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Near-Term Foreign Market Potential for U.S. Photovoltaic System Manufacturers

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ABSTRACT

Foreign markets for photovoltaic systems may be attractive in the near term for U.S. manufacturers. The potential for sales of U.S. manufactured photovoltaic systems abroad appears to be of the order of 10-20 GWp peak. This represents the potential for U.S. industry in supplying photovoltaic systems to rural areas--villages and farms--of 81 developing countries throughout the world.

It was found that maximum benefit to the U.S. photovoltaics industry would be obtained if this foreign trade took the form of exporting as opposed to other possible modes of trade.

Other issues were considered, including system costs, priorities, and the ability to pay in the context of the developing countries; competition from other photovoltaics-producing countries and from other technologies; and information gaps which need to be filled by industry in order to address these markets successfully.

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SECTION I

SUMMARY AND CONCLUSIONS

This study was conducted to estimate the potential foreign market for U.S. photovoltaic manufacturers as a factor contributing to the growth of the photovoltaic industry in the United States. Estimates were made of the potential near-term foreign market and the portion of that market that might be open to U.S. manufacturers of these systems. The estimate of market potential takes into account the likely energy growth in the individual countries and the historical U.S. market share of these foreign markets. Section III addresses other issues and uncertainties that affect the ability of the U.S. manufacturers to realize this market potential.

Near-term markets for photovoltaic systems at system prices generally higher than those required for mass markets in the U.S. are important. These markets would help encourage U.S. manufacturers to invest in the production capacity needed to achieve system prices low enough to compete with conventionally generated utility electricity.

The most probable near-term foreign markets were estimated by first determining electricity prices in a sample of 21 countries. Industrialized and nonindustrialized countries in Europe, Asia, Africa, and North and South America were selected for this preliminary screening. Most industrialized countries have much the same electricity price structure as the U.S. Large near-term market penetrations in these industrialized countries are subject to the

same or similar competition from utility-generated electricity as in the U.S. In nonindustrialized nations, urban areas are served by central power generation. Although prices are higher than in industrialized nations, many of the same hurdles remain to market penetration by photovoltaics.

Rural areas of developing countries are the primary near-term foreign marketing targets. These areas are not presently served by central electricity generating facilities. Also, the costs for connection to utility or for providing other remote generation may be competitive with photovoltaic systems.

Rural areas of 81 developing countries were studied and estimates were made of current population with no access to grid electricity. A village model was adopted to estimate energy needs. The model was applied to each of the 81 countries, taking into account variations due to local climate and agricultural conditions. Based on this model and the population estimates, a market potential for photovoltaic systems was estimated for each country.

By summing the potentials for the 81 countries, a total potential market of 93 GWp was estimated for rural electric systems outside of the U.S. in 1979. If left unfulfilled, this market would be about 140 GWp by the year 2000.

By examining existing patterns of trade between U.S. companies and the 81 developing countries, it was concluded that U.S. industry would lose a portion of this potential to energy system manufacturers

from other countries. The market potential available to U.S. manufacturers was estimated to be 16 GWp in 1979 and 14 to 25 GWp in 2000.

Of the 81 countries studied, six countries represented about two-thirds of the U.S. market potential. These are located in the Americas (Brazil and Mexico), in Africa (Nigeria and Zaire), and in Asia (Bangladesh and India*). Asia represents more than half the potential market. The balance of the market potential for U.S. manufacturers (about 5 GWp total in 1979) is distributed among the remaining 75 countries.

The period during which a market potential exists that is sufficient to have a meaningful impact on the growth of the U.S. photovoltaics industry may be limited. Aggressive rural electrificacion programs, competition from conventional and other solar technologies, and population migration toward urban areas could conceivably cause a reduction in market potential by 2000. There could also be delays inherent in establishing foreign trade of substantial magnitude.

Examination of various modes of foreign trade suggests that maximum benefit to the U.S. photovoltaics industry may be obtained through a product export program in which infrastructure development and expenditures for capital facilities, labor, and materials take

*Although India is now supporting an internal photovoltaic development program, MITRE knows of no production capacity in India.

place in the U.S. Modes of trade other than product export would benefit individual manufacturers but not necessarily the entire U.S. photovoltaics industry.

Other issues could significantly affect the outcome of any foreign marketing venture.

Developing countries represent not only marketing opportunities but also unique problems in addressing those opportunities. The real costs of doing business would increase the installed price of imported (i.e., exported from the U.S.) photovoltaic systems. National priorities may preclude investments in photovoltaic systems although such systems could contribute to reduction in the undesired growth of urban population. Foreign exchange to pay for photovoltaic systems could be difficult to obtain.

The effects of competition could limit markets for photovoltaic systems. Technological parity among nations could increase the number of competitive nations beyond the number accounted for in this study.

Photovoltaic systems may have to share the stated market potential with other advanced technology systems. Cultural and historic ties with other photovoltaics-producing nations may reduce market potential for U.S. producers.

Gaps may exist in the detailed information needed by U.S. manufacturers to successfully address foreign markets. In-depth market analysis of high potential regions is needed, market interests and

priorities must be understood, costs for competitive technology must be understood, and assessments of the real cost of doing business must be made.

SECTION II

METHODOLOGY

Twenty-one sample countries were analyzed to determine the scope of this investigation. The number of countries was then expanded. The analysis was performed in four steps:

1. Countries were selected and screened.

2. The total foreign photovoltaic market potential was estimated.

3. The total foreign photovoltaic market potential that might be addressed by the U.S. photovoltaic industry was estimated. In this analysis, total U.S. market potential has been defined as the largest possible photovoltaic market that might be available for near-term penetration by the United States photovoltaic industry. Communist countries have been excluded.

4. Estimates from steps 2 and 3 were extended to the year 2000.

SELECTION AND PRELIMINARY SCREENING OF SAMPLE COUNTRIES

The twenty-one sample countries chosen represent a broad range of geographic locations (see Figure 1), insolation level, population size and economic development. A preliminary screening of the 21 countries was performed to determine the photovoltaic market potential. It was assumed that a country with photovoltaic market potential must have a relatively high insolation level and a relatively high cost of electricity from alternative energy sources. A high insolation level improves photovoltaic system cost effectiveness and reduces the cost of energy produced. The high cost of electricity would improve the economic viability of photovoltaic systems.

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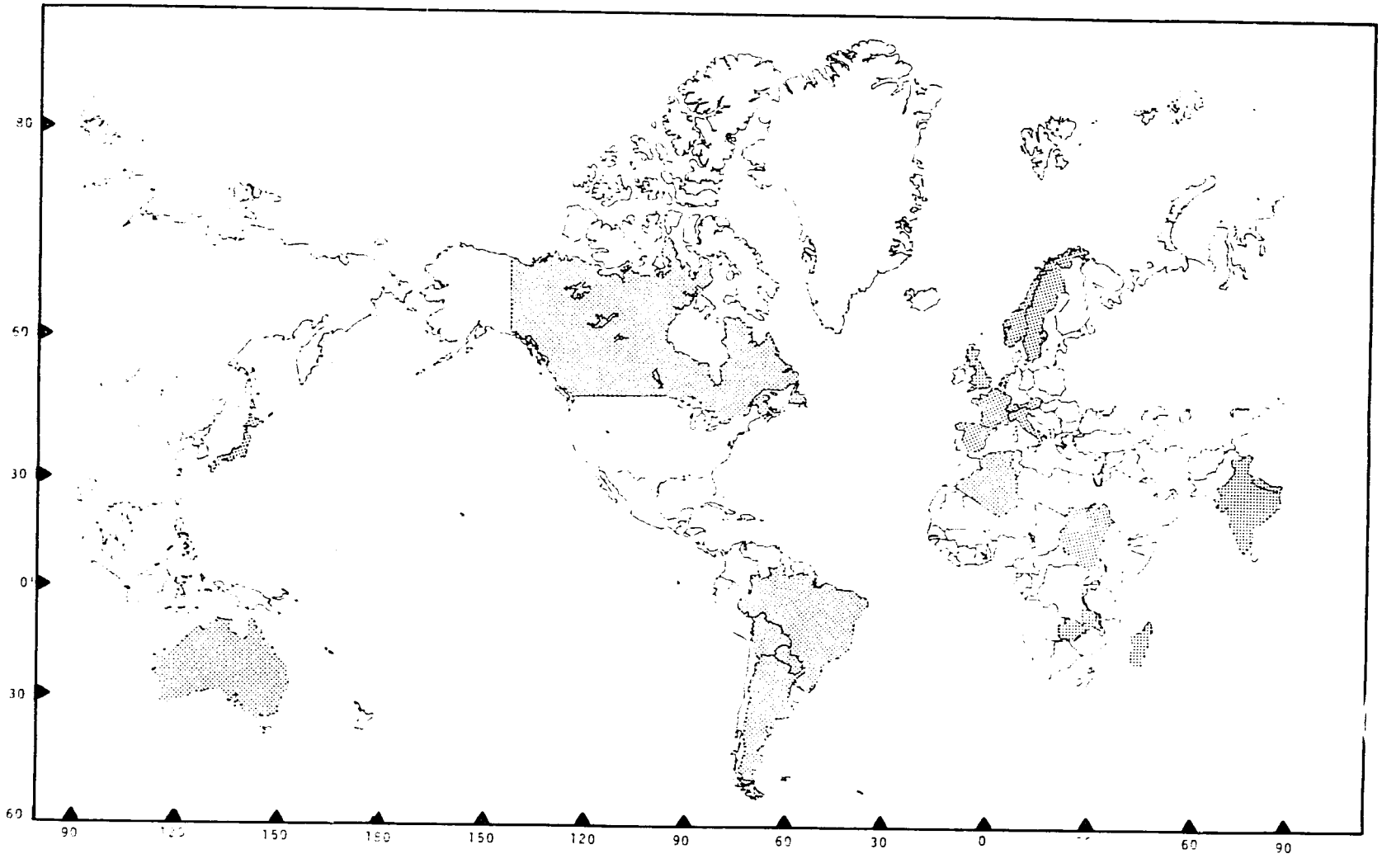

FIGURE 1
THE TWENTY-ONE COUNTRIES IN THE INITIAL SAMPLE

As indicated in Tables I through III, the industrialized countries in the sample have relatively low insolation and electricity prices which indicate a relatively low market potential. In industrialized countries, suppliers of photovoltaic systems would have to face the same types of economic competition as in grid-connected areas of the U.S. Markets in industrialized countries would not be available for penetration by photovoltaic systems any earlier than would the mass markets in the U.S. The remainder of the analysis, therefore, focuses on the photovoltaic market potential in developing countries.

TOTAL PHOTOVOLTAIC FOREIGN MARKET POTENTIAL IN 1979

As a result of the preliminary screening of the 21 sample countries, it was concluded that developing countries could represent a viable, near-term market for the U.S. photovoltaics industry. To quantify the market, however, more countries and more detailed information were needed. A list of 81 developing countries* was compiled from World Bank statistics (see Figure 2).

To quantify the foreign market potential, the following factors were considered for each of the 81 countries:

- population that could use photovoltaic systems
- per capita electricity needs
- per capita collector requirements

*Noncommunist countries with over 1 million inhabitants.

TABLE I

INSOLATION LEVELS IN THE TWENTY-ONE SAMPLE COUNTRIES
(Langleys Per Day)

COUNTRY	AVERAGE
United States	387
Austria	260
Belgium	218
France	308
Italy	332
Netherlands	227
Norway	190
Spain	380
Sweden	220
Switzerland	335
United Kingdom	213
Australia	426
Canada	285
Japan	308
Africa	
Algeria	500
Madagascar	500
Sudan	490
Tunisia	440
Zambia	425
Asia	
India	500
South America	
Argentina	395
Brazil	417

Source: World Distibution of Solar Radiation, Report No. 21. Solar Energy Laboratory, The University of Wisconsin. July 1966.

TABLE II

ELECTRICITY PRICES IN SAMPLE DEVELOPED COUNTRIES*
(Constant in 1978 U.S. Cents)

COUNTRY	1968	1969	1970	1971	1972	1973	1974	1975	1976
Austria	1.40	1.33	1.12	1.20	1.35	2.88	3.30	4.92	5.26
Belgium	1.76	1.88	1.95	2.33	2.49	3.09	3.61	5.91	6.05
France	1.66	1.77	1.71	1.89	2.29	3.09	3.35	4.93	5.08
Italy	2.02	1.83	1.95	2.08	2.22	2.45	2.46	4.27	5.79
Netherlands	1.03	1.16	1.24	1.45	1.62	2.37	2.34	4.35	5.26
Norway	0.93	1.00	1.30	1.39	1.55	2.02	2.38	3.37	3.33
Spain	1.35	1.44	1.89	2.15	2.29	3.02	3.38	4.27	5.26
Sweden	1.09	1.16	1.24	1.32	1.41	1.73	1.77	2.54	3.33
Switzerland	1.19	1.27	1.24	1.45	1.68	2.59	2.84	3.86	4.38
United Kingdom	1.14	1.22	1.30	1.45	1.75	2.16	2.15	3.04	3.76
Canada	1.86	1.99	2.30	2.46	2.62	3.17	3.84	4.43	4.73
Japan	0.98	1.05	1.12	1.20	1.68	1.94	2.31	2.71	4.03
Australia**	----	----	----	----	----	----	----	----	4.09

*Average price paid per KWH at the 1st of January for an annual consumption of 3600 KWH, domestic and industrial users.

**Average price per KWH in the state of New South Wales in 1978. Residential only.

Source: Energy Statistics, OECD 1974/76, 1978. The prices shown are converted from U.S.$/$10^7$ Kcal to U.S.$/kWh.

TABLE III

RESIDENTIAL ELECTRICITY PRICES IN SAMPLE DEVELOPING COUNTRIES
(Constant 1978 U.S. Cents)

COUNTRY	PRICE (Cents/kWh)	NOTES
Africa		
Algeria	8.79	Average price in 1975
Madagascar	15.00	Average price in 1978
Sudan	39.80	Off peak rate, 1978
	103.0	Critical hours, 1978
Tunisia	8.93	Average price in 1978
Zambia	14.43	Prices in 1976. Fixed charges of 2.19 cents/kv/month not included.
Asia		
India		Information on prices not sufficient
South America		
Argentina	7.8	With a consumption of 2.5 kWh/months, 1978
	4.9	With a consumption of 100 kWh/months, 1978
	8.0	With a consumption of 400 kWh/months, 1978
Brazil	6.13	With a consumption of >30 kWh/month. Base price (<30 kWh/month) is 138 cents.

Sources: Regional Offices, The World Bank, Washington, D.C.

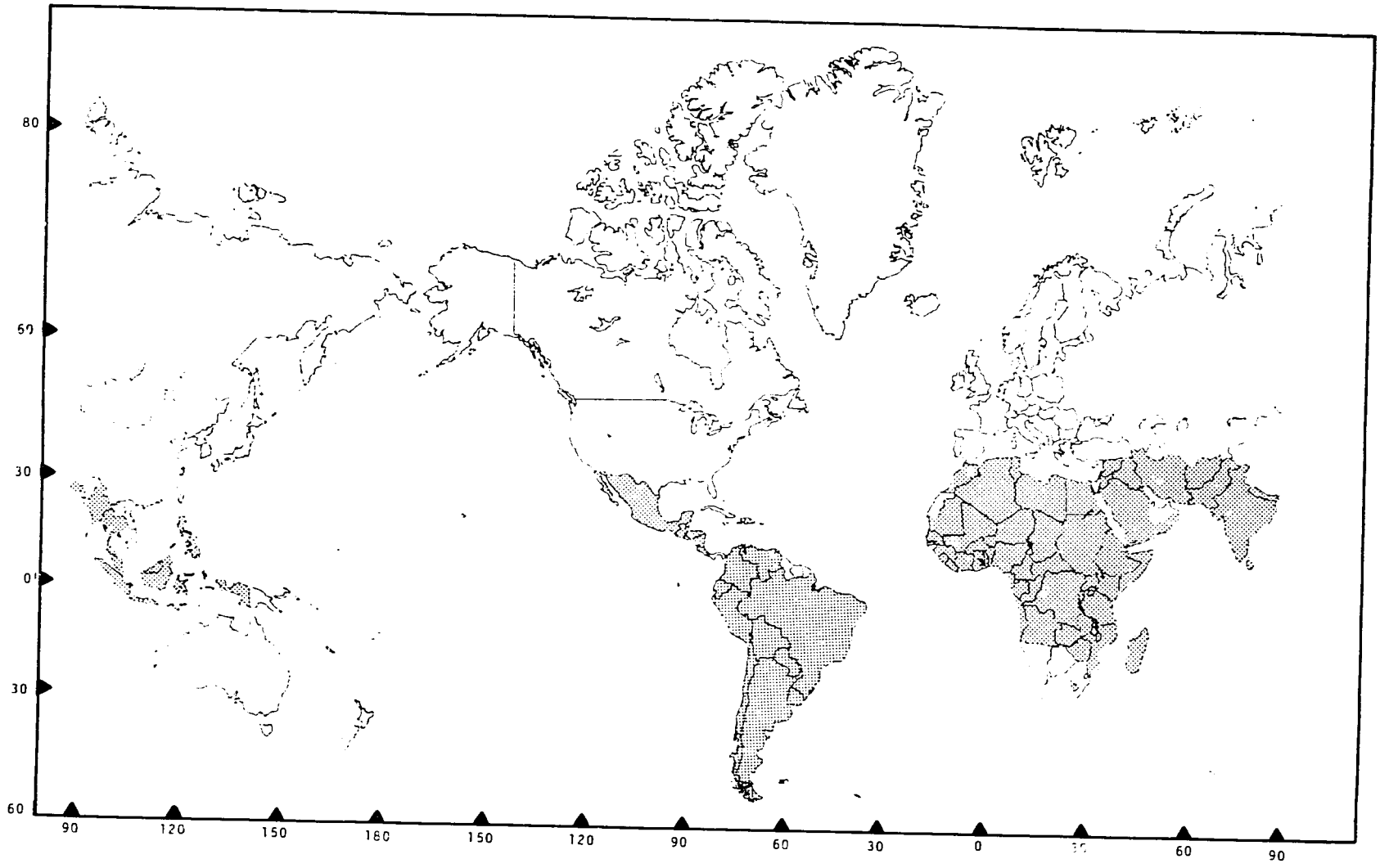

FIGURE 2
THE EIGHTY-ONE DEVELOPING COUNTRIES EXAMINED

the estimates are described below.

Population That Could Use Photovoltaic Systems

Building density in urban areas may severely limit the space available for photovoltaic systems. Also, urban areas are generally served by central utility systems. For these reasons, photovoltaic potential in each developing country was quantified only for rural areas without access to electricity.

Data on rural population without access to electricity* was acquired for 15 of the developing countries.** However, due to the difficulties encountered in collecting this data and the time constraints of this study, an alternative method was used to estimate the rural population without access to electricity in the rest of the world's developing countries.

Data acquired for the fifteen developing countries (see Table IV) indicated that the share of rural population without access to electricity decreases as the Gross National Product (GNP) per capita increases. For each of the developing countries where data was not available, the rural population without access to electricity (as a

*Generally, access to electricity means that grid electricity is available within "reasonable" distance (100-200 yards) but not installed.

**Economic Memoranda by the World Bank and Area Handbooks prepared by the Foreign Area Studies of the American University.

TABLE IV

RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY

COUNTRY	RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY (Percent)	(Millions)	GNP PER CAPITA (U.S. $)
Argentina	20	1.0	1,150
Morocco	69	7.3	540
Malaysia	70	6.2	860
Egypt	80	15.8	280
Turkey	82	41.2	990
Tunisia	83	2.4	840
Brazil	85	37.4	1,140
Algeria	88	7.1	990
Nicaragua	93	1.1	750
Nigeria	93	50.8	380
Philippines	93	25.7	410
Bolivia	95	3.3	390
Nepal	97	11.9	120
Yemen P.D.R.	98	1.1	280
Yemen A.R.	99	5.4	250

Sources: World Bank Reports.

percentage of total rural population) was estimated with the relationship

$$Y = EXP(B_o + B_1X^4 + B_2X^3 + B_3X^2 + B_4X + B_5(\frac{1}{X}))$$

Where: Y = percent rural population without access to electricity
X = gross national product
Bi = multiple regression coefficients*

The rural population without access to electricity was then estimated by multiplying the percentage, Y, by the rural population for each country. Estimates of the rural population without access to electricity and the GNP/capita for each of the world's developing countries are summarized in Tables V through VII.

Per Capita Electricity Needs

In this analysis, energy requirements for rural areas of developing countries were derived from information on a fictitious village in northern India called Sonargram.**

The characteristics of this village, which are summarized in Table VIII, represent a composite of data from thousands of existing villages in northern India. Sonargram was chosen for the basis of MITRE's analysis because information on the village's characteristics were relatively detailed, clearly presented, and represented a large number of real villages.

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*See Appendix A, Table A-V.
**Douglas V. Smith, Photovoltaic Power in Less Developed Countries, Massachusetts Institute of Technology, Lexington, Massachusetts, March 1977.

Table V
Population Statistics, Africa

COUNTRY	TOTAL POPULATION (Millions)	RURAL POPULATION (Millions)	GNP PER CAPITA (U.S. $)	RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY (Percent)	(Millions)
Ethiopia	28.7	25.5	100	99	25.2
Mali	5.8	5.0	100	99	4.9
Rwanda	4.2	4.0	110	98	3.9
Somalia	3.3	2.4	110	98	2.3
Upper Volta	6.2	5.7	110	98	5.6
Burundi	3.8	3.6	120	97	3.4
Chad	4.1	3.5	120	97	3.3
Benin	3.2	2.6	130	97	2.5
Malawi	5.2	4.9	140	97	4.7
Zaire	25.4	18.8	140	97	18.2
Guinea	5.7	4.5	150	96	4.3
Niger	4.7	4.3	160	96	4.1
Lesotho	1.2	1.1	170	96	1.0
Mozambique	9.5	8.9	170	96	8.5
Tanzania	15.1	14.0	180	96	13.4
Madagascar	9.1	7.5	200	96	7.2
Sierre Leone	3.1	2.6	200	96	2.5
Central African Empire	1.8	1.1	230	95	1.0
Kenya	13.8	12.2	240	95	11.5
Uganda	11.9	10.9	240	95	10.3
Togo	2.3	2.0	260	94	1.8
Egypt	38.1	19.8	280	80*	15.8
Cameroon	7.6	5.8	290	93	5.3
Sudan	15.9	13.8	290	93	12.8
Angola	5.5	4.5	330	91	4.0
Mauritania	1.4	1.2	340	91	1.0
Nigeria	77.1	54.7	380	93*	50.8
Senegal	5.1	3.7	390	88	3.2
Zambia	5.1	3.2	440	86	2.7
Liberia	1.6	1.1	450	85	0.9
Congo, P.R.	1.4	0.8	520	82	0.6
Morocco	17.2	10.7	540	69*	7.3
Rhodesia	6.5	5.2	550	80	4.1
Ghana	10.1	6.9	550	80	5.5
Ivory Coast	7.0	5.6	610	78	4.4
Tunisia	5.7	3.0	840	83*	2.4
Algeria	16.2	8.1	990	88*	7.1
Libya	2.5	1.7	6.310[1]	20*	0.3
Total	312.1	294.7	301	90	267.5

*World Bank Country Report or American University's Area Handbooks.
*Estimate
[1]Not considered in the total average

TABLE VI

POPULATION STATISTICS, ASIA

COUNTRY	TOTAL POPULATION (Millions)	RURAL POPULATION (Millions)	GNP (U.S. $)	RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY (Percent)	(Millions)
Bhutan	1.2	1.1	70	99	1.1
Bangladesh	80.4	73.1	110	98	71.7
Burma	30.8	24.0	120	97	23.2
Nepal	12.9	12.3	120	97*	11.9
Afghanistan	14.0	12.3	160	96	11.8
Pakistan	71.3	52.1	170	96	50.0
Sri Lanka	13.8	10.5	200	96	10.0
Indonesia	135.2	109.5	240	95	104.0
Yemen, A.R.	6.0	5.5	250	99*	5.4
Yemen, P.D.R.	1.7	1.2	280	98*	1.1
Thailand	43.0	35.7	380	89	31.7
Philippines	43.3	27.7	410	93*	25.7
Jordan	2.8	1.2	610	78	0.9
Syrian, A.R.	7.7	4.2	780	77	3.2
Malaysia	12.7	8.9	860	70*	6.2
Turkey	41.2	23.4	990	82	19.2
Lebanon	3.2	1.3	1070	84	1.0
Iraq	11.5	4.4	1390	53	2.3
Iran	34.3	19.2	1930	20●	3.8
Hong Kong	4.3	0.2	2110	20●	0.0
Saudi Arabia	8.6	6.2	4000[1]	20●	1.2
Kuwait	1.1	0.1	15,480[1]	20●	0.0
India	620.4	483.9	150	48*	230.3
Total	1201.4	918.1	489	67	615.7

*World Bank Country Reports or American University's Area Handbooks
●Estimate
[1]Not considered in the total averages

TABLE VII

POPULATION STATISTICS, SOUTH AND CENTRAL AMERICA

COUNTRY	TOTAL POPULATION (Millions)	RURAL POPULATION (Millions)	GNP per Capita (U.S. $)	RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY (Percent)	(Millions)
Haiti	4.7	3.5	200	96	3.3
Bolivia	5.8	3.5	390	95*	3.3
Honduras	3.0	0.9	390	88	0.7
El Salvador	4.1	2.5	490	83	2.0
Colombia	24.2	8.5	630	78	6.6
Guatemala	6.5	4.2	630	78	3.3
Ecuador	7.3	4.0	640	78	3.1
Paraguay	2.6	1.6	640	78	1.2
Nicaragua	2.3	1.2	750	93*	1.1
Dominican Rep.	4.8	2.6	780	77	2.0
Peru	15.8	6.3	800	78	4.9
Costa Rica	2.0	1.2	1040	84	1.0
Chile	10.5	1.6	1050	84	1.3
Jamaica	2.1	1.1	1070	84	0.9
Mexico	62.0	21.7	1090	84	18.2
Brazil	110.0	44.0	1140	85*	37.4
Panama	1.7	0.9	1310	68	0.6
Uruguay	2.8	2.1	1390	53	1.1
Argentina	25.7	5.1	1550	20*	1.0
Trinidad & Tobago	1.1	0.8	2240	20**	0.1
Venezuela	12.4	9.3	2570	20**	1.8
Total	311.4	126.6	990	75	94.9

*World Bank, Country Reports or American University's Area Handbooks
**Estimate

TABLE VIII

THE CHARACTERISTICS OF SONARGRAM, A FICTITIOUS VILLAGE IN NORTHERN INDIA BASED ON COMPOSITE DATA

- The village has 500 persons, including 200 children and very old people, living in 110 family units.
- Total cultivatable land areas is just under 200 hectares.
- Mean annual rainfall is slightly in excess of 100 centimeters (cm) per year, but may vary between 50 to 180 cm per year. Irrigation and flood control are needed.
- Abundant ground water lies within 10 meters of the surface.
- Average daily solar radiation is 440 Langley's per day (1 Langley per day = 1 $cal/cm^2/day$).
- Mean daily radiation is 500 Langley's per day in May and 340 Langley's per day in November, December and January. Radiation in August and September is only slightly greater than 340 Langley's per day because of the monsoon cloud cover.

Source: Photovoltaic Power in Less Developed Countries. Douglas V. Smith, Massachusetts Institute of Technology, Lexington, Massachusetts, March 1977.

Based on data for Sonargram, it was assumed that a "typical" village of 500 people would require 10 KWp (or 20 Wp per person) for miscellaneous applications consisting of drinking water, light industry, educational television and lighting. An additional 55 KWp (or 110 Wp per person) may then be required for irrigation. Power requirements are summarized in Table IX.

It was assumed that irrigation would not be necessary if the terrain precludes cultivation of crops or if the rainfall is sufficient. To determine if either case exists in each developing country, maps of population distribution, topography, climate and precipitation were consulted.* The criteria for determining the share of rural population that could use photovoltaics for irrigation by using this information are summarized in Table X. The population shares calculated by this procedure are shown in Tables A-I through A-III in the Appendix.

Per Capita Collector Requirements

To estimate the collector size required for each of the developing countries, the insolation level must be known. Data on insolation level was available for 41 countries.** For the remaining countries, estimates were made by comparing the insolation in those

*Britannica Atlas, Encyclopedia Britannica, Mc., Helen Hemingway Benton.

**World Distribution of Solar Radiation, by O.G. Lof, J.A. Duffie, C.O. Smith, Solar Energy Laboratory and the University of Wisconsin, July 1966.

TABLE IX

POWER REQUIREMENTS FOR A "TYPICAL" VILLAGE BASED ON THE DATA FOR SONARGRAM

APPLICATION	POWER (kW)
Irrigation of 200 hectares (ha) (5.5 kW pump per 20 ha)	55
Potable Water	3
Light industry (power used at different time for several machines to crush sugarcane, mill wheat and rice, and to hull rice)	6
Educational TV and lighting	1
Total	65

Source: Photovoltaic Power in Less Developed Countries. Douglas V. Smith, Massachusetts Institute of Technology, Lexington, Massachusetts, March 1977.

TABLE X

CRITERIA FOR DETERMINING RURAL POPULATION THAT MAY NEED IRRIGATION POWER

HABITAT CHARACTERISTICS	PERCENTAGE OF POPULATION THAT MAY NEED PHOTOVOLTAICS FOR IRRIGATION
Mountains of great relief; steeper slopes predominate; local relief more than 1,500 meters Rainy, tropical climate--only one or two dry months, all months warm or hot, or Yearly rainfall greater than 200 cm	0
Mountains: steeper slopes predominate; local relief 300 - 1,500 meters. Humid, subtropical climate, precipitation in all seasons	50
All other areas	100

neighboring countries for which insolation data was available. Tables XI through XIII show average insolation by country.

An insolation factor for each of the world's developing countries was estimated by dividing the average insolation level in Sonargram by the average insolation level for each "new" country.

The rating of per capita collector size was adjusted by multiplying the per capita peak energy requirement by the insolation factor. This is shown in Tables A-I through A-III in the Appendix.

THE TOTAL FOREIGN PHOTOVOLTAIC MARKET POTENTIAL IN 1979

The total foreign photovoltaic market potential is given by the following equation:

Total market potential in a country =		Population which could use photovoltaics for irrigation and other applications	x 130 Wp/person
	+	Population which could use photovoltaics for other applications only	x 20 Wp/person

The total foreign photovoltaic market potential in 1979 is then found by adding the results for each developing country.

Tables XIV through XVI show the total foreign photovoltaic market potential in 1979. The total for all 81 countries is about 93 GWp.

TABLE XI

INSOLATION IN AFRICAN COUNTRIES

COUNTRY	INSOLATION IN LANGLEYS PER DAY	
	DATA*	ESTIMATED
Ethiopia		490
Mali	532	
Rwanda		450
Somalia		500
Upper Volta		470
Burundi		450
Chad	558	
Benin		430
Malawi		490
Zaire	436	
Guinea		430
Niger	557	
Lesotho		450
Mozambique	486	
Tanzania		480
Madagascar	500	
Sierra Leone	414	
Central African Empire	429	
Kenya	502	
Uganda	575	
Togo		430
Egypt		460
Cameroon		430
Sudan	490	
Angola	453	
Mauritania	545	
Nigeria	433	
Senegal	458	
Zambia		470
Liberia		420
Congo	434	
Morocco		470
Rhodesia	500	
Ghana	450	
Ivory Coast		430
Tunisia	440	
Algeria	500	
Libya		480

*Solar Energy Laboratory, The University of Wisconsin, July 1966.

TABLE XII

INSOLATION IN ASIAN COUNTRIES

COUNTRY	INSOLATION IN LANGLEYS PER DAY	
	DATA*	ESTIMATED
Bhutan		470
Lao		460
Bangladesh		470
Burma	473	
Nepal		460
Afghanistan		450
Pakistan	452	
Sri Lanka	503	
Indonesia	402	
Yemen A.R.		480
Yemen P.D.R.		480
Thailand	440	
Philippines	353	
Syria		400
Malaysia		380
Turkey		400
Lebanon	405	
Iraq		420
Iran		430
Hong Kong	376	
Singapore	376	
Saudi Arabia		450
Kuwait		450
Jordan		410
Oman		470
United Arab Emirates	483	
Bahrain		470
Qatar		470
India	500	

*Solar Energy Laboratory, The University of Wisconsin, July 1966.

TABLE XIII

INSOLATION IN CENTRAL AND SOUTH AMERICAN COUNTRIES

COUNTRY	INSOLATION IN LANGLEYS PER DAY	
	DATA*	ESTIMATED
Haiti		500
Bolivia		490
El Salvador	519	
Colombia	403	
Guatemala		500
Dominican Rep.		500
Peru	570	
Ecuador		400
Paraguay		400
Nicaragua		400
Costa Rica		430
Chile	523	
Jamaica		490
Mexico	452	
Panama	426	
Uruguay	444	
Trinidad	484	
Venezuela	474	
Argentina	395	
Brazil	417	

*Solar Energy Laboratory, The University of Wisconsin, July 1966.

TABLE XIV

TOTAL PHOTOVOLTAIC POTENTIAL IN AFRICA IN 1979

COUNTRY	TOTAL PV POTENTIAL (GWp)
Ethiopia	2.651
Mali	0.522
Rwanda	0.475
Somalia	0.253
Upper Volta	0.684
Burundi	0.400
Chad	0.338
Benin	0.331
Malawi	0.470
Zaire	1.878
Guinea	0.525
Niger	0.421
Lesotho	0.127
Mozambique	0.945
Tanzania	1.501
Madagascar	0.755
Sierra Leone	0.344
Central African Empire	0.110
Kenya	1.205
Uganda	1.017
Togo	0.204
Egypt	1.971
Cameroon	0.590
Sudan	1.497
Angola	0.450
Mauritania	0.104
Nigeria	6.114
Senegal	0.399
Zambia	0.285
Liberia	0.100
Congo P.R.	0.056
Morocco	0.770
Rhodesia	0.439
Ghana	0.700
Ivory Coast	0.583
Tunisia	0.279
Algeria	0.753
Libya	0.036
Total	30.282

TABLE XV

TOTAL PHOTOVOLTAIC POTENTIAL IN ASIA IN 1979

COUNTRY	TOTAL PV POTENTIAL (GWp)
Bhutan	0.071
Bangladesh	6.836
Burma	0.532
Nepal	1.131
Afghanistan	1.261
Pakistan	5.722
Sri Lanka	0.843
Indonesia	2.766
Yemen A.R.	0.524
Yemen P.D.R.	0.090
Thailand	3.527
Philippines	1.944
Jordan	0.101
Syrian A.R.	0.276
Malaysia	0.297
Turkey	2.140
Lebanon	0.081
Iraq	0.314
Iran	0.391
Hong Kong	0.000
Saudi Arabia	0.130
Kuwait	0.000
Tot. (excl. India)	28.977
India	24.410
Total	53.387

TABLE XVI

TOTAL PHOTOVOLTAIC POTENTIAL IN
SOUTH AND CENTRAL AMERICA IN 1979

COUNTRY	TOTAL PV POTENTIAL (GWp)
Haiti	0.183
Bolivia	0.287
Honduras	0.031
El Salvador	0.145
Colombia	0.694
Guatemala	0.339
Ecuador	0.160
Paraguay	0.147
Nicaragua	0.088
Dominican Republic	0.083
Peru	0.320
Costa Rica	0.065
Chile	0.104
Jamaica	0.065
Mexico	2.080
Brazil	4.412
Panama	0.058
Uruguay	0.097
Argentina	0.119
Trinidad and Tobago	0.001
Venezuela	0.176
Total	9.654

U.S. SHARE OF FOREIGN PHOTOVOLTAIC MARKETS

It was considered that U.S. industrial import shares could reflect the potential U.S. photovoltaic import shares in each of the 81 developing countries. Therefore, the potential market that could be penetrated by U.S. photovoltaics manufacturers was estimated for each of the 81 countries by adjusting the total potential according to current import share data.

Data on the U.S. share of existing industrial imports were available* for 19 countries. Data on the U.S. share of total imports were available from the same source for most of the remaining countries.** See Tables XVII through XIX.

To get the market size for each of the developing countries the total market potential for each country was multiplied by the U.S. share of existing industrial imports or, if this was not available, by the U.S. share of total imports for the respective countries. The total U.S. photovoltaic foreign market potential in 1979 is shown in Tables XX through XXII. Tables A-I through A-III in Appendix A show all the steps in the calculation and totals by country.

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* U.S. Department of Commerce, Office of International Economic Research.

**Where no data was available, a 20 percent market share was estimated. This would distribute the total market equally among the five primary candidate photovoltaic manufacturer countries: the U.S., France, Japan, England, and West Germany. "Energy For Rural Development," National Academy of Sciences, 1977.

TABLE XVII

U.S. SHARE OF EXISTING IMPORTS
IN DEVELOPING COUNTRIES OF AFRICA IN 1979

COUNTRY	U.S. IMPORTS (Percent)*
Ethiopia	7.6
Mali	5.0
Rwanda	8.1
Somalia	10.8
Upper Volta	4.5
Burundi	6.5
Chad	4.0
Benin	20.0**
Malawi	5.2
Zaire	25.8 •
Guinea	16.7
Niger	5.1
Lesotho	20.0**
Mozambique	6.5
Tanzania	2.8
Madagascar	13.6
Sierra Leone	8.3
Central African Empire	5.6
Kenya	9.1 •
Uganda	16.0 •
Togo	5.7
Egypt	6.1
Cameroon	7.7
Sudan	10.0 •
Angola	10.9
Mauritania	14.3
Nigeria	12.9 •
Senegal	8.3
Zambia	27.9 •
Liberia	33.8
Congo P.R.	6.8
Morocco	11.8 •
Rhodesia	6.8
Ghana	18.1
Ivory Coast	7.9
Tunisia	9.3 •
Algeria	17.4 •
Libya	13.8

*U.S. imports as a percentage of total imports. The dot • means U.S. imports as a percentage of total industrial products.
**When no information was available, a 20 percent market share was assumed because there are five known photovoltaic-producing countries.

TABLE XVIII

U.S. SHARE OF EXISTING IMPORTS
IN DEVELOPING COUNTRIES OF ASIA IN 1979

COUNTRY	U.S. IMPORTS (Percent of total)*
Bhutan	20.0**
Bangladesh	31.8
Burma	7.0
Nepal	20.0**
Afghanistan	5.6
Pakistan	15.7 •
Sri Lanka	5.7
Indonesia	24.0 •
Yemen A.R.	20.0**
Yemen P.D.R.	2.0
Thailand	14.1 •
Philippines	28.9
Jordan	11.2
Syrian A.R.	1.0
Malaysia	8.7
Turkey	20.0 •
Lebanon	9.9
Iraq	3.6
Iran	18.1 •
Hong Kong	12.5
Saudi Arabia	18.5
Kuwait	20.0
India	15.6 •

*The dot • means U.S. imports as a percentage of total industrial products.
**When no information was available, a 20 percent market share was assumed because there are five photovoltaic-producing countries.

TABLE XIX

U.S. SHARE OF EXISTING IMPORTS IN DEVELOPING COUNTRIES OF SOUTH AND CENTRAL AMERICA IN 1979

COUNTRY	U.S. IMPORTS (Percent of total)*
Haiti	52.3
Bolivia	31.3
Honduras	43.2
El Salvador	29.0
Colombia	39.2 •
Guatemala	35.1
Ecuador	32.6
Paraguay	25.5
Nicaragua	36.2
Dominican Republic	49.9
Peru	33.8 •
Costa Rica	34.7
Chile	38.5
Jamaica	43.3
Mexico	62.4
Brazil	32.1 •
Panama	39.1
Uruguay	13.6
Argentina	24.7
Trinidad & Tobago	14.7
Venezuela	48.5

*The dot • means U.S. imports as a percentage of total industrial products.

TABLE XX

TOTAL U.S. PHOTOVOLTAIC MARKET POTENTIAL IN AFRICA IN 1979

COUNTRY	MARKET POTENTIAL (GWp)
Ethiopia	0.201
Mali	0.026
Rwanda	0.038
Somalia	0.027
Upper Volta	0.031
Burundi	0.026
Chad	0.013
Benin	0.066
Malawi	0.024
Zaire	0.484
Guinea	0.088
Niger	0.021
Lesotho	0.025
Mozambique	0.061
Tanzania	0.042
Madagascar	0.103
Sierra Leone	0.029
Central Africa	0.006
Kenya	0.110
Uganda	0.162
Togo	0.011
Egypt	0.120
Cameroon	0.045
Sudan	0.149
Angola	0.049
Mauritania	0.015
Nigeria	0.788
Senegal	0.033
Zambia	0.079
Liberia	0.033
Congo P.R.	0.003
Morocco	0.091
Rhodesia	0.029
Ghana	0.126
Ivory Coast	0.046
Tunisia	0.025
Algeria	0.131
Libya	0.004
Total	3.36

TABLE XXI

TOTAL U.S. PHOTOVOLTAIC MARKET POTENTIAL IN ASIA IN 1979

COUNTRY	MARKET POTENTIAL (GWp)
Bhutan	0.014
Bangladesh	2.173
Burma	0.037
Nepal	0.226
Afghanistan	0.070
Pakistan	0.898
Sri Lanka	0.048
Indonesia	0.663
Yemen, A.R.	0.104
Yemen, P.D.R.	0.001
Thailand	0.497
Philippines	0.561
Jordan	0.011
Syrian A.R.	0.003
Malaysia	0.024
Turkey	0.428
Lebanon	0.008
Iraq	0.011
Iran	0.071
Hong Kong	0.000
Saudi Arabia	0.024
Kuwait	0.000
India	3.808
Total	9.681

TABLE XXII

TOTAL U.S. PHOTOVOLTAIC MARKET POTENTIAL
IN SOUTH AND CENTRAL AMERICA IN 1979

COUNTRY	U.S. FIRMS MARKET POTENTIAL (GWp)
Haiti	0.095
Bolivia	0.089
Honduras	0.013
El Salvador	0.042
Colombia	0.272
Guatemala	0.120
Ecuador	0.052
Paraguay	0.037
Nicaragua	0.032
Dominican Republic	0.041
Peru	0.108
Costa Rica	0.023
Chile	0.040
Jamaica	0.028
Mexico	1.297
Brazil	1.416
Panama	0.023
Uruguay	0.013
Argentina	0.029
Trinidad & Tobago	0.000
Venezuela	0.085
Total	3.855

PROJECTED TOTAL AND U.S. FOREIGN MARKET POTENTIAL IN THE YEAR 2000

The projected total foreign market potential in the year 2000 was based on 1979 estimates of per capita energy requirements, insolation and World Bank population projections for the year 2000.

Historically, rural populations, tempted by the higher salaried jobs in the urban areas, has decreased as a percentage of total population in most countries. It is likely that this trend will continue through the year 2000, especially in the developing countries where industrialization has just started or is about to begin.

The rate at which rural population changes is different for each country depending upon its stage of economic development. The World Bank defines three categories of economic development that are appropriate to this study. They are: low income countries, middle income countries, and capital surplus oil exporters.* For these categories, historical changes in urban population as a percentage of total are given by the World Bank.

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*World Bank definition: low income countries are countries with annual income per person up to U.S. $250. Poverty alleviation depends overwhelmingly on increasing agricultural productivity to raise the purchasing power of the small and marginal farmer and to create employment for the landless at higher wages. The Middle Income developing countries are a heterogeneous group in their economic structure, development experience, and level of income per person. Progress in alleviating poverty in these countries is less hampered by the shortage of resources than in the low income countries, but nonetheless will require strenuous efforts. World Development Report, 1978. The World Bank, August 1978.

Based on these historical changes, projections were made for the average change by year 2000 (by economic category) for all countries. Where the historical rate of urbanization differed significantly from either the average of these 81 countries or the economic category, the projected rate was adjusted accordingly.

Summarizing the data from all countries, the rural population, given by continent, was estimated and is shown in Tables XXIII through XXV.

Rural population without access to electricity (by continent) was then projected. However, available data on the progress of rural electrification for the developing countries was not available. In order to see what impact the development of rural grid electricity might have on the size of foreign photovoltaic markets, four alternative scenarios were considered:

1. The percentage of rural population without access to electricity in year 2000 is assumed to remain the same as in year 1979.

2. The percentage of rural population without access to electricity in year 2000 is assumed to be 10 percent less than in year 1979.

3. The percentage of rural population without access to electricity in year 2000 is 20 percent less than in year 1979.

4. The percentage of rural population without access to electricity in year 2000 is 30 percent less than in year 1979.

Table XXVI shows rural population without access to electricity in year 2000 for each of the four alternative scenarios. The rest of the analysis uses the same methodology as was used for the 1979

TABLE XXIII

RURAL POPULATION IN AFRICA IN YEAR 2000,
BY INCOME CATEGORY

COUNTRIES	TOTAL POPULATION (Millions)	RURAL POPULATION (Percent)	RURAL POPULATION (Millions)
Low-income Countries	312	75	234.0
Middle-income Countries	428	45	192.6
Capital Surplus Exporters (Libya)	5	58	2.9
Total	745	58	429.5

Source: World Development Report, 1978, The World Bank, August, 1978.

TABLE XXIV

RURAL POPULATION IN ASIA IN YEAR 2000,
BY INCOME CATEGORY

COUNTRIES	TOTAL POPULATION (Millions)	RURAL POPULATION (Percent)	RURAL POPULATION (Millions)
Low-income Countries	607	75	455.3
+ India (adjusted individually)	958	70	670.6
Middle-income Countries	327	45	147.1
+ Iraq (adjusted individually)	25	30	7.5
Capital Surplus Exporters (Saudi Arabia)	19	68	13.0
Total	1,873	69	1,293.5

Source: World Development Report, 1978, The World Bank, August, 1978.

TABLE XXV

RURAL POPULATION IN SOUTH AND CENTRAL AMERICA IN YEAR 2000, BY INCOME CATEGORY

COUNTRIES	TOTAL POPULATION (Millions)	RURAL POPULATION (Percent)	RURAL POPULATION (Millions)
Low-income Countries	9	70	6.3
Middle-income Countries	82	45	36.9
Individually Adjusted			
Colombia	37	31	11.5
Peru	29	38	11.0
Chile	15	15	2.3
Mexico	126	31	39.1
Uruguay	4	15	0.6
Venezuela	24	15	3.6
Argentina	33	16	5.3
Brazil	205	37	75.9
Total	564	34	192.5

Source: World Development Report, 1978, The World Bank, August 1978.

TABLE XXVI

PROJECTION OF RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY IN YEAR 2000

CONTINENT	RURAL POPULATION (Millions)	Scenario	RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY (Percent of rural population)	(Millions)
Africa	429.5	Alt 1	90	386.5
		Alt 2	80	343.6
		Alt 3	70	300.6
		Alt 4	60	257.7
Asia	1,293.5	Alt 1	67	866.6
		Alt 2	57	737.3
		Alt 3	47	607.9
		Alt 4	37	478.6
South and Central America	192.5	Alt 1	75	144.4
		Alt 2	65	125.1
		Alt 3	55	105.9
		Alt 4	45	86.6
Total	1,887.2	Alt 1	74	1,397.5
		Alt 2	64	1,206.0
		Alt 3	54	1,014.4
		Alt 4	44	822.9

estimates; that is, per capita energy requirements and insolation factors are the same. The total market potential for the year 2000 is shown in Table XXVII.

To estimate the U.S. foreign market potential in the year 2000, the same import shares used in the 1979 estimates were used. The average import share (by continent) was multiplied by each continent's total market potential, and the U.S. foreign photovoltaic market potential size was obtained after adding the results from the three continents. The U.S. market potential for the year 2000 is shown in Table XXVIII. A work sheet showing the different steps taken for estimating the potential market size in the year 2000 is presented in Appendix A, Table A-IV.

TABLE XXVII

TOTAL MARKET POTENTIAL IN YEAR 2000

CONTINENT	SCENARIO	PHOTOVOLTAIC POTENTIAL FOR IRRIGATION AND OTHER USES (GWp)	PHOTOVOLTAIC POTENTIAL FOR OTHER USES ONLY (GWp)	TOTAL PHOTOVOLATIC POTENTIAL* (GWp)
Africa	Alt. 1	42.5	0.6	43.1
	Alt. 2	37.8	0.5	38.3
	Alt. 3	33.1	0.5	33.6
	Alt. 4	28.3	0.4	28.7
Asia	Alt. 1	75.1	5.9	81.0
	Alt. 2	63.8	5.0	68.8
	Alt. 3	52.7	4.1	56.8
	Alt. 4	41.5	3.3	44.8
South & Central America	Alt. 1	13.2	0.7	13.9
	Alt. 2	11.4	0.6	12.0
	Alt. 3	9.7	0.5	10.2
	Alt. 4	7.9	0.4	8.3
Total	Alt. 1	130.8	7.2	138.0
	Alt. 2	113.0	6.1	119.1
	Alt. 3	95.5	5.1	100.6
	Alt. 4	77.7	4.1	81.8

*No market reduction is assumed other than that due to rural electrification programs.

TABLE XXVIII

U.S. MARKET POTENTIAL IN YEAR 2000

CONTINENT	ALTERNATIVE SCENARIO	MARKET POTENTIAL (GWp)
Africa	Alt. 1	4.7
	Alt. 2	4.2
	Alt. 3	3.7
	Alt. 4	3.2
Asia	Alt. 1	14.5
	Alt. 2	12.3
	Alt. 3	10.2
	Alt. 4	8.0
South and Central America	Alt. 1	5.5
	Alt. 2	4.8
	Alt. 3	4.0
	Alt. 4	3.3
Total	Alt. 1	24.7
	Alt. 2	21.3
	Alt. 3	17.9
	Alt. 4	14.5

SECTION III

ISSUES AND UNCERTAINTIES*

The foreign photovoltaic market potential of 16 GWp in 1979 estimated in this study is attractive from the U.S. photovoltaics manufacturer's point of view. In this section, some of the major issues and uncertainties regarding foreign market penetration are discussed.

THE DEVELOPING COUNTRY

The response from the market itself is of great importance to the success of foreign market penetration. The nature of this response is due to a set of parameters which is specific for each market:

- the cost of photovoltaic systems
- national goals and priorities
- the ability to pay for photovoltaic systems

Cost of Photovoltaic Systems

The cost of photovoltaic systems will vary significantly depending upon agreements made between buyer and seller.

The cost, insurance, and freight (c.i.f.) cost of a photovoltaic system shipped to Zaire, Africa was estimated (see Table XXIX) and

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* We are grateful to Dr. Franklin Root of the Wharton School of the University of Pennsylvania. His seminar in Foreign Market Entry Strategies and comments provided a great deal of insight into the issues and uncertainties discussed in this section.

TABLE XXIX

ESTIMATED COST, INSURANCE, AND FREIGHT FOR A
65-kWp PHOTOVOLTAIC SYSTEM FOR A VILLAGE IN ZAIRE*

ITEM	COST	WEIGHT	VOLUME
Collectors: 3250 X 20 Wp Glass Collectors (12 lb.)**	$195,000.	58,500 lb.	1,140 ft.^{3}
Inverter for non-DC loads: 20 KVA @ $200/KVA	4,000.	250	9
Batteries: 20 kWh @ $75/kWh	1,500.	1,200	30
Misc.: @ 1% Cost, 1% Weight, 30 ft.^{3}	2,000.	600	30
SUBTOTALS	$202,500.	60,550 lb.	1,209 ft.^{3}
Packing for overseas shipment: @ 5% Cost, 10% Weight	10,125.	6,055	--
Insurance: @ 1.2%**	2,430.	--	--
Shipping Cost: @ $4.95/ft.^{3} (Baltimore to Zaire)†	5,985.	--	--
TOTALS	$221,040.	66,605 lb.	1,209 ft.^{3}

*Does not include tariffs, taxes, fees, local transport in Zaire or installation expenses.
**Solenergy Corp. Model SG1230G
†Overseas Shipping Company, International, Upper Marlboro, Maryland

showed that shipping costs alone would increase the total system price by about 10 percent. This percentage can serve as a representative norm for most of the developing countries in this study.

To this c.i.f. cost there must be added costs for pre- and post-sale service, agent fees, warehousing, local handling and transportation, tariffs, taxes and product adaptation. These costs are likely to vary significantly from country to country and may depend upon the foreign market's desire to have photovoltaic systems. Therefore, these costs are difficult to estimate before direct contacts are made.

National Goals and Priorities

National goals may have an impact on the desire to have photovoltaic systems. If, for example, the possession of photovoltaic systems becomes a status symbol, this could have a significant impact on future sales.

Priorities concerning general economic development are also of great concern. If photovoltaic systems in foreign markets are to be used in the agricultural sector, the structure and development of this sector is important to future photovoltaic sales.

The impact of the development of rural electrification and market penetration by other technologies will also depend on priorities of foreign governments and will have an influence on future photovoltaic sales. It is obvious that more energy and more efficient use of energy is an essential part in promoting agriculture and thus

raising food production in the developing world. However, electricity in remote areas, even though important, might not be the highest priority item in foreign government budgets.

Ability to Pay for Photovoltaic Systems

Developing countries may have difficulty in paying for photovoltaic systems. Many are already dependent upon foreign aid to support imports of food and energy supplies and for basic economic development.

Many developing countries are creating foreign exchange credits by exporting extractable resources (minerals, etc.). Expansion of these activities may require capital investments of the same magnitude or more as that required for purchase of photovoltaic systems.

Additional foreign aid may be required to pay for photovoltaic systems. This may be available from several sources such as the Agency for International Development, United Nations Development Program or the International Bank for Reconstruction and Development or from benefactor, industrialized or oil-rich nations.

U.S. INDUSTRY

Once it is decided that a particular foreign market represents an attractive business opportunity, the manufacturer must determine the best strategy for entering that market. There are three major options: exporting (production at home and sales abroad), joint ventures (joining with foreign companies in some way) or direct investment abroad (foreign production or multinational enterprises).

From the producing company's point of view it can generally be said that each of these alternatives brings about different political and economic risks which will vary in magnitude from country to country (see Table XXX). Before choosing the entry strategy, these risks must be weighed against the size of the market and potential returns.

The best mode of foreign trade from the manufacturer's point of view may not be best from the national (U.S.) perspective. Table XXXI presents a comparison of four modes of foreign trade according to several parameters of U.S. national interest. In the short-term view, only financial returns are of interest to the manufacturer. For manufacturers with a long-term point of view, more than one parameter may be of interest.

If the purpose of federal involvement in promoting foreign trade is to encourage growth of the photovoltiacs industry in the U.S., then only the export mode which offers significant national benefits supporting that growth should be promoted.

The time required to enter the foreign markets will, to some extent, depend on the entry strategy chosen. Export is generally the quickest way of entering a market. Direct investment would require more time for planning than would any other mode. Depending on economic and political reasons, the time span for entering foreign markets will vary for different countries.

Experimental or pilot tests of photovoltaic systems may be needed in most developing countries to satisfy concerns about

TABLE XXX

EXAMPLES OF RISKS FOR U.S. INDUSTRIES
IN FOREIGN MARKETS

POLITICAL RISKS	ECONOMIC RISKS
Stability	Repatriation
Blacklisting	Floating Exchange Rates
Treaties and Agreements	
Patent Protection	
Contract Concessions	
Forced Renegotiation	
Coerced Sales	

TABLE XXXI

MODES OF ENTERING AND OPERATING IN FOREIGN MARKETS

U.S. INDUSTRY OPTION	PRODUCTION BASE	INCURRED PRODUCTION COSTS	FINANCIAL RETURNS
Export	U.S.	U.S.	U.S.
Licensing	Foreign	Foreign	Royalties-U.S.
Foreign Production	Foreign	Foreign	Profits-U.S.
Multinational Enterprise	U.S. & Foreign	U.S. & Foreign	Profits in Host Country

economic and social acceptability. Pilot tests might take up to five years for planning, implementation and evaluation. The time needed for social acceptability is unpredictable.

The degree of economic development within each foreign market, (including degree of industrialization, level and quality of education, and number of educated white- and blue-collar workers) might have an impact on the ability and desire of the developing country to accept the different modes of trade.

COMPETITION

Competition from foreign photovoltaic system producers will reduce the market potential for U.S. manufacturers. The question is, how much? There are three basic considerations. If other nations are producing technology that is equivalent to ours, this will have an impact on U.S. sales.

Cultural and historic ties may also decrease the U.S. foreign market. France, for example, maintains trade relationships with its previous colonies in Africa.* It is believed, therefore, that U.S. photovoltaic manufacturers may have difficulties in entering markets where similar relationships exist. The impact of such relationships must be considered when U.S. market opportunities are considered.

Finally, competition from other technologies, both solar and conventional, must be considered and studied for each developing

*Algeria, Morocco, Madagascar, Tunisia, for example.

country. In Egypt, for example, wind energy may be considered to be more viable than other technologies.*

INFORMATION GAPS

With a market potential of 16 GWp in 1979 and between 14 and 25 GWp in the year 2000, the impact on U.S. industry could be very large. However, more information is needed to realistically project foreign market impact on U.S. industry. A danger exists in not adequately characterizing the market. If the countries with seemingly large potential are in some way misjudged as to the real magnitude of market potential, the manufacturer could find that his real market is highly fragmented--distributed over numerous countries. This situation could bring about unforeseen expenses in infrastructure development, marketing and sales, distribution costs, adaptation costs and other unforeseen expenses.

In-depth Analysis of Countries or Regions with the Greatest Total of Photovoltaic Market Potential

A more detailed analysis of countries or regions with photovoltaic market potential would be required to more exactly determine the magnitude of that potential. Cooperation with representatives from these countries or regions would be needed. A detailed analysis would include more information on the villages in remote areas without access to electricity. Such information would include type of

*Abdel H. El Sawy, The MITRE Corporation, Potential Application of Renewable Energy Technologies for Desert Development. A paper presented at the Desert Development Workshop, Cairo, Egypt, September 1978.

soil, access to water, type of crops, area of cultivated land that needs irrigation, population and population growth, topography, weather conditions and type of small industries and number of current and/or potential small industries. This type of information would be needed to size the photovoltaic systems to the needs of each specific village. The assembled data from these villages would then constitute the market potential for the country or region.*

Goals and Priorities of Developing Countries with the Greatest Total Photovoltaic Potential

It was stated earlier in this study that the goals and priorities of developing countries are of great importance to the success of photovoltaic systems marketing efforts. The less positive the response to photovoltaic systems, the longer the time span for penetrating the markets. Information concerning goals and priorities might be available at international institutions like the World Bank and through contacts with foreign government representatives.

Unless the use of photovoltaic systems becomes widespread in a country, they might not have much direct impact on the energy economy of that country. However, photovoltaic systems would contribute to the improvement of the quality of rural and village life in situations where conventional fuels and power systems have not yet penetrated or are too expensive to become a significant factor in the foreseeable future.

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*Some work of this sort is being done as part of the U.S. Photovoltaics Program.

Photovoltaics could contribute to keeping the people in rural or remote areas from moving to the cities and would help relieve the pressure from the economic and social problems that result from overpopulated urban areas in the developing world. Contributions toward a solution of this problem could increase the interest in photovoltaic systems in the developing countries.

Better Estimates of Competing Technology Costs On Site

The competing technologies to power small villages in rural or remote areas of the developing countries in the near term would essentially be diesel-generated electricity and wind-generated electricity. To get a more reliable estimate of the size of the market potential in each of the developing countries, the costs of these technologies, together with the costs of extending grid electricity to the remote areas, must be weighed against the costs of photovoltaic systems in each country.*

Better Assessment of the Cost Involved in Doing Business with Developing Countries

It was stated earlier that certain costs will depend primarily upon the foreign country's desire to have photovoltaic systems. Tariffs and taxes, for example, might be reduced if there is a high desire to have these systems. These costs might be estimated with moderate accuracy based upon previous U.S. exports of other technical products to these foreign countries.

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*Some of this type of work has been done by the World Bank. Economic Report, 1977.

Modes of Foreign Trade that Would be Most Beneficial

Exporting is by far the most common way used by U.S. industry to enter foreign markets. Exporting is relatively easy to initiate: capital requirements are low, start up costs are low, risks are few and limited by a modest financial exposure and profits are provided by immediate sales. Determination of whether exporting or other ways of entering the foreign markets would be most beneficial to U.S. photovoltaic programs or to determine what need there is for federal support, would require more detailed information from both the foreign market and the U.S. photovoltaics industry.

In developing countries where capital and foreign exchange is scarce and where GNP per capita is low, raising the capital needed for imports of photovoltaic systems might be a difficult task. On the other hand, manufacturing photovoltaic systems requires resources of sophisticated electronic capabilities and most developing countries lack these capabilities.

From the U.S. point of view, exporting will create more employment within the U.S. than any other mode of trade and will bring about attendant benefits. This might be an incentive for federal support for exporting photovoltaics rather than producing abroad. In any case, other ways of entering the foreign markets must be considered to determine what would be most beneficial to the U.S. photovoltaics industry.

Appendix A

TABLE A-I
Potential Markets in Africa

Country	Total Population 1976 Million	Rural Population 1976 Million	GNP/CAP 1976 US $	Rural Population Without Access to Electricity %	Rural Population Without Access to Electricity Million	Rural Population That Can Use PV for Irrigation and Other Uses	Insolation Factor	PV Potential Irrigation and Other Uses, 130 W_p/Person in GW_p	Rural Population That Can Use PV for Other Uses Only; Million	PV Potential For Other Uses Only 20 W_p/ Person in GW_p	Total PV Potential In GW_p	U.S. Share Of Imports In %**	U.S. Firms Market Size In GW_p
Ethiopia	28.7	25.5	100	99	25.2	22.2	0.90	2.397	3.0	0.054	2.651	7.6	0.201
Mali	5.8	5.0	100	99	4.9	4.9	0.82	0.522	0.0	0.000	0.522	5.0	0.026
Rwanda	4.2	4.0	110	98	3.9	3.7	0.98	0.472	0.2	0.003	0.475	8.1	0.038
Somali	3.3	2.4	110	98	2.3	2.2	0.88	0.252	0.1	0.001	0.253	10.8	0.027
Upper Volta	6.2	5.7	110	98	5.6	5.6	0.94	0.684	0.0	0.000	0.684	4.5	0.031
Burundi	3.8	3.6	120	97	3.4	3.1	0.98	0.394	0.3	0.006	0.400	6.5	0.026
Chad	4.1	3.5	120	97	3.3	3.3	0.79	0.338	0.0	0.000	0.338	4.0	0.013
Benin	3.2	2.6	130	97	2.5	2.5	1.02	0.331	0.0	0.000	0.331	20.0Q	0.066
Malain	5.2	4.9	140	97	4.7	3.9	0.90	0.456	0.8	0.014	0.470	5.2	0.024
Zaire	25.4	18.8	140	97	18.2	13.6	1.01	1.786	4.6	0.092	1.878	25.8 •	0.484
Guinee	5.7	4.5	150	96	4.3	3.9	1.02	0.517	0.4	0.008	0.525	16.7	0.088
Niger	4.7	4.3	160	96	4.1	4.1	0.79	0.421	0.0	0.000	0.421	5.1	0.021
Lesotho	1.2	1.1	170	96	1.0	1.0	0.98	0.127	0.0	0.000	0.127	20.0Q	0.025
Mozambique	9.3	8.9	170	96	8.5	8.0	0.90	0.936	0.5	0.009	0.945	6.5	0.061
Tanzania	15.1	14.0	180	96	13.4	12.4	0.92	1.483	1.0	0.018	1.501	2.9 •	0.042
Madagascar	9.1	7.5	200	96	7.2	6.5	0.88	0.743	0.7	0.012	0.755	13.6 •	0.103
Sierre Leone	3.1	2.6	200	96	2.5	2.5	1.06	0.344	0.0	0.000	0.344	8.3	0.029
Central Africa Emp.	2.8	1.1	230	95	1.0	0.8	1.02	0.106	0.2	0.004	0.110	5.6	0.006
Kenya	13.8	12.2	240	95	11.5	10.5	0.87	1.188	1.0	0.017	1.205	9.1 •	0.110
Uganda	11.9	10.9	240	95	10.3	10.3	0.76	1.017	0.0	0.000	1.017	16.0 •	0.162
Togo	2.3	2.0	260	94	1.8	1.5	1.02	0.198	0.3	0.006	0.204	5.7	0.011
Egypt	38.1	19.8	280	80*	15.8	15.8	0.96	1.971	0.0	0.000	1.971	6.1	0.120
Cameron	7.6	5.8	290	93	5.3	4.3	1.02	0.570	1.0	0.020	0.590	7.7	0.045
Sudan	13.9	13.8	290	93	12.8	12.8	0.90	1.497	0.0	0.000	1.497	10.0 •	0.149
Angola	5.5	4.5	330	91	4.0	3.5	0.97	0.441	0.5	0.009	0.450	10.9	0.049
Mauritania	1.4	1.2	340	91	1.0	1.0	0.80	0.104	0.0	0.000	0.104	14.3	0.015
Nigeria	77.1	54.7	380	93*	54.8	45.8	1.01	6.013	5.0	0.101	6.114	12.9 •	0.788
Senegal	5.1	3.7	390	88	3.2	3.2	0.96	0.399	0.0	0.000	0.399	8.3	0.033
Zambia	5.1	3.2	440	86	2.7	2.3	0.93	0.278	0.4	0.007	0.285	27.9 •	0.079
Liberia	1.6	1.1	450	85	0.9	0.7	1.05	0.096	0.2	0.004	0.100	33.8	0.033
Congo P.R.	1.4	0.8	520	82	0.6	0.4	1.01	0.052	0.2	0.004	0.056	6.8	0.003
Morocco	17.2	10.7	540	69*	7.3	6.2	0.93	0.750	1.1	0.020	0.770	11.8 •	0.091
Rhodesia	6.5	5.2	550	80	4.1	3.8	0.88	0.434	0.3	0.005	0.439	6.8	0.029
Ghana	10.1	6.4	550	80	5.5	5.5	0.98	0.700	0.0	0.000	0.700	18.1	0.126
Ivory Coast	7.0	5.6	610	78	4.4	4.4	1.02	0.583	0.0	0.000	0.583	7.9	0.046
Tunisia	5.7	3.0	840	33*	2.4	2.1	1.00	0.273	0.3	0.006	0.279	9.1 •	0.025
Algeria	19.2	8.1	990	88*	7.1	6.5	0.88	0.743	0.6	0.010	0.753	17.4 •	0.131
Libya	2.5	1.7	6.310	20°	0.3	0.3	0.92	0.036	0.0	0.000	0.036	13.8	0.004
Total	392.1	294.9	301	90	267.8	245.1	0.93	29.852	22.7	0.430	30.282	11.1	3.36

*World Bank, Country Reports or American University's Area Handbooks.

**U.S. imports as a percentage of total imports. When indicated by the dot •, U.S. imports as a percentage of total industrial products.

°Estimate.

QWhen no information was available, a 20% market share was assumed.

TABLE A-II
Potential Markets in Africa

Country	Total Population 1976 Million	Rural Population 1976 Million	GNP/CAP 1976 US $	Rural Population Without Access to Electricity (%)	Rural Population Without Access to Electricity (Million)	Rural Population That Can Use PV for Irrigation and Other Uses	Insolation Factor	PV Potential Irrigation and Other Uses, 130 W_p/Person In GW_p	Rural Population That Can Use PV for Other Uses Only; Million	PV Potential For Other Uses Only 20 W_p/Person in GW_p	Total PV Potential In GW_p	U.S. Share Of Imports In %**	U.S. Firms Market Size In GW_p
Bhutan	1.2	1.1	70	99	1.1	0.5	0.93	0.060	0.6	0.011	0.071	20.0 Q	0.014
Bangladesh	80.4	73.2	110	98	71.7	51.7	0.96	6.452	20.0	0.384	6.836	31.8	2.173
Burma	30.8	24.0	120	97	23.2	1.0	0.93	0.120	22.2	0.412	0.532	7.0	0.037
Nepal	12.9	12.3	120	97*	11.9	8.9	0.93	1.076	3.0	0.055	1.131	20.0 Q	0.226
Afghanistan	14.0	12.3	160	96	11.8	9.8	0.96	1.223	2.0	0.038	1.261	5.6	0.070
Pakistan	71.3	52.1	170	96	50.0	44.0	0.98	5.605	6.0	0.117	5.722	15.7•	0.898
Sri Lanka	13.8	10.5	200	96	10.0	6.0	0.97	0.766	4.0	0.077	0.084	5.7	0.048
Indonesia	135.2	109.5	240	95	104.0	10.0	0.87	1.131	94.0	1.635	2.766	24.0•	0.663
Yemen, A.R.	6.0	5.5	250	99*	5.4	3.4	1.09	0.481	2.0	0.043	0.524	20.0Q	0.104
Yemen, PDR	1.7	1.2	280	98*	1.1	0.7	0.97	0.083	0.4	0.007	0.090	2.0	0.001
Thailand	43.0	35.7	380	89	31.7	26.3	1.00	3.419	5.4	0.108	3.527	14.1•	0.497
Philippines	43.3	27.7	410	93*	25.7	10.7	1.15	1.599	15.0	0.345	1.944	28.9	0.561
Jordan	2.8	1.[illegible]	610	78	0.9	0.7	1.0	0.097	0.2	0.004	0.101	11.2	0.011
Syrian A.R.	7.7	4.2	780	77	3.2	1.7	1.10	0.243	1.5	0.033	0.276	1.0	0.003
Malaysia	12.7	8.9	860	70*	6.2	1.2	1.16	0.181	5.0	0.116	0.297	8.7	0.025
Turkey	41.2	23.4	990	82	19.2	14.2	1.10	0.030	5.0	0.110	2.140	20.0Q	0.428
Lebanon	3.2	1.3	1.670	84	1.0	0.5	1.09	0.071	0.5	0.010	0.081	9.9	0.008
Iraq	11.5	4.4	1.39[illegible]	53	2.3	2.3	1.05	0.314	0.0	0.000	0.314	3.6	0.011
Iran	34.3	19.2	1.930	20°	3.8	2.8	1.02	0.371	1.0	0.020	0.391	18.1•	0.071
Hong Kong	4.3	0.2	(2.110)	20°	0.0	0	1.17	0.000	0.0	0.000	0.000	12.5	0.000
Saudi Arabia	3.6	6.2	(4.000)	20°	1.2	1.0	0.97	0.126	0.2	0.004	0.130	18.5	0.024
Kuwait	1.1	0.1	(15.480)	20°	1.2	0	0.98	0.0	0.0	0.00	0.000	20.5	0.000
Total (excl. India)	581.0	434.2	506	88	385.4	197.4	1.01	25.448	188.0	3.529	28.977	20.3	5.873
India	620.4	483.9	150	48*	230.3	210.3	0.68	24.058	20.0	0.352	24.410	15.6	3.808
Total	1,201.4	918.1	489	67	615.7	40.7	1.01	49.506	208.0	3.881	53.247	18.1	9.681

*World Bank, Country Reports or American University's Area Handbooks.

**U.S. Imports as a percentage of total imports. When indicated by the dot •, U.S. imports as a percentage of total industrial products.

°Estimate.

QWhen no information was available, a 20% market share was assumed.

TABLE A-III
Potential Markets in South and Central America

Country	Rural Population 1976 Million	Rural Population 1976 Million	GNP/cap 1976 US $	Rural Population Without Access to Electricity %	Rural Population Without Access to Electricity Million	Rural Population That Can Use PV for Irrigation and Other Uses	Insolation Factor	PV Potential Irrigation and Other Uses, 130 W_p/Person In GW_p	Rural Population That Can Use PV For Other Uses Only; Million	PV Potential For Other Uses Only 20 W_p/Person in GW_p	Total PV Potential In GW_p	U.S. Share Of Imports In %**	U.S. Firms Market Size In GW_p
Haiti	4.7	3.5	200	96	3.3	1.3	0.88	0.148	2.0	0.035	0.183	52.3	0.095
Bolivia	5.8	3.5	390	95*	3.3	2.3	0.90	0.269	1.0	0.018	0.287	31.3	0.089
Honduras	3.0	0.9	390	88	0.7	0.2	0.88	0.023	0.5	0.008	0.031	43.2	0.013
El Salvador	4.1	2.5	490	83	2.0	1.2	0.85	0.132	0.8	0.013	0.145	29.0	0.042
Colombia	24.2	8.5	630	78	6.6	4.6	1.09	0.651	2.0	0.043	0.694	39.2°	0.272
Guatemala	6.5	4.2	630	78	3.3	2.9	0.88	0.332	0.4	0.007	0.339	35.1	0.120
Ecuador	7.3	4.0	640	76	3.1	1.1	0.88	0.125	2.0	0.035	0.160	32.6	0.052
Paraguay	2.6	1.6	640	78	1.2	1.0	1.10	0.143	0.2	0.004	0.147	25.5	0.037
Nicaragua	2.3	1.2	750	93*	1.1	0.7	0.90	0.081	0.4	0.007	0.088	36.2	0.032
Dominican Rep.	4.8	2.6	780	77	2.0	0.5	0.88	0.057	1.5	0.026	0.083	49.9	0.041
Peru	15.8	6.3	800	78	4.9	2.9	0.77	0.290	2.0	0.030	0.320	33.8°	0.108
Costa Rica	2.0	1.2	1040	84	1.0	0.4	1.02	0.053	0.6	0.012	0.065	34.7	0.023
Chile	10.5	1.6	1050	84	1.3	0.9	0.84	0.098	0.4	0.006	0.104	38.5	0.040
Jamaica	2.1	1.1	1070	84	0.9	0.5	0.90	0.058	0.4	0.007	0.065	43.3	0.028
Mexico	62.0	21.7	1090	84	18.2	16.2	0.97	2.042	2.0	0.038	2.080	62.4	1.297
Brazil	110.0	44.0	1140	85*	37.4	31.4	1.05	4.286	6.0	0.126	4.412	32.1°	1.416
Panama	1.7	0.9	1310	68	0.6	0.4	1.03	0.054	0.2	0.004	0.058	39.1	0.023
Uruguay	2.8	2.1	1390	53	1.1	0.7	0.99	0.090	0.4	0.007	0.097	13.6	0.013
Argentina	25.7	5.1	1550	20*	1.0	0.8	1.11	0.115	0.2	0.004	0.119	24.7	0.029
Trinidad & Tabago	1.1	0.8	2240	20°	0.1	0.0	0.91	0.000	0.1	0.001	0.001	14.7	0.000
Venezuela	12.4	9.1	2576	20°	1.8	1.4	0.93	0.169	0.4	0.007	0.176	48.5	0.085
Total	311.4	126.6	990	73	92.9	71.4	0.94	9.216	23.5	0.438	9.654	39.9	3.855

*World Bank, Country Reports or American University's Area Handbooks.

**U.S. imports as a percentage of total imports. When indicated by the dot o, U.S. imports as a percentage of total industrial products.

°Estimate.

°When no information was available, a 20% market share was assumed.

TABLE A-IV
Market Projections in Year 2000, Market Potential and Market Size

	Rural Population Million	Rural population w/out access to electricity: In % of rural population	Rural population w/out access to electricity: Million	Rural Population that can use PV for irrigation and other uses %	Rural Population that can use PV for other uses only %	Photovoltaic potential for irrigation and and other uses (in millions)	Photovoltaic potential for other uses only (in millions)	Insolation factor	Photovoltaic potential for and other uses 130wp/person in GWp	Photovoltaic potential for other uses only 20wp/person in GWp	Total Potential in GWp	U.S. share of Imports in %	U.S. Firms Market Potential in GWp
AFRICA	429.5	Alt. 1 90	386.5	91	9	351.7	34.8	0.93	42.5	0.6	43.1	11	4.7
		Alt. 2 80	343.6			312.7	30.9		37.8	0.5	38.3		4.2
		Alt. 3 70	300.6			273.5	27.1		33.1	0.5	33.6		3.7
		Alt. 4 60	257.7			234.5	23.2		28.3	0.5	28.7		3.2
ASIA	1293.5	Alt. 1 67	866.6	66	34	572.0	294.6	1.01	75.1	5.9	81.0	18	14.5
		Alt. 2 57	737.3			486.6	250.7		63.8	5.0	68.8		12.3
		Alt. 3 47	607.9			401.2	206.7		52.7	4.1	56.8		10.2
		Alt. 4 37	478.6			305.9	162.7		41.5	3.3	44.8		8.0
SOUTH AND CENTRAL AMERICA	192.5	Alt. 1 75	144.4	75	25	108.3	36.1	0.94	13.2	0.7	13.9	40	5.5
		Alt. 2 65	125.1			93.8	31.3		11.4	0.6	12.0		4.8
		Alt. 3 55	105.9			79.4	26.5		9.7	0.5	10.2		4.0
		Alt. 4 45	86.6			64.9	21.7		7.9	0.4	8.3		3.3
TOTAL	1887.2	Alt. 1	1397.5	74	26	1032.0	365.5	0.96	130.8	7.2	138.0	18	24.2
		Alt. 2	1206.0			893.1	312.9		113.0	6.1	119.1		21.3
		Alt. 3	1014.4			754.1	260.3		95.5	5.1	100.6		17.9
		Alt. 4	822.9			615.3	207.6		77.7	4.1	81.8		14.5

TABLE A-V

MULTIPLE REGRESSION COEFFICIENTS FOR CALCULATING RURAL POPULATION WITHOUT ACCESS TO ELECTRICITY

$B_0 = 4.047$

$B_1 = -4.251 \times 10^{-12}$

$B_2 = 1.170 \times 10^{-8}$

$B_3 = -1.066 \times 10^{-5}$

$B_4 = 3.556 \times 10^{-3}$

$B_5 = 28.436$