufacturer contemplating entry into one of the latter countries is strongly advised to gather comprehensive market data through an in-country investigation.

3.1 Attitudes and Information Availability

Adequate knowledge of PV systems and a favorable disposition towards them are essential to market penetration. Such awareness is not only important for users, but also for government officials and financial institutions.

The level of user awareness of PV will directly influence demand for the systems in the private sector. In all of the case-study countries, potential users had very little knowledge of PV. Moreover, when they were initially introduced to the technology by project members, many were skeptical about PV's appropriateness to their needs. These findings suggest that U.S. PV manufacturers will need to establish information dissemination programs in order to effectively penetrate the private sector in many developing countries.

The degree to which governmental officials are familiar with and receptive to PV will influence the emphasis the technology is given in a country's development plans. Our case-study investigations revealed a range of levels of awareness. In the Philippines, it was generally not difficult to find individuals in agricultural or energy agencies who had some knowledge of PV systems. For example, officials in the Ministry of Agriculture, the National Grains Authority, and the National Irrigation Administration had been considering possible applications and had therefore taken the time to educate themselves about PV systems. Similarly, in Colombia, understanding of PV technology and possible applications was widespread among government officials involved in energy planning. On the other hand, in Nigeria, knowledge of PV systems and of new energy systems in general, was lacking. The most knowledgeable individuals interviewed were associated with universities.

The perceptions of financial institution officials will influence their willingness to provide loans for PV projects. For example, portfolio directors and loan analysts of the National Agricultural Credit Bank of Morocco, which provides about 70% of all financing for agricultural equipment, termed PV an "energy of the future" and stated that new technologies were not within their purview. In the Philippines, interviews with senior private and government financial institution representatives revealed a general sense of enthusiasm towards considering PV systems for loans; unfortunately, the impact of this enthusiasm will be dampened by the skepticism of project staff directly responsible for recommending loans. One bright spot for PV financing encountered in all the visited countries, however, was the general view that if PV systems can be shown to be cost-effective, financing will be forthcoming.

3.2 Availability of Financing

The availability of financing, translating into a potential purchaser's ability to pay, is quite obviously a basic condition which must be satisfied in order for PVs to effectively penetrate a foreign market. In particular, due to the high initial capital cost of PV systems, long-term loans of generally more than 10 years in duration must be available.

Analysis of the suitability of a country's financial environment for PV sales centers on addressing two fundamental questions:

- Does the country as a whole have sufficient resources to foster development of PV?
- If these resources do exist, are they readily available to potential PV purchasers in agriculture, and at the requisite long time horizon?

The lack of financial resources will hinder the penetration of PV systems into many "poor" countries. For example, in Upper Volta, one of the poorest countries in the world, a majority of its population engage in traditional subsistence farming, earning an estimated annual per capita income of only $177 in 1980.[1] Similarly, Chad's GNP per capita was estimated at $110 in 1979.[2] There are poor nations which have pledged to utilize solar technology; Bangladesh (GNP per capita of $90 in 1979[3]) has announced a nationwide solar energy program whose first phase proposes to provide 12.6 million rural families with solar cookers.[4] However, such sales will be concentrated in the public sector, and for the most part, "poor" nations will not be a prime market for private-sector PV purchases.

In more prosperous nations, PV sales may still be restricted by the unavailability of long-term capital in the agricultural sector. This can be due to a variety of circumstances. In many countries, commercial banks are the primary source of financing for private investment, and these prefer to grant short-term loans. For example, in the Philippines, commercial banks accounted for 72% of all outstanding capital as of June, 1978, and 69% of the loans made

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[1] U.S. Department of Commerce, International Trade Administration. Foreign Economic Trends and Their Implications for the United States: Upper Volta , GPO, August, 1981.

[2] The World Bank, World Development Report 1981, Oxford University Press, 1981.

[3] Ibid.

[4] Solar Energy Research Institute, Solar Markets Conditions and Potentials Bangladesh, GPO, January, 1981.

by these and savings banks were for short-term, working capital loans.[1]

Financial institutions' attitude toward PV, and the breadth of their awareness and understanding of the technology, can limit long-term loans even when such financing is available. Some reluctance to grant loans for PV systems was exhibited by private and government financial institution representatives that were interviewed in all of the case-study countries. Many officials expressed concern that such systems might not be competitive with other alternative technologies. Factors often found to be unfavorable for PV included:

- the initial capital cost of PV systems
- a belief that gasoline or diesel generators are generally more economical than PVs
- a belief that other energy sources, such as biogas and low-head hydro, should be financed before PVs
- a reluctance to finance projects using unfamiliar technologies

A general lack of information on PVs is a major cause of this skepticism on the part of bank officials. Accordingly, the availability of financing for PV applications can be markedly improved by increased dissemination of information about PV applications to financial institutions and the successful introduction and operation of the first systems.

Developing countries' internal capability to finance PV projects is often bolstered by external sources of aid such as The World Bank and the U.S. Agency for International Development. However, the amount of government funding that filters down to PV applications will depend upon the development priorities established by individual countries. For example, Jamaica, 99% dependent on imported oil for its commercial energy needs, has an explicit National Energy Plan for 1978-83 and is actively pursuing a variety of energy projects.[2] Botswana, on the other hand, does not direct energy development through any formal development plan.[3]

Even within the countries that attach great importance to energy development, the type of power sources being emphasized will influence the availability of PV financing. For example, Argentina encourages solar energy projects, but the government's major emphasis is on the development of large hydroelectric and nuclear power plans.[4] Egypt's Ministry of Electric Power is conducting

[1] This 69% estimate is as of March, 1976.

[2] Solar Energy Research Institute, Solar Market Conditions and Potentials: [illegible]. GPO, March, 1981

[3] Solar Energy Research Institute, Solar Market Conditions and Potentials: Botswana, GPO, January, 1981.

[4] Solar Energy Research Institute, Solar Market Conditions and Potentials: Argentina, GPO, March, 1981.

research on the use of solar energy for a wide variety of applications, including electricity generation, television receiving power and refrigeration.[1] The suitability of PV for these applications indicates that Egypt could allocate a substantial share of its energy development funding to PV. Please note that a fuller discussion of the importance of a nation's energy policy to PV penetration is contained in Section 3.3.

In sum, financing for PV systems in many developing countries will not be be readily available. Nevertheless, a number of countries (e.g., Nigeria, Indonesia, Gabon, Saudi Arabia, Western Europe) command the financial resources to foster PV development, and many others receive large amounts of external aid. Confidence in the economic viability of PV systems needs to be created, with a major step in this process being vigorous information dissemination. Our case studies suggest that if this can be accomplished, many developing countries would be willing to finance PV projects that are economically and financially viable.

3.3 Energy Pricing

Conventional-energy pricing directly affects the cost competitiveness of PV systems in potential foreign markets. The cost of fuel varies across countries depending upon sources of supply and distance from suppliers. The price a consumer pays within a nation further depends upon the country's energy policies. For example, in the Philippines, the price of gasoline at the National Philippine Oil Corporation refinery outlet was $1.18 per gallon in October 1980 including wholesale markup. However, taxes and duties raise this price to $2.42 per gallon. Thus, the Philippine Government's taxation of conventional energy supplies makes PV systems more attractive to the private sector.

On the other hand, some nations subsidize consumer fuel purchasers, thereby lessening the competitiveness of PV versus gasoline and diesel engines for consumer

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[1] Solar Energy Research Institute, Solar Market Conditions and Potential: Egypt, GPO, February, 1981.

applications. Mexico, a country self-sufficient in energy, keeps internal fuel prices below world prices as a means of encouraging industrial growth and of controlling inflation. As of January, 1981, gasoline sold for $0.46 per gallon and diesel for $0.16 per gallon. Gasoline and diesel fuel prices for a selected group of countries are contained in Table 3.1.

An additional factor that influences energy pricing is the level of availability of fuel within a country. Assurance of supply can be particularly difficult in remote, rural areas, and this serves to drive up the actual fuel price paid by consumers and enhance PV systems' competitiveness. For example, despite Nigeria's petroleum abundance, supplies are poorly distributed and fuel prices are often 2 to 3 times higher than the official price outside the urban areas.

In measuring the cost competitiveness of PV from the public sector point-of-view, energy costs, sans taxes, subsidies and availability surcharges should be considered. For oil importing countries, these costs are represented by the real prices of gasoline and diesel fuel. For oil exporting countries, the opportunity price of fuel, i.e., the price that could be obtained by selling the petroleum in the world market, will determine the cost competitiveness of PV. For example, in measuring PV's economic viability in Saudi Arabia, the appropriate price of gasoline to be considered is not the $0.23 per gallon figure referenced in Table 3.1, but the much higher price that a gallon of gasoline can fetch in the world market.

3.4 Energy/Agricultural Policy

The role PV is alloted in a nation's energy and agricultural development plans can significantly affect the nature and size of the market that the country represents for PV. In particular, the priority attached to PV will determine the amount of capital made available by the government to finance PV projects, as well as the number of financial and other incentives offered to promote its development. Additionally, the extent of direct government involvement specified in development plans will influence whether sales in a country will primarily be concentrated in the public or private sector.

A country's disposition toward PV will be influenced by its level of information availability and its cost of energy. These factors are discussed in greater length in Sections 3.1 and 3.3, respectively. Our case study investigations illustrate how energy and agricultural policies toward PV can differ across countries. In Mexico, agricultural and energy development plans favor PV applications. For example, agricultural development plans call for support for small

Table 3.1

Consumer Fuel Prices--January, 1981 (US$/Gallon)

	Gasoline (Regular)	Diesel
Australia	1.57	1.61
Brazil	2.52	.97
Ethiopia	1.38	.97
Ghana	3.12	1.97
Greece	2.58	1.38
India	2.49 (July 1980)	1.11 (July 1980)
Indonesia	.91	.27
Italy	3.28	1.35
Japan	2.74	1.93
Morocco[a/]	3.10	1.65
Nigeria[a/]	1.15	.90
Pakistan	1.91	1.17
Peru	.69	.37
Philippines	2.35	1.39
Portugal	3.25	1.59
Republic of Korea	3.92	1.24
Saudi Arabia	.23	--
Spain	2.76	1.78
Sri Lanka	1.98 (premium)	1.26
Thailand	2.13	1.38
Tunisia	2.07	.79

U.S. Department of Energy, International Sources: Energy Annual, GPO, September, 1981.

a/ Case study data.

farmers (especially cooperatives in rain-fed regions), including minimum guarantees. Moreover, Mexico's commitment to incorporating PV technology is illustrated by the country's drive to establish a local PV industry.

In other countries, while PV is not specifically mentioned in development plans, energy and agricultural policy would still appear to encourage PV penetration. For example, in Nigeria, the Fourth Development Plan documents the commitment to increase agricultural production, reduce product loss, and increase amenities and other support for the small-holder, the "backbone of agricultural production." Significant financial resources are committed to these objectives, although reduced oil production and concomitant reduction in revenues may significantly alter these goals. On paper, there is no great concern for renewable energy or non-conventional sources, and the country plans to proceed with rural electrification. However, in actuality the existing grid is highly unreliable. This would suggest that PV may fit very well with the development plans of Nigeria.

Similarly, in the Philippines, development plans establish priority programs in agriculture, both with regard to specific crops and geographic areas. In terms of energy policy, there is a commitment by the Ministry of Energy to reduce dependency on foreign oil, with a large role for renewable and non-conventional sources spelled out in detail. Although PV is omitted, the role of PV may be enhanced by the high unreliability of the present grid in rural areas and the generalized commitment toward replacing conventional energy supplies.

Other nations, while striving toward energy self-sufficiency, appear to not have a place for PV in their development plans. Kenya, for example, is primarily attempting to reach its goal of energy self-sufficiency through development of hydropower generating facilities and extension of accompanying transmission facilities to outlying areas.[1] Similarly, Venezuela's Ministry of Energy and Mines plans to spend 95% of the $11.5 billion it has budgeted for developing non-petroleum energy sources or hydroelectric.[2]

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[1] DHR, Incorporated, et. al. Market Assessment of Photovoltaic Energy Systems for Worldwide Agricultural Applications: Phase I, Appendix C, May 31, 1980.

[2] "Venezuela Sets Five-Year Plan for New Energy Development," Solar Energy Intelligence Report, August 24, 1981.

3.5 Business Environment

Countries differ considerably with respect to the business environment they offer the U.S. PV firm. Some of the major criteria with which to evaluate the business environment are:

- tariff rates
- tax provisions and special incentives
- regulations (e.g., exchange controls, restrictions on ownership)
- resources for manufacture/assembly
- special cultural factors

These factors affect both the desirability of entering a foreign market and the optimal form of that entry (i.e., exporting versus in-country manufacture, etc.).

Tariff provisions influence the price of a PV system, and hence its competitiveness, or alternatively the profit rate of the U.S. PV firm. Tariff rates vary across countries and generally reflect whether there is a need for the product, whether there is an indigenous industry, and whether the product is brought in fully assembled or requires in-country assembly. In Colombia, imported American PV arrays are assessed with a 10% tariff on the certified insured freight (C.I.F.) price plus a 6% sales tax on the C.I.F. price[1]. This rate applies only to the cells themselves, imported PV systems are subject to the highest tariff applicable to any component part (i.e., 35% for batteries). Therefore, in Colombia, Mexico, the Philippines and other countries where such a provision applies, the U.S. manufacturer should ship balance of system components separately in order to avoid paying the higher rate on the entire PV systems.

The "tariff rates" factor is difficult to evaluate in assessing business environments because many countries have not definitely decided upon a tariff policy for PV. For example, in Nigeria, PV powered irrigation pump might be subject to a 15% energy systems equipment rate, or it may be included along with agricultural inputs and assessed a very low tariff. Consequently, the U.S. PV firm contemplating export should be most careful to clarify with country officials prior to

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[1] In addition, most imports are assessed the following surcharges: 5% of C.I.F. value for the Export Promotion Fund, 1.5% of C.I.F. value for the Coffee Promotion Fund, and 1% of f.o.b. value for the Consular Invoice.

entry the tariff his goods will be charged.

Nations also differ to the degree their tax provisions encourage foreign firm entry. The tax regulations that are applicable in a foreign market depend upon the form of entry chosen. Generally, the most favorable tax status can be attained by establishing local production facilities, especially with local equity participation.

Some nations are very attractive from a taxation point of view. For example, Oman levies no personal income tax, estate or gift tax, capital gains tax, tax on interest or dividends, or sales or transaction tax. The only tax is on profits from trade or business, and with majority Omani ownership these are taxed at only 15%.[1] The Philippine government has granted the local manufacturers of PV systems "pioneer industry" status. This entitles such projects to a whole range of incentives, including: exemption from all taxes under the National Energy Revenue code except income tax, exemption/reduction of tariff duties on imported machinery and equipment, post-operative tariff protection, partial abrogation of Filipino requirements, and priority in receiving government loans. Special tax and other incentives are also available to the U.S. PV firm intent on establishing manufacturing operations in selected countries if it locates its production facilities in special areas where these nations are attempting to encourage development. In Sri Lanka, enterprises located in its Free Trade Zone are eligible for modification of, or exemption from several laws, including those dealing with taxation, exchange control, and customs.[2]

The presence of a variety of regulations can, depending on their severity worsen the business environment. Such regulations can take the form of import licensing requirements, exchange controls, restrictions on foreign national employment, local equity participation requirements, and credit restrictions. As we have seen in the discussion above, many nations weaken these regulations to induce investments; in nations where this is not the case, doing business will be more difficult and possibly less profitable.

For the U.S. PV firm planning to manufacture or assemble systems overseas, a country's productive resources need to be evaluated. Many less-developed countries lack the labor skills and manufacturing infrastructure necessary

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[1] U.S. Department of Commerce, International Trade Administration, Overseas Business Reports: Marketing on Oman, GPO, August, 1981.

[2] The Hong Kong Bank, Business Profile Series: Sri Lanka, July, 1979.

for producing PV equipment. For example, Bangladesh industrial activity is primarily concerned with jute processing, and the country has experienced labor difficulties in attempting textile production.[1] Similarly, Botswana lacks the technological capability to fabricate or assemble solar products.[2]

Finally, special cultural factors, specific to individual nations must be considered. These influences are the most difficult to identify without an on-site investigation, yet they can potentially have a dramatic impact on sales. Two unexpected side effects from the installation of PV pumps in Mali illustrate this problem. In one case, a local leader decided that he would take possession of the pumps by using some remote clause in the unwritten local laws to assert to villagers that by virtue of grazing rights he was legally entitled to the PV array. He subsequently charged the villagers for the water the pumps produced. In a second case, women who used to draw water from the well where PV pumps were installed were left with no work and subsequently fell into habits unacceptable to village customs.[3]

3.6 Distribution Network

Another factor which must be considered in evaluating the suitability of a country is whether a distribution network that is adaptable to PV currently exists. Such a network will not only facilitate sales of PV systems, but it will also aid the manufacturer in installing and servicing his products.

The Philippines provides an example of a country with a well-established diesel and gasoline engine distribution network that should be able to accomodate PV. Dealer outlets which are amenable to selling competing products already exist. In addition, service and inventories of spare parts are either made directly available in smaller cities and rural areas or provided through small electrical repair shops. Presidential decree has also mandated that dealers supply parts and service along with any products sold to the government or used in government development projects.

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[1] U.S. Department of Commerce, International Trade Administration, Foreign Economic Trends and Their Implications for the United States: Bangladesh, GPO, March, 1981.

[2] Solar Energy Research Institute, Solar Market Conditions and Potential, Botswana, GPO, January, 1981.

[3] DHR, Incorporated, et al, op. cit. Appendix G.

On the other hand, Nigeria presents an example of the absence of an adaptable infrastructure. The availability of service and spare parts is extremely limited outside the major cities. Many rural development and agricultural mechanization projects have experienced great difficulties because of maintenance problems. Accordingly, U.S. PV firms contemplating entry into Nigeria should plan on developing full service and installation capabilities. In particular, balance-of-system components which may be the most vulnerable aspects of systems, need to be stocked for quick repair or replacement. This is particularly critical since reliability is such a key factor in the Nigerian market, with users willing to pay a premium for reliable systems.

Dealer practices on product markup are also salient. For example, in Morocco, dealers are accustomed to receiving 30% markup on sales. On a $20,000 1KW PV system, this would translate to $6000 and could very well price PV systems out of the marketplace. Such high markup rates can possibly be lowered by offering dealers innovative credit plans by which they do not have to bear the entire cost of carrying PV systems in inventory. Nevertheless, U.S. PV firms should either refrain from entering markets where high markup rates will render PV systems uncompetitive, or should insist on dealer's orienting themselves toward high sales volume and low markups.[1]

3.7 Competitive Environment

The extent of competition from foreign and local PV manufacturers is a major determinant of the ease of market entry for U.S. PV firms. Additionally, the vigor of a country's conventional power equipment industry, and the strength of historical footholds of foreign firms within it, will affect the magnitude of U.S. PV sales.

U.S. firms currently dominate the world PV market. They generally enjoy superior technology and lower production costs than foreign rivals. As illustrated, U.S. product shipments were about 770KWp in the second half of 1979.[2]

[1] As was noted in the competitive environment section, the Japanese have succeeded with the latter strategy in the Philippines, holding dealers to 3% markup on gasoline and diesel engine sales. This has allowed them to secure a large share of the market in just a few years.

[2] U.S. Department of Energy Information Administration, Energy Data Report: Solar Collector Manufacturing Activity, July through December 1979, GPO, March, 1980.

Japan, a new entrant into the PV field had product shipments of only 18-20 KWp in all of 1979.[1]

Nevertheless, U.S. PV firms should expect to find foreign competition in a number of developing countries. European firms are concentrating their sales efforts in third world nations. In particular, our case studies indicate that French marketing efforts are very active. In the Philippines, they currently have two small 200 watt demonstration systems located in the Province of Bulacan outside of Manila. Thomson CSF is selling PV-powered rural television station systems in Mexico, and Guinard and Briau are both marketing water pumping stations equipped with PV modules. Further, a French company is active in Nigeria with a 5KW demonstration in northwest Nigeria currently under development.

West German, Dutch and Australian firms are vying for PV sales. The German firms AEG-Telefunken and Messerschmidt, as well as Phillips Holland, are currently marketing PV in Colombia. In the Philippines, AEG-Telefunken will supply a $4 million PV system for the Province of Illocos del Norte; an Australian firm is selling used American solar panels to a Filipino entrepreneur. Moreover, Phillips Holland was the first PV firm to enter the Mexican market, in 1972-73, and is reported to be planning to begin assembly of PV modules in Mexico in the near future. And in Europe, the Germans (as well as the French) are currently operating demonstration projects of 20-100 KW in size on the Greek Islands.[2]

Perhaps the most serious long-term threat to U.S. PV sales in developing countries comes from Japanese firms. As noted above, Japan does not presently hold a strong position in the international markets. However, the Japanese are vigorously seeking advancement of their PV technology. Sanyo and Fuji Electric claimed to have developed amorphous silicon PV trial cells with conversion efficiencies of 6.91% and 6.47%, respectively; in April, 1981, the best similar cell produced in the U.S. had a conversion efficiency of 6.1%.[3] Similarly, scientists at Japan's government-operated Telecommunications Research Institute claimed to have succeeding in producing 20-micron thin, 5-centimeter-wide ribbons of crystalized silicon "at a revolutionary high speed and at a production cost less than one-thousandth of that of conventional methods.[4]

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[1] "The Japanese Photovoltaic Threat", Solar Age, February, 1981.

[2] IIT Research Institute, Renewable Energy Systems Market and Requirements Analysis in Italy, Spain and Greece, April, 1981.

[3] "Sanyo Electric, Fuji Electric Boast Amorphous Si PV Efficiencies of 6.91%, 6.47% Solar Energy Intelligence Report, April 29, 1981. It should be noted that efficiencies attained in trial cells would be lower in commercial production.

[4] "Japanese Report Low-Cost, High-Speed PV Production", Solar Energy Intelligence Report, April 14, 1980.

Japanese firms were found to be pursuing PV sales in two of the case-study countries. In Colombia, both Sharp and Sanyo are active. Moreover, both Sharp and Sanyo are advancing their position in the market by being more willing to set up PV demonstrations than either U.S. or European firms. In the Philippines, Japanese firms have approached local entrepreneurs to gauge their interest in PV systems. In this market, U.S. PV firms are well-advised to offer low dealer margins in order to prevent the same kind of share losses to Japanese firms that occurred in the engine industry. In just a few years, Japan was able to garner 75% of the diesel and gasoline engine market, mostly as the expense of U.S. engine manufacturers, by holding dealers to a 3% markup.[1] In general, Japan's superlative acumen in exporting goods and services will likely make its PV firms formidable competition in developing country markets once its PV industry matures.

Local PV firms are another source of competition. Such competition is likely to be a major factor in Mexico since its Instituto Politechnico Nacional (National Polytechnic Institute) is planning to expand its installed production capacity to 20KWp by 1982 and is seeking funding for a commercial-scale (300KWp/year) plant. Similarly, in the Philippines, a large, Filipino industrial firm and a large commercial bank have expressed interest in establishing an indigenous PV industry based on American technology.

In addition to investigating current PV activity in foreign markets, it is instructive in assessing the competitive environment to examine countries' conventional power equipment industry (gasoline and diesel generators). This factor can have either a positive or a negative effect on PV sales. In a country where PV systems are economically competitive with gasoline and diesel engines, a well-developed conventional power equipment industry will provide the infrastructure with which to market PV. However, where PV are not cost-effective, a strong conventional equipment industry will serve to heighten this barrier to sales.

A further consideration with regards to a country's conventional power industry is the relative strength within it of U.S. firms versus their foreign

[1] Solar Energy Intelligence Report, April 20, 1981.

competitors. A well-established working relationship in the conventional power industry can be carried over to PV sales, thereby impeding other would-be suppliers. A prime example of such a relationship is Francophone Africa (Algeria, Morocco, Ivory Coast, Senegal, Gabon, Cameroon, and Tunisia). Most of these countries are former French colonies, and in Algeria, Morocco, Ivory Coast, and Senegal, French imports receive special trade preferences. France supplies most of the region's electric power equipment, accounting for the largest share of imports in Algeria, Senegal, and the Ivory Coast. The U.S. and Germany are each major suppliers to only one country in the area.[1] On the other hand, the U.S. is a major supplier of electric power equipment in such areas as the Middle East, Taiwan, South Korea and Brazil.[2]

3.8 Trading Status with U.S.

Well-developed trade relations between the U.S. and a target international market will have a favorable influence on PV market penetration. The familiarity bred through trade in various goods and services makes nations more receptive to each others' products. Moreover, historical trade relations will simplify the mechanisms of U.S PV systems exports. The organs and officials necessary to conduct such trade will be in place.

Table 3.2 details America's leading trading partners, as defined by exports plus imports, in 1980. As might be expected, developed countries and U.S. oil suppliers dominate this list. The 15 countries account for over two-thirds of total U.S. trade in 1980.

While extensive trade relations can aid PV penetration by U.S. firms, the absence of a significant level of historical trade will not preclude PV sales. Rather, this market factor should be thought of more as a positive influence promoting PV sales than as a significant barrier.

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[1] DHR, Incorporated, et. al., op cit. Appendix F.

[2] Ibid.

Table 3.2

15 Leading Trading Partners with U.S. in 1980

Country	Exports Plus Imports ($ billion)
Canada	76.9
Japan	51.5
Mexico	27.7
Federal Republic of Germany	22.6
United Kingdom	22.4
Saudi Arabia	18.3
France	12.7
Nigeria	12.1
Taiwan	11.2
Netherlands	10.6
Venezuela	9.9
Italy	9.8
Republic of Korea	8.8
Belgium/Luxemborg[1]	8.6
Brazil	8.1

SOURCE: U.S. Bureau of Census, Highlights of U.S. Export and Import Trade, FT990, December, 1980.

1/ There are grouped together in Census Bureau statistics.

3.9 Conclusions

Our investigation revealed the importance of several market-related factors. Informational and attitudinal concerns were found to be one of the most important. Not only will the level of knowledge about PV systems directly affect consumer demand, but it will also influence the availability of financing and energy/agricultural policy. In fact, it will also indirectly shape the business environment of a potential market as well; a nation's development plans, as expressed in its energy/agricultural policy, will have a bearing upon the regu' tory and tax policies it institute.

An equally important factor limiting PV sales is the availability of long-term financing. There is a critical capital shortage in most developing countries; the exceptions being the oil exporting countries, although due to depressed oil markets, they too are being faced with capital shortfalls. This implies that PV companies may have to devise innovative financing strategies or develop new sources of capital.

Several of the market-related factors influence the cost-competitiveness of PV systems. If a nation chooses to subsidize petroleum prices to consumers, PV will have a much harder time penetrating the private sector. Similarly, the competitiveness of PV systems will be hindered by dealer's taking high mark-ups on sales. Such problems will be exacerbated for U.S. firms if competitors are able to hold down the margins added to their prices, as the Japanese have done so successfully in the conventional energy power equipment industry in the Philippines.

Finally, several factors will determine the ease of entry. The existence of restrictive statutes, high tariff rates, or impeding cultural traditions will make a country less attractive as a potential market. On the other hand, the presence of an existing distribution network that can be adapted to PV sales, and well-developed trade relations with the U.S., will facilitate entry into a market.

4.0 POTENTIAL MARKET FOR PV IN AGRICULTURE

The purpose of this chapter is to use the results and insights gained during the field studies to estimate the worldwide market potential of PV in remote, stand-alone agricultural sector applications.

4.1 Estimation Procedure Employed in Case Study Countries

The market estimation procedure used in the case study countries was based on the hypothesis that a market will start developing when PV systems are cost-competitive, on a life-cycle basis, when compared to the least cost, practical alternative. At this point the market share of PV will be close to zero as the conventional systems have the advantages of existing supply and repair systems, tradition, less initial capital investment and greater end-use flexibility. As the cost advantage of PV over conventional systems grown so will its market share. Once the cost equality point for PV is passed, their rate of penetration will be determined by market-related factors. Another assumption made in estimating the market is that PV systems will first penetrate into areas where users are already using mechanically or electrically powered equipment. For example, PV systems will be more acceptable to a farmer using a gasoline engine driven pump than one who irrigates the field manually.

The bounds on the market size were set by a "bottom-up" approach. The bound is defined as the peak power required for the total number of cost competitive, practical applications. A discussion of feasible, cost-competitive agricultural applications were given in Chapter 2. The upper bound is then adjusted by an appropriate market penetration rate which is a function of factors such as: equipment turnover rates, awareness, financing availability, institutional barriers/incentives and other market related factors such as the premium that is placed on PV's low maintenance requirements.

The market estimates for the case study countries are summarized in Table 4.1. The table also shows the major factors that influenced the selection of an appropriate market penetration rate. A significant potential for PV use in agriculture was found in all the countries except Morocco, where a lack of cost-competitiveness caused the market to be small.

TABLE 4.1 1981-86 PV MARKET POTENTIAL IN THE CASE STUDY COUNTRIES

COUNTRY	1981-86 PV Agricultural Sector Market Potential KWp	Major Factors Influencing Market Size	
		Pro	Con
Philippines	60-700 (Average 200 KWp)	High fuel prices, financial incentives for PV government commitment to renewable energy, PV a priority industry, large agriculture sector, entrepreneurial interest, availability of marketing channels, good trade relations with U.S., low level of rural electrification.	Capital shortage, lack of awareness & good facilities for maintaining conventional power systems, high PV first costs, no significant PV marketing activities.
Mexico	605 (includes 300KWp for rural potable water supply)	Recognition of US superiority in PV field, good reputation of US PV firms already in market.	High first cost, lack of incentives, low domestic energy prices, extensive electricity grid, lack of capital, little awareness except in public energy sectors, good distribution and service network for gasoline and diesel engines.
Nigeria	1900 (includes 1000 KWp for power for rural potable water supply health and education centers)	Poor gasoline and diesel engine maintenance facilities, high fuel prices in rural areas, poor rural electrification, availability of finance, interested in more US trade.	Lack of awareness, life-cycle costing rarely used, poor accessibility of farmer to loans, no distribution network.
Morocco	340 (all of it in non-agricultural applications).	high fuel prices limited extent of grid, interest in PV, encouragement of US investment, attractive investment incentives.	not cost-competitive with diesel systems in agriculture sector, lack of incentives, high dealers margins, financing difficulties, good distribution and serving network for diesels, no specific incentives for PV. Reduced attention to agric. sector, lack of awareness, high first costs.
Colombia	1200 KWp (includes 700 KWp for non-agricultural applications)	High fuel prices and unavailability in some remote areas not served by the grid, central electrical generation behind schedule and does not meet current demand, facilities and expertise available for balance of systems manufacture in country.	Lack of familiarity, experience and awareness about PV, great hydroelectric power potential beginning to be exploited, relatively inexpensive power is developed in rural areas.

4.2 Estimation of the Worldwide Agricultural Sector PV Market

The purpose of this section is to use the information obtained in, and conclusions drawn from, the case studies to estimate the size of the worldwide market. They are based on aggregate data available in the U.S. and should only be considered "order of-magnitude" estimates of market size. They will be useful in identifying countries with a high sales potential. However, a detailed country specific assessment must be conducted prior to launching a marketing campaign. In this section various indicators are examined to evaluate their appropriateness in extrapolating case study results to other countries. In Section 6.3 an appropriate indicator is used to estimate the size of the worldwide market for PV systems in the agricultural sector PV market.

A variety of aggregate data indicators could be used to evaluate the PV market potential in the agricultural sector of a country. The indicators attempt to measure the intensity of PV use in the agricultural sector. Some indicators that may be applicable are:

- KWp per agricultural holding
- KWp per hectare of agricultural land
- KWp per agricultural worker
- KWp per dollar of agricultural output
- KWp of PV per KWp equivalent of agricultural sector energy use for stationery purposes.

They are used in the same sense that per capita energy use, energy used per GDP dollar, or energy used per sectoral value-added is used to measure the energy intensity of a country. While these indicators are useful in drawing broad conclusions regarding a country's energy intensity, using them to derive market estimates would enable only first order approximations to be made. Similarly, the indicators used to assess PV market size should only be used to identify countries that probably should be evaluated more closely. In particular some problems associated with use of aggregate data are:

- The market penetration process is much more complex and involves more factors than can be represented by one or several indicators.
- There could be considerable error in the data.
- The PV market estimates reflect to some extent the subjectives biases and expectations of the field investigators.
- Given the rapid changes that have taken place in the last decade, neither current activity nor trends may accurately reflect the future.

These caveats should be borne in mind when studying the remainder of this chapter. Table 4.2 shows the value of each indicator in the case study countries.

TABLE 4.2 INDICATORS OF INTENSITY OF PV USE IN AGRICULTURE

Country	1981-86 PV Agric. Sector Market Size	KWp per 10^3 Agric. Holding*	KWp per 10^3 ha of Agricultural Land	KWp per 10^3 Agricultural Worker	KWp per 10^6 dollars of Agriculture Production	% PV KWp per KWp # equivalent of Agri. Sector Energy Use for Stationary Applications
Philippines	200	0.138	0.038	0.040	0.058	0.1
Mexico	305	0.300	0.011	0.043	0.043	0.02
Nigeria	900	1.46	0.038	0.062	0.139	0.6
Morocco	small	-	-	-	-	-
Colombia	560	0.50	.010	0.25	0.15	0.25

*Data from FAO Agricultural Production Yearbook 1980.

#Based on data from The World Bank - The World Development Report 1980 and FAO, Energy in Agriculture 1980. The latter estimates that approximately 1.8-6.4% of total commercial energy used in a country is used for agricultural production (including energy for equipment manufacture). Of this amount only a small fraction is for stationary power for production and processing operations. The calculations above assume that one percent of commercial energy used is for stationary uses in the agricultural sector.

Nigeria and Mexico are anomalies which cannot be considered "typical" middle-income developing countries. The large market expected in Nigeria (0.6% of agricultural sector energy use) is primarily due to availability of capital, ambitious rural development plans and a poor rural electrification and a lack of engine maintenance facilities. On the other hand, even though Mexico has capital and has an ambitious rural development program, its rural electrification program is more achieveable. Furthermore, fuel prices are subsidized and there are no engine maintainability problems in Mexico. Thus, the market in Mexico is much smaller than in Nigeria (0.02% agriculture sector energy use). The lower percentage is also due to the greater energy intensity of Mexican agriculture. Countries such as the Philippines and Colombia are more typical of the middle-income developing countries. The market penetration in these two, range from 0.1 to 0.25 percent of agricultural sector energy use. There is, however, considerable variation in the other indicators.

Since commercial energy use statistics tend to be more reliable, and because the "energy use" indicator appears to fall into a more rational pattern, it will be used to extrapolate the case study results to other countries.

The following procedure will be used in estimating the market size:

1. Countries are grouped into high, medium and low market potential. The procedure adopted in the classification into high medium and low market potential countries was based on comparing several key factors considered important when assessing PV sales potential. The criteria and their surrogate measures are detailed below:

1) The financial capability of a country and its farmers to purchase photovoltaics.

   Financial capability of a country and its farmers is assumed to rely upon four major variables:

   - the value of its agricultural production, since total agricultural products' worth can affect revenue available for PV purchase;
   - the purchasing power of exports, as this can affect a country's economic trends and ability to pay for PV;
   - farmer per capita income, since the private market depends upon farmers with sufficient capital for purchases; and
   - the percent agriculture contributes to a country's export earnings, as the importance of agriculture to a country's overall economic structure affects the likelihood of capital investments.

2) The need for photovoltaics

The need for photovoltaics is dependent upon two important issues: the amount of export earnings used to import energy (this is of special importance when agricultural products make up the bulk of export earnings), and the extent of rural electrification.

3) The extent of trade, and the ease of trade between the U.S. and respective countries:

   Extent of trade was measured in terms of dollar volume of U.S. products imported into a country. Ease of trade was measured in terms of the number of selective trade barriers existing between the United States and each country.

4) The ability of a country to service and maintain conventional power systems.

   The importance of thiscriterion was stressed to the country study teams, particularly in Nigeria. In Nigeria, extremely low reliability and maintainability of gasoline and diesel engines in the rural areas makes a technology such as PV, with its low maintenance requirements, very valuable. In instances such as this, where capital is available and/or the crop's value worthy of investment, photovoltaics become a realistic alternative source of energy despite the current use of gasoline or diesel engines.

   The criterion,however, is difficult to analyze statistically because of this type can only be gathered reliably by in-country field visits since field visits could not be made to all countries. Rankings were based upon the percent of active employment in manufacturing. High percentages indicate more persons familiar with engines and machines, as well as accessibility to manufactured or imported machine parts.

5) Solar Insolation

   The criterion used was the average solar insolation falling upon a country. Too great an emphasis was not placed on this criteria since: a) most countries had adequate levels of sunshine, b) available data is often unreliable, and (c) site-specific, rather than country-wide, average values are more important.

   A multiattribute scoring function based on the above criterion as used to rank countries. Appendix A gives the details of the ranking procedure. Table 4.3 shows results of the ranking. It should be noted that countries where the current environment is unsuitable for U.S. trade were not considered in the ranking.

2. Market potential is then defined as:

   High--0.1 to 0.5 percent of the KWp equivalent of agricultural sector energy use.

   Medium--0.05 to 0.1 percent

   Low--0.01 to 0.05 percent

4.3 Market Size Estimation

The above procedure estimated that the worldwide total agricultural sector market potential ranged from 14MWp to 55MWp between 1981 and 1986. Opportunities for PV systems would primarily be in applications requiring less than 4KW of power. These include: battery charging, power for maintenance yards and domestic needs on large farms, irrigation for small farms, livestock watering and produce coolers. If JPL cost goals cannot be met in the expected timeframe, and costs are exceeded by 20 percent, the potential agricultural sector market could only be attained in the 1981-88 timeframe.

Table 4.4 shows the countries which account for over 90% of the regional market. From a regional perspective, Sub-Sahara Africa appears to have the worst potential. This conclusion is not unexpected, given the worsening economic conditions in that region. In terms of regional market concentration, the top three countries in the Central and South American region account for 90 percent of the potential market. In the Europe, Middle East and North African region the top six countries accout for 90 percent of the market share. The top three account for 60 percent of the market share. In Asia and Oceania, 90 percent of the potential market is held by seven countries. The top three countries account for 74 percent of the market share. Appendix B gives detailed, country-specific market estimates.

4.4 Conclusions

Several countries which may have high agricultural sector PV market potential were identified. These order-of-magnitude estimates should only be used to select countries for further, more detailed, country specific evaluations prior to developing a marketing strategy.

The basis of the estimates was a "top-down" process utilizing agricultural sector energy use data; market estimates for the case study countries; and a ranking of countries based on their photovoltaic need, financial capability, and ease of trade. Detailed market and applications data could not be used since such data were not available on a worldwide basis.

Developed countries in Western Europe were not included in the analysis since their rural areas are electrified. They constitute a post-1986 grid-connected

TABLE 4.3

COUNTRY RANKINGS

OF PHOTOVOLTAIC MARKET POTENTIAL

	EUROPE	NORTH AMERICA	SOUTH AMERICA	AUSTRALIA & S. PACIFIC	AFRICA	ASIA
HIGH	Portugal; Greece, Turkey; Yugoslavia	Dominican Rep.; Guatemala; Panama	Brazil, Uruguay; Peru; Argentina, COLOMBIA, Paraguay	New Zealand	Kenya; MOROCCO, Mozambique, Tanzania, Ethiopia, Egypt, Ghana	Syria, Bangladesh, Pakistan; Yemen Arab Rep.; PHILIPPINES, Sri Lanka; India; Thailand, Israel, Jordan
MEDIUM	Italy, Denmark; Netherlands, Sweden, Finland; Ireland, Spain	Honduras; Barbados, Haiti, Guadeloupe, Canada, MEXICO; Jamaica	Venezuela, Ecuador, Chile, Guyana, Bolivia, Surinam	Australia; Indonesia	Tunisia, Sudan; Malawi, Chad, Seychelles, NIGERIA; Gambia, Uganda; Angola, Madagascar, Mali, Senegal; Zambia, Cameroon	Saudi Arabia, Afghanistan, Burma, Malaysia
LOW	United Kingdom, Switzerland, Belgium-Luxembourg, Norway; Austria, Cyprus, Germany (Fed. Rep.)	Costa Rica; Trinidad & Tob.; Martinique		Papua New Guinea	Upper Volta; Zaire, Niger, Ivory Coast, Mauritania, Somalia; Liberia, Gabon, Rwanda, Algeria, Central Af. Rep., Congo, Sierra Leone; Togo	Iraq; Lebanon; Kuwait, Singapore; Korea (South)

TABLE 4.4

COUNTRIES ACCOUNTING FOR 90% OF THE MARKET IN EACH REGION

Asia and Australia

Australia
India
New Zealand
Pakistan
Philippines
Thailand

Sub-Sahara Africa

Ghana
Kenya
Nigeria
Mozambique

Europe, North Africa and Middle East

Egypt
Greece
Italy
Portugal
Spain
Yugoslavia

Central and South America

Argentina
Brazil
Mexico

market. Eastern European countries and the Peoples Republic of China were not considered due to trading difficulties.

It is most likely that the demand for PV especially for rural services and telecommunications may exceed PV demand for agricultural applications.

5.0 STRATEGIC RECOMMENDATIONS AND CONCLUSIONS

5.1 Important Market Factors

Previous chapters in this report have generically characterized and analyzed the international PV marketplace with regards to attitudes, policies, financing and market potential. This analysis was supported by evidence gathered from the five countries that were visited. Based on this research, the following factors were judged to have a significant impact on the development of the agricultural PV market and on the strategies employed to penetrate and develop the marketplace.

- Characteristics of PV power: Certain applications, such as water pumping, are best suited for PV's unique power generation profiles. Marketing strategies should be based on those applications that are technically matched with PV rather than initially attempting to change consumer behavior.

- Price: Consumer buying behavior in the developing nations is characterized by high discount rates and consequently very fast payoff times on investments. PV's high initial price will not be appealing to small landholders unaccustomed to life-cycle cost decision making. Price also limits the range of feasible PV applications. Based on country visits, applications below 3KW in size are generally economically competitive with diesel and gasoline power generation today. Therefore marketing PV systems will require a focus on small power applications in agribusiness and medium to large landholder settings.

- Competing Price of Fuels: Energy surplus nations that subsidize their energy cost to the consumer will not be prime private sector PV markets. Feasible PV applications will most likely be 1KW or less in size and located in remote locations away from the grid. This increases marketing costs two ways. First, many more systems will have to be sold to justify a marketing position in this type of country. Second, potential buyers in remote locations are difficult to contact and inform thereby increasing advertising and marketing costs. Sales to the public sector which would evaluate PV applications based on opportunity costs of competing fuels are equally feasible in both energy surplus and energy importing countries.

- Financing: Other than the oil exporting nations, most farmers and agribusiness have limited access to long-term financing. In addition, PV 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. This implies that PV dealers and manufacturers may have to provide financing mechanisms.

- Attitudes and Awareness: Initial PV market entry will be limited by the lack of information by potential customers and the general public on PV systems. Information dissemination through traditional and non-traditional advertising channels will be important in developing the market.

- Fragmented Marketplace: Potential PV customers can range from government financed rural development projects, agribusinesses, cottage industries, to medium sized landholders. Each market segment has an associated buying behavior and value system that the marketing strategy must reflect.

The next few sections describe some of the options that American PV manufacturers, PV dealers and the U.S. Government have open to them in marketing PV systems abroad.

5.2 Strategic Recommendations

From the field visits, it is clear that American PV manufacturers or dealers of PV systems are developing a virgin market that requires innovative marketing tools and an aggressive market strategy. There are six components of a marketing strategy that are important in developing the international photovoltaic market: advertising and information dissemination; financing and pricing; product distribution; product-market fit; product or service availability and trade relationships. Each of these components are described in greater detail in the next few pages. Together they represent a comprehensive approach to marketing PV. These strategies outlined in this report should be considered generic suggestions to PV manufacturers and dealers. The actual market strategies employed would depend significantly on the market characteristics of the individual nations concerned.

5.2.1 Advertising/Information Dissemination

A significant barrier to marketing PV abroad is the lack of information and awareness on the technical and economic advantages of PV systems. Potential users of PV systems, government agencies, current diesel and gasoline engine users, etc., do not have a sense of what PV is and how it can be used. Exacerbating the problem is the inadequacy of information transfer mechanisms in developing countries. Thus, the dissemination of product information in developing countries becomes a complicated and expensive task.

There have been a number of successful agricultural information dissemination programs operating in the developing countries. Most notable among these programs, are those promoting the "green revolution" methods of increasing agricultural yields. Although mounting a similar information dissemination program by an individual company is prohibitive in terms of cost and time; an effective alternative may be an industry financed trade association whose objectives is to promote PV use overseas. This association through briefing of important government officials, advertising, demonstration, etc., would increase the general level of knowledge of PV within the country and help promote US manufactured PV systems. At the same time, the association could send back to subscribers both market information and opportunities.

For the individual company, brand name identification will be an important component of any marketing strategy. This association of name and product could be accomplished through dissemination of company literature, advertising and use of information media found within the country. To effectively reach the potential customer and more importantly create demand for the company's PV product, demonstrations of PV systems 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; thus the advantages of providing high profile PV demonstration units are considerable. First, demonstrations will show farmers the energy and cost saving advantages of PV. Second, demonstrations could disseminate information on where and from whom to buy PV equipment.

Many agricultural research stations also provide training for agricultural extension workers and farmers. One example, the International Rice Research Institute (IRRI) in Laguna, Philippines provides tours to about 20,000 persons from around the world each year. A PV demonstration unit at IRRI would have a high profile and associate a brand name with the product. Similar research institutions focusing on other agricultural products are located in several countries worldwide. Small demonstration units placed with agricultural extension workers may also be an effective marketing tool. Note that any form of demonstration should be constructed to follow closely the agricultural practices currently being introduced into a country, plus, it must be cost-effective.

As a final note, any information dissemination program should account for differences in values, economics and policy within a country. An information program based on an American or European audience may be less effective in a developing country.

5.2.2 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. There are a few solutions to this problem: Some development banks will offer long-term loans at low interest rates but only to 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 financing difficulties is leasing the PV equipment to the customer. Although leasing arrangements are generally not used in the developing countries, there are some advantages of leasing that make it an attractive financial alternative. First, leasing a PV system will spread PV systems costs over a period of years. For a small 1KW system, a year's lease would amount to about $684 comparable to $1049 for leasing, operating and maintaining a 1KW gasoline system (see Table 5.1). Second, leasing programs can be operated by a local distributor who would purchase panels from a US manufacturer and in turn rent the panels to farmers in the area. With this type of arrangement, panels could be rented seasonally, say for water pumping at a significantly lower cost than a gasoline engine and then reused for battery charging when demand for water pumping decreases. The above case is applicable to small scale units which are transportable. Larger units could be leased for five years--a decision-making time frame acceptable to a farmer who would have purchased a conventional power source. Thus, the farmer sees a lower energy cost and does not have to make a 20-year comittment, the U.S. PV manufacturer sells the panel outright, and the dealer realizes a substantial profit. Furthermore, it could be financed by short-term loans. Not only are farmers more familiar with obtaining short-term capital loans, the amount of funds available is also much greater than long-term loan funds. Despite the obvious financial advantages of such an approach, leasing programs must be considered with care. Since most people in developing nations are accustomed to receiving a product in exchange for money, a leasing program may be looked upon with some mistrust. In addition, losses though theft and vandalism may be substantial. However, with all things considered, leasing or lease-buy programs may be one means to increase market size of PV systems by reducing the financial burden on the customer.

Pricing PV units is a complex task since PV is fundamentally different technically and economically from other energy alternatives such as gasoline and diesel generators. Additionally, many consumers in developing countries do not evaluate purchases on a life-cycle basis instead consider first costs or pay back period in making investment decisions. Competition with other PV firms, as well as conventional energy prices, also figures into any pricing decision.

TABLE 5.1

COMPARISON OF A PV LEASING PROGRAM TO THE LEASE OF A GASOLINE ENGINE

	PV SYSTEM	1KW GASOLINE ENGINE
1. Capital Cost ($)	1974[1]	762[2]
2. Operating Cost ($/yr.)	12[3]	642[4]
3. Lifetime (yrs.)	20	5
4. Power Array (KW)	1	1
5. Salvage Value ($)	785[5]	76[6]
6. Depreciation	5 year straight line depreciation	
7. Investment Tax Credit	10%	-
8. Tax Rate	5%	5%
9. Return on Investment	20%	20%
10. Period of Analysis	5 years	5 years
Annual leasing cost	$684	$1049

1) Assuming $1000 for two storage batteries plus $974 for a 1KWp array at 1982 prices of $9.74 per peak watt.

2) Assuming a 1982 price of $762.

3) Operating cost for cleaning is assumed to be 0.02 hrs./day for 300 days per year at $2/per hour for labor.

4) Assuming an operating time of 4 hrs/day and 0.3 gallons of fuel per hour for 300 days at a 1982 price of $1.75 for the gasoline.

5) Salvage value is assumed to be 10% of battery cost plus a 1986 cost of array of $6.85 per peak watt in 1986.

6) Assuming a salvage value of 10% capital cost.

7) Rental Income for Five years $= \frac{1}{1 - \text{tax rate}}$ return on investment
+ capital cost & operating cost
- tax rate (depreciation + operating cost)
- investment tax credit - salvage value)

5.2.3 Product Distribution

Dealers and distributors are an essential and costly component of any successful overseas marketing effort. In the case of PV, the market to date is too small to support an extensive distribution system within any developing country. For an individual company it is clearly out of the question. This does not imply, however, the a PV manufacturer should not try to develop an elementary distribution network within a country.

There are a number of ways in which a distribution network could be established; 1) piggyback on to 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.

Of these three options, a piggyback option may be the most advantageous. Initial sales of PV units will be in the less than 3KW range and initial competition will be with small gasoline and diesel pumps and generators. Given that gasoline costs are high plus government programs to reduce gasoline usage are being pushed in many developing countries, sales of small gasoline and diesel pumps have suffered. Currently, many distributors of pumps and engines would welcome an alternative that would smooth out the sales cycle. From interviews with overseas distributors, the majority expressed interest in carrying PV products as a source of supplemental income to their product line. The advantage of using existing system are twofold. First, the costs of marketing the PV product would be greatly reduced by having the distribution infrastructure already in-place. Second, the existing distribution network has a working knowledge of the marketplace. As a disadvantage, PV systems will be sold as a source of secondary income and may not be given priority by the sales people. This approach would likely be best suited for small complete package systems.

Options Two and Three have the major disadvantage in that they will be expensive to develop and initially less effective in reaching a large proportion of the marketplace population. However, the advantages are that the PV product will receive full attention of the sales people, and a dedicated distribution system to PV will begin. Option Two has an additional advantage over Option Three in that a local entrepreneur would bring to the venture, knowledge about the marketplace. It should be mentioned that many countries do not allow foreign firms to participate in retail sales, however, most nations do allow foreign companies to participate in wholesale trade.

5.2.4 Product-Market Fit

Today's agricultural market for photovoltaics will be limited to small applications, those less than 3KW PV stand-alone systems located away from the utility grid system. These applications includes battery charging, small field irrigation and livestock watering from shallow depths, small grinding mills and small produce coolers. By 1985-86 assuming PV price goals are met, PV could be used in applications requiring 4 to 6 KW of power including deeper well irrigation and livestock watering, larger grinding/milling operations and aquacultural uses.

In offering PV systems to the agricultural community, the PV manufacturer should initially offer small complete package systems that are economically and financially viable as compared to other alternative energy sources. Later as costs drop, the manufacturer should expand product lines to include larger power outputs. Offering an entire range of PV systems from the small to the large may be expensive both in terms of development and inventory. As a rule PV will compete only on those markets in which it has a comparative advantage over other energy sources.

There is also a tendency among new companies marketing new products to fit the customer behavior to the product. In developing countries, there is less likelihood that traditional agricultural practices could be altered to fit the unique characteristics of PV systems. In marketing PV, the systems offered for sale should correspond to farming practice currently in use. As an example, consider the problems of selling a PV powered produce cooler to farmers unaccustomed to refrigerating vegetables, not only does the PV power source have to be sold to the farmer but also the produce cooler. This task would be made simpler if farmers are currently using these systems.

5.2.5 Product and Service Availability

Closely tied to the development of a distribution infrastructure are the problems 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. An an example, after World War II an American manufacturer of diesel engines offered to service any large diesel sold anywhere in the Philippines. The goodwill (and surprise on seeing an American engineer so far from home) to this day has helped this company maintain its market there and become a household name in the Philippines. To generate similar goodwill, the American PV companies should try to offer a complete range of quick maintenance and repair services to all potential customers. Although costly, such service will generate a positive image of the PV industry as a whole and of a company in particular. The same can be said of having a ready supply of PV systems so customers do not have to wait for PV systems to be imported (often a process that takes months).

5.2.6 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 many cases, a manufacturer will forego some incentives offered by developing countries in order to maintain an equity position, protect a patent, 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 advantage of financial, tax and other incentives offered by a developing country may prevent significant market development later as competitors establish themselves in the marketplace.

APPENDIX A

Characterizing Countries with Potential for High PV Sales

The purpose of this Appendix is to classify countries based on the probability of achieving high PV sales in agricultural applications. The procedure used for this classification was to compare several key factors considered important when assessing photovoltaic sales potential. It should be noted that such a classification indicates the relative probability of successful marketing in any particular country. Although these factors that indicate success are well known; the availability and uncertainty of data requires a second best approach to the problem. Therefore, the reader should keep in mind that these assessments should not be substituted for careful market research. However, this classification scheme does aid the manufacturer in selecting countries for further examination. For this purpose, we feel that this classification is the best available.

In order to evaluate countries consistently, a multi-attribute scoring function was devised to reflect the relative importance of each factor to the decisions. Five criteria were viewed as essential for comparison:

1) the financial capability of a country and its farmers to purchase photovoltaics;
2) the need for photovoltaics;
3) the extent of trade, and the ease of trade between the U.S. and respective countries:
4) solar insolation; and
5) the ability of a country to service and maintain conventional power systems.

Data for the analysis is primarily from sources such as the World Bank and United Nations publications.

Surrogate variables used to measure each criteria mentioned above are as follows:

- Financial capability of a country and its farmers is assumed to rely upon four major variables:
  - the value of its agricultural production, since total agricultural products' worth can affect revenue available for PV purchase;
  - the purchasing power of exports, as this can affect a country's economic trends and ability to pay for PV;
  - farmer per capita income, since the private market depends upon farmers with sufficient capital for purchases; and

- the percent agriculture contributes to a country's export earnings, as the importance of agriculture to a country's overall economic structure affects the likelihood of capital investments.[1]

- The need for photovoltaics is dependent upon two important issues: the amount of export earnings used to import energy (this is of special importance when agricultural products make up the bulk of export earnings), and the extent of rural electrification.[2]

- Extent of trade is measured in terms of the dollar volume of U.S. products imported into each country. The second measure used was the number of selective trade barriers existing between the United States and each country, as a means of determining the ease of trade.[3]

- The fourth criteria used was the average solar insolation falling upon a country. Less emphasis was placed on this criteria because (a) most countries had adequate levels of sunshine, (b) available data is often unreliable, and (c) site-specific, rather than country-wide, average values are more important.[4]

- The importance of the final criteria: conventional power system maintainability was stressed to the country study teams, particularly in Nigeria. In Nigeria, extremely low reliability and maintainability of gasoline and diesel engines in the rural areas makes a technology such as PV, with its low maintenance requirements, very valuable. In instances such as this, where capital is available and/or the crop's value worthy of investment, photovoltaics become a realistic alternative source of energy despite the current use of gasoline or diesel engines.

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[1]Data for these variables was obtained and/or computed from the World Bank Tables, 1980, and the United Nation's Handbook of International Trade and Development Statistics, Supplement, 1980.

[2]The amount of money spent by countries importing fuels was obtained from the United Nation's Handbook of International Trade ... (Ibid) and compared to each country's export earnings (same source). Data for the extent of rural electrification came from the World Bank/International Finance Corporation's 1977 power sector data. Additional percentages were obtained from an unpublished World Bank transcript titled "Summary of 1978 Power Sector Data for LDC's".

[3]Importation of power generating equipment was obtained from the United Nation's Commodity Trade Statistics. A PRC Energy Analysis Company and DHR, Inc. report to the Solar Energy Research Intitute titled, "Prospects for Foreign Applications of Wind Energy Systems" (July 1981), was used for enumeration of selective trade barriers.

[4]Annual sunshine hours were obtained primarily from isopleths on H.E. Landsberg's maps "Total Hours of Sunshine (Annual)" in World Maps of Climatology (1966). This was compared, when possible, to solar radiation figures presented in A.I. Voeikov's Solar Radiation and Radiation Balance Data; The World Network (1964-68).

The criteria, however, is difficult to analyze statistically because data of this type can only be gathered reliably by in-country field visits. Since field visits could not be made to all countries, rankings were based upon the percent of active employment in manufacturing. High percentages indicate more persons familiar with engines and machines, as well as accessability to manufactured or imported machine parts.[1]

The multi-attribute procedure used to rank countries is described at the end of this Appendix. The relative importance of the criteria was subjectively determined with financial capability and the need for photovoltaics considered the most important. Ease of trade, solar radiation and diesel maintainability received lesser emphasis in the order given. Results of the charting process were given in Table 4.3 Criteria scores are given at the end of this Appendix. The Table shows countries ranked within regions and spaced according to the score received in the ranking process.[2]

Table 4.3 in Chapter 4, is adequate for obtaining a first approximation of countries with likely potential for photovoltaic marketing. However, the table is only as good as the available data, and in some cases inaccurate aggregate and country-wide average statistics may not correctly predict the suitability of a country for PV markets. A country ranked as "low" on the chart might still be a good potential market. Data, weighting procedure, and scores used for ranking have been provided so readers can reach their own conclusions.

Bangladesh, for instance, ranks within the upper third of the countries even though its farmer per capita income is very poor. This is because the value of its agricultural production is high; agriculture contributes nearly 40% to total export earnings with the same amount of earnings spent on imported energy, and only 2% of its rural population is served by electrical grid systems. Much the same pattern exists for Brazil, ranked at the very top of the chart, except its farmer per capita earnings are eight times higher than those in Bangladesh.

Countries which fall into the lowest grouping either have little need for photovoltaics (as many of the European countries), their agricultural production is of little value compared to other countries, and/or their financial capability is severly limited (as many of the Sub-Saharan and Central American countries).

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[1] Manufacturing employment figures were obtained from the World Bank's World Development Report, 1980.

[2] Centrally planned economics and countries whose current state of affairs precludes U.S. trade relationships have been omitted from the chart, as have a number of smaller countries and islands for which data was lacking.

A.1 Comparisons from Case Studies with Classifaction.

Case studies developed from extensive field visits to Morocco, Mexico, Colombia, Nigeria, and the Philippines during the course of this project indicate mixed success of this generalized classification scheme in being able to predict accurately the potential market for stand-alone PV systems in agriculture. This section will indicate the findings of the field study teams in countries visited in comparison to the ranking in classification.

Morocco: Morocco is ranked within the high group of countries, second only to Kenya in the African region. The major factors appear to be a high score for value of agricultural contribution relative to GDP, and high score for percent of export earnings spent on energy. These two factors are weighted highly in the classification scheme. Nonetheless, the case study results indicate a rather poor market for PV with the maximum size over the years estimated to be 340 KWp. This represents little or no market for agricultural applications, a slightly better prospect for other rural sector service applications and the primary focus in the area of telecommunications and signalling.

While there are clear needs in Morocco to supply power to remote agricultural projects, the case study indicates that within the next five years no power use will be established in many of these sites. For public sector applications, severe budget limitations will constrain use of PV systems even when greater reliability compared with diesel systems is a factor. High initial capital costs of PV systems will be a significant barrier. In the case of private sector uses of power in Moroccan agriculture, with the exception of mobile power use (i.e., tractors and combines), power use is limited to water pumping for irrigation. With the deep water table of most Moroccan applications, PV systems will not be cost-competitive within the next five years.

Morocco, with indigenous manufacture of diesel systems, presents a situation when only stand-alone systems of 1-2 KW (e.g., irrigation from very shallow wells, or portable water supplies for very small villages) will be competitive. Within this range, the smallest diesel systems available are significantly underutilized. While private sector operation of small diesel systems appear to be maintained because the individual's livelihood depends upon it, in the public sector experience is not often good. Although PV systems may be chosen for these applications, cost constraints in a developing country like Morocco will militate against them.

In summary, the classification scheme did not take into account the nature of power use in agriculture in Morocco which is either non-existent or of a greater magnitude than cost-effective for PV systems within the next five years. The non-agricultural applications favorably indicated are those which expressly rely on the characteristic strengths of PV systems, or require very small amounts of power--the types of systems presently cost-effective in the United States.

Mexico: Mexico is ranked within the middle group of countries, between Canada and Jamaica in the North American region. According to the case study report, the market for PV in agriculture during the next five years will be 300-605 KWp. In terms of actual market for PV this may be an overestimate since it is based on opportunity cost of diesel and gasoline rather than the present subsidized fuel costs within the country. While strong government activity exists within the rural sector, energy is cheap in Mexico and the electric grid is extensive. Even if this estimate is approximately accurate for the PV market, American manufacturers should be cautioned that Mexico is probably the Third World country which is most advanced in PV technology. There is also a policy to keep it highly diversified with regard to solar technologies and with regard to specific suppliers. Thus, no firm should believe they will have much of an opportunity to corner the market.

Nigeria: Nigeria is ranked with the middle group of countries, on the same level as the Seychelles within the African region but according to the case study, the potential market for the next five years will be within 1.9 and 4.7 MWp for the agricultural sector and rural services. This sizeable market is based on the high availability of capital and the premium placed on high reliability, low maintenance systems. This points out clearly the fact that the classification on one hand weights maintainability rather low, and it may be a very significant factor, and the availability of capital to drive the market may be a highly vulnerable aspect of the market assessment. The market will consist primarily of government-funded, small power applications and government communications projects with some sales going to affluent individuals and corporations. The first factor, capital availability, is tightly linked to the level estimated in January, 1981, with consequent reductions in revenues. Apparently, funds for rural development projects have been severely curtailed for the present, and if one were estimating the market for PV in Nigeria today for the next five years, one might get a different picture, with a much reduced size.

Philippines: The Philippines falls in the high group of countries in the rankings, on the same level as Sri Lanka in the Asian region. Its high ranking is based on high value of agricultrual contributions to GDP and on a high percent of export earnings spent on energy. Market size for PV in the 1981-1986 time frame was estimated between 60KWp and 700KWp in the case study. However, if capital availability for financing PV systems does not increase, the lower figure, or a less favorable one, will prevail. That is, cost-competitive applications for PV based on high cost of conventional energy supplies are present in significant volume in the Philippines, but actual market will depend on availability of adequate amounts of capital for long-term financing of these systems in the private sector.

Colombia is ranked high using the ranking procedure described earlier. This is due mostly to the large agricultural contribution to GDP, poor rural electrification and high imports of U.S. made power generating equipment. These factors were recognized immediately during the conduct of the field study.

The assessment of the market size indicates that somewhere between 1200 and 2500 KWp of PV equipment may be sold in Colombia between the years 1981 and 1986. The large range in these figures are a reflection of the great needs that exists but also the uncertainty of the possible market due mostly to shortage of long-term financing and a lack of awareness of PV technology and its capabilities.

The classification scheme presented here has been demonstrated to have modest success in correlation with conclusions of case studies based on field visits to a number of countries. The classification represents an attempt to rank countries in terms of potential market for PV based on aggregated data available from donor agencies and other international organizations. Most importantly, there is some indication that most critical factors in rating the PV market potential for a country must be based on significant knowledge of a wide variety of factors for the country in question. Critical factors enhancing or limiting PV markets may be quite country-specific and may be stronger than those factors considered in the general ranking.

APPENDIX A - ANNEX 1

Explanation for weighting formula for Table A.1

The total score awarded a country was based upon a weighting formula where the total equaled the sum of: financial capability score + need for photovoltaic score + conventional power maintainability score. Of a total 100 scoring points for all charted variables, financial capability and need for photovoltaics were weighted most heavily, each representing 35% of the total score. Ease of trade was weighted at 15%, solar radiation at 10%, and conventional power system maintainability at 5%. Many of these five major components had various sub-categories, and the formula for assessing scores is ennumerated below.

Financial Capability (possible total of 35 points)

value ag. contributes to GDP...

over $1 billion	=	high	(15 points)
$300 million to $1 billion	=	med	(7.5 points)
less than $300 million	=	low	(0 points)

purchasing power of exports since 1975...

low and decreasing	=	poor	(0 points)
low and steady	=	poor	(0 points)
low and increasing	=	fair	
medium and decreasing	=	poor	(0 points)
medium and steady	=	fair	(1.25 points)
medium and increasing	=	good	(2.5 points)
high and decreasing	=	fair	(1.25 points)
high and steady	=	good	(2.5 points)
high and increasing	=	good	(2.5 points)

ag. laborer GDP per caput...

$7,242 to $35,145	=	highest	(15 points)
$1,513 to $6,130	=	high	(10.75 points)
$1,000 to $1,338	=	med	(7.5 points)
$556 to $982	=	low	(3.75 points)
$52 to $500	=	poor	(0 points)

% ag. contributes to export earnings...

66% to 100%	=	great	(2.5 points)
33% to 65%	=	med	(1.25 points)
0 to 32%	=	little	(0 points)

Need for Photovoltaics (possible total of 35 points)

% export spent on energy...

33% to 100%	=	great	(17.5 points)
20% to 32%	=	med	(8.75 points)
0 to 19%	=	little	(0 points)

extent rural electrification (% served)...

50% to 100%	=	good	(0 points)
30% to 49%	=	fair	(8.75 points)
0 to 29%	=	poor	(17.5 points)

Ease of Trade (possible total of 15 points)

import from United States ...

over $25 million	importation from U.S. =	much	(10 points)
$10 to $25 million	importation from U.S. =	some	(6.6 points)
$1 to $10 million	importation from U.S. =	little	(3.3 points)
$0 to $1 million	importation from U.S. =	none	(0 points)

ease of import trade ...

Ease of import index reflects three potential import barriers: import restrictions; licensing requirements; and exchange controls. For each country a separate score of zero or one was assigned to each barrier. A score of "0" indicates a barrier exists in that country, while a score of "1" means that it does not. Thus a country with an ease of import index value of "0" has been found to possess all three barriers. While an index value of "1", "2", or "3" are indications of the absence of barriers. Therefore ...

3	=	easiest	(5 points)
2	=	easy	(3.3 points)
1	=	awkward	(1.6 points)
0	=	difficult	(0 points)

Solar Annual Sunshine (possible total of 10 points)

solar annual sunshine...

2800 - 4000 hours	=	high	(10 points)
2000 - 2600 hours	=	med	(5 points)
1200 - 1800 hours	=	low	(0 points)

Conventional Power System Maintainability (possible total of 5 points)

conventional power system maintainability...

based on active employment within the manufacturing segment

21% to 57%	=	good	(0 points)
11% to 21%	=	fair	(2.5 points)
2% to 9%	=	poor	(5 points)

APPENDIX B

Agricultural Sector Market Size Estimates*

Asia and Oceania	Range of Agricultural Sector Market Size (KWp)	
India	1900	9000
Australia	1500	7000
Philippines	260	1300**
Thailand	240	1200
Pakistan	220	1100
New Zealand	200	1000
Indonesia	300	600
Syrian Arab Rep	130	600
Korea Rep	80	400
Bangladesh	60	300
Taiwan	60	300
Saudi Arabia	90	180
Malaysia	80	160
Sri Lanka	25	130
TOTAL	5145	23270

Sub-Sahara Africa		
Kenya	30	170
Ghana	30	150
Nigeria	70	140***
Mozambique	25	120
TOTAL	155	580

*Lists only countries with upper bounds greater than 100KWp.

**Estimate based on in-country study ranged from 60 to 700KWp with an average market size of about 200KWp.

***Nigeria is an anomaly since historically low agriculture sector energy use does not reflect ambitious plans to develop the agricultural sector. Market size estimate based on in-country study was about 1.9-4.7 MWp.

Europe, Middle East and North Africa	Range of Agricultural Sector Market Size (KWp)	
Yugoslavia	700	3700
Italy	1500	3000
Spain	700	1500
Egypt	300	1500
Greece	300	1500
Portugal	200	800
Israel	150	700
Morocco	90	450*
Turkey	60	300
Jordan	30	130
Algeria	20	100
TOTAL	4050	13680

*In-country survey estimate was about 340 KWp with only a small agricultural sector market.

Central and South America

Brazil	1600	8000
Argentina	800	4000
Mexico	750	1500*
Colombia	300	1500*
Peru	180	900
Venezuela	300	700
Uruguay	50	250
Chile	90	200
Dominican Republic	40	200
Guatemala	30	150
Panama	30	150
TOTAL	4170	17550

*In-country survey estimate for Mexico was 605 KWp. In-country estimate for Colombia ranged from 1.2 to 2.5 MWp.

REGION	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
NORTH AMERICA Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Barbados	0	0	10.75	1.25	17.5	0	10	1.6	10	0	51.10
Canada	15	2.5	15	0	0	0	10	5	0	0	47.50
Costa Rica	7.5	1.25	10.75	2.5	0	0	10	3.3	5	0	40.30
Dominican Rep.	7.5	0	3.75	2.5	17.5	17.5	10	0	10	2.5	71.25
Guadelope	0	0	7.5	2.5	0	8.75	3.3	1.6	5	2.5	48.65
Guatemala	15	0	7.5	2.5	0	17.5	10	3.3	5	5	61.60
Haiti	7.5	0	0	1.25	0	17.5	10	3.3	5	5	49.55
Honduras	7.5	1.25	8.75	2.5	0	17.5	6.6	3.3	10	2.5	54.90
Jamaica	0	0	10.75	0	17.5	0	10	0	5	2.5	43.25
Martinique	0	1.25	8.75	1.25	17.5	0	0	0	5	2.5	31.25
Mexico	15	1.25	7.5	1.25	0	0	10	1.6	10	0	46.[illegible]
Nicaragua	7.5	1.25	7.5	2.5	0	17.5	10	0	5	2.5	51.75
Panama	7.5	0	10.75	1.25	17.5	0	10	5	5	2.5	59.50
Trinadad & Tobago	0	1.25	7.5	7.5	0	8.75	10	0	5	[illegible]	32.50

REGION	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
SOUTH AMERICA Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Argentina	15	2.5	10.75	2.5	0	17.5	10	0	5	0	63.25
Bolivia	7.5	1.25	0	0	0	17.5	10	3.3	10	0	49.55
Brazil	15	1.25	7.5	1.25	17.5	17.5	6.6	1.6	5	0	73.20
Chile	7.5	2.5	3.75	0	0	17.5	10	0	10	0	51.25
Colombia	15	1.25	10.75	2.5	0	17.5	10	0	5	0	62.00
Ecuador	15	1.25	3.75	1.25	0	17.5	6.6	1.6	5	0	51.95
Guyara	0	0	10.75	1.25	8.75	17.5	10	0	0	2.5	50.75
Paraguay	7.5	1.25	7.5	2.5	8.75	17.5	6.6	1.6	5	2.5	60.70
Peru	15	2.5	3.75	1.25	8.75	17.5	10	0	10	0	68.75
Suriname	0	0	10.75	0	17.5	8.75	10	0	0	2.5	49.50
Uruquay	15	0	10.75	0	0	8.75	6.6	3.3	5	0	71.90
Venezuela	15	0	10.75	0	0	8.75	10	3.3	5	5	52.80

REGION	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
AUSTRALIA & S. PACIFIC Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Australia	15	2.5	15	1.25	0	0	10	3.3	10	0	56.10
Indonesia	15	1.25	0	0	0	17.5	3.3	3.3	0	2.5	42.85
New Zealand	15	1.25	15	2.5	0	8.75	10	1.6	5	0	59.10
Papua New Guinea	7.5	1.25	0	1.25	0	8.75	3.3	3.3	5	5	35.35

REGION	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
AFRICA Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Algeria	7.5	1.25	0	0	0	8.75	3.3	0	10	0	30.80
Cameroon	7.5	1.25	0	1.25	0	17.5	3.3	1.6	5	5	42.40
Cen. Afr. Regs.	0	1.25	0	1.25	0	17.5	0	0	5	5	30.00
Chad	0	0	0	2.5	17.5	17.5	0	0	10	5	52.50
Cong	0	0	7.5	0	0	17.5	3.3	1.6	0	0	29.90
Egypt	15	0	3.75	1.25	0	17.5	6.6	5	10	0	59.10
Ethiopia	15	1.25	0	2.5	0	17.5	6.6	1.5	10	5	59.45
Gabon	0	1.25	3.75	0	0	17.5	3.3	1.6	0	5	32.40
Gamora	0	0	0	2.5	0	17.5	10	3.3	10	5	48.30
Ghana	15	1.25	7.5	2.5	0	17.5	6.6	0	5	2.5	57.85
Ivory Coast	7.5	1.25	0	2.5	0	17.5	3.3	0	0	5	37.05
Kenya	15	1.25	0	2.5	8.75	17.5	6.6	3.3	5	5	64.90
Liberia	0	0	0	1.25	0	17.5	10	1.6	0	2.5	32.85
Libya	7.5	1.25	10.75	0	0	17.5	3.3	3.3	10	0	53.60
Madagascar	7.5	0	0	2.5	0	17.5	3.3	0	10	5	45.80
Malawi	7.5	0	0	2.5	8.75	17.5	0	1.6	10	5	52.85

REGION	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
AFRICA (Con't.) Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Mali	0	1.25	0	2.5	8.75	17.5	0	0	10	5	45.00
Mauritania	0	0	0	0	0	17.5	3.3	0	10	5	35.80
Morocco	15	0	3.75	1.25	8.75	17.5	3.3	0	10	2.5	62.05
Mozambique	15	0	0	2.5	8.75	17.5	3.3	1.6	10	2.5	61.15
Niger	0	1.25	0	1.25	0	17.5	3.3	0	10	5	38.30
Nigeria	15	1.25	8.75	0	0	17.5	6.6	0	[illegible]	2.5	51.60
Rwanda	0	1.25	0	2.5	0	17.5	0	0	5	5	31.25
Senegal	7.5	0	0	1.25	0	17.5	3.3	0	10	5	44.55
Seychelles	0	1.25	7.5	2.5	17.5	17.5	0	3.3	0	2.5	52.05
Sierra Leone	0	1.25	0	0	0	17.5	3.3	0	5	2.5	29.55
Somalia	0	0	0	2.5	0	17.5	0	0	10	5	35.00
Sudan	15	1.25	0	2.5	0	17.5	3.3	0	10	5	54.55
Tanzania	15	1.25	0	2.5	8.75	17.5	3.3	1.6	5	5	59.90
Togo	0	0	0	1.25	0	17.5	0	0	5	2.5	26.25
Tunisia	15	2.5	0	2.5	0	17.5	0	0	5	5	47.50
Uganda	0	0	0	2.5	8.75	17.5	0	0	10	2.5	41.25

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REGION	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
AFRICA (Con't.) Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Upper Volta	0	0	0	2.5	8.75	17.5	0	0	10	2.5	41.25
Zaire	7.5	1.25	0	0	0	17.5	3.3	1.6	5	2.5	38.65
Zambra	7.5	0	0	0	0	17.5	3.3	1.6	10	2.5	42.40

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REGION ASIA	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Afghanistan	7.5	1.25	0	2.5	0	17.5	3.3	1.6	10	5	48.65
Bangladesh	15	2.5	0	1.25	17.5	17.5	3.3	1.6	10	2.5	71.15
Burma	15	2.5	0	2.5	0	17.5	3.3	0	5	2.5	48.10
India	15	1.25	0	1.25	8.75	17.5	6.6	0	10	2.5	62.85
Iraq	7.5	0	3.75	0	0	17.5	3.3	0	10	0	42.05
Israel	7.5	1.25	15	0	8.75	0	10	5	10	0	57.50
Jordan	0	1.25	3.75	0	17.5	17.5	6.6	0	10	0	56.60
S. Korea	15	1.25	7.5	0	0	0	3.3	1.6	5	0	33.65
Kuwait	0	0	0	0	0	17.5	6.6	3.3	10	0	37.40
Lao	0	1.25	0	2.5	17.5	17.5	0	0	5	5	48.75
Lebanon	0	0	10.75	0	0	8.75	6.6	3.3	10	0	39.40
Malaysia	15	2.5	7.5	1.25	0	8.75	3.3	3.3	5	2.5	49.10
Pakistan	15	2.5	0	1.25	17.5	17.5	3.3	0	10	2.5	69.55
Philippines	15	1.25	3.75	1.25	17.5	17.5	6.6	0	0	2.5	63.35
Saudi Arabia	7.5	1.25	0	0	0	17.5	10	1.6	10	2.5	50.35
Singapore	0	1.25	10.75	0	8.75	0	6.6	5	5	0	37.35

REGION — ASIA (Con't.)	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Sri Lanka	15	2.5	0	2.5	8.75	17.5	6.6	0	10	2.5	65.15
Syria	15	1.25	7.5	0	17.5	17.5	3.3	0	10	0	72.05
Thailand	15	1.25	0	1.25	8.75	17.5	3.3	1.6	5	5	58.65
Yemen Arab Rep.	7.5	1.25	1.75	2.5	17.5	17.5	3.3	1.6	10	2.5	67.40

REGION	FINANCING CAPABILITY				NEED FOR PV		TRADE		SOLAR		
EUROPE Country	Value ag. Contributes To GDP	Purchasing Power of Exports Since 1975	Ag Labor GDP per Caput	% ag contributes to export Earnings	% Export Earnings Spent on Energy	Extent Rural Electr. (% Served)	Extent Of Trade	Ease of Import Trade	Annual Sunshine Hour	Conventional Power system Maintainability	Total Score
Austria	15	1.25	15	0	0	0	3.3	1.6	0	0	36.15
Belgium-Lux.	15	1.25	15	0	0	0	3.3	5	0	0	39.45
Cyprus	0	2.5	7.5	1.25	8.75	0	3.[illegible]	1.6	10	0	34.90
Denmark	15	1.25	15	1.25	8.75	0	3.3	5	0	0	49.55
Finland	15	1.25	15	0	8.75	0	3.3	3.3	0	0	46.60
Greece	15	1.25	10.75	1.25	17.5	0	3.3	1.6	5	0	59.90
Ireland	15	1.25	10.75	1.25	0	0	6.6	3.[illegible]	0	0	44.10
Italy	15	1.25	10.75	0	8.75	0	3.3	1.6	5	0	49.90
Netherlands	15	1.25	15	0	8.75	0	3.3	5	0	0	48.30
Norway	15	1.25	15	0	0	0	3.3	3.3	0	0	37.85
Portugal	15	1.25	10.75	0	17.5	0	3.3	0	10	0	62.05
Spain	7.5	1.25	0	0	17.5	0	6.6	0	10	0	42.85
Sweden	15	0	15	0	8.75	0	3.3	5	0	0	48.30
Switzerland	15	0	15	0	0	0	3.3	5	0	0	39.55
Turkey	15	1.25	3.75	2.5	17.5	8.75	3.3	0	5	2.5	59.55
United Kingdom	15	1.25	15	0	0	0	6.6	3.3	0	0	41.15