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PHOTOVOLTAIC VILLAGE POWER APPLICATION: ASSESSMENT OF THE NEAR-TERM MARKET

Louis Rosenblum, William J. Bifano,
William A. Poley, and Larry R. Scudder
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

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16. Abstract

A preliminary assessment of the near-term market for photovoltaic village power applications is presented. One of the objectives of the Department of Energy's (DOE) National Photovoltaic Program is to stimulate the demand for photovoltaic power systems so that appropriate markets will be developed in the near-term to support the increasing photovoltaic production capacity also being developed by DOE. The village power application represents such a potential market for photovoltaics. The price of energy for photovoltaic systems is compared to that of utility line extensions and diesel generators. The potential "domestic" demand (including the 50 states of the union plus the areas under legal control of the U.S. government) is defined in both the government and commercial sectors. The foreign demand and sources of funding for village power systems in the developing countries are also discussed briefly. It is concluded that a near-term domestic market of at least 12 MW(peak) and a foreign market of about 10 GW (peak) exists and that significant market penetration should be possible beginning in the 1981-82 period.

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INTRODUCTION

A major goal of the Department of Energy (DOE) National Photovoltaic Program is to raise solar cell array production from the present 700 kW/year to 500 MW/year by 1986; a corollary goal is to stimulate the demand of potential users to absorb this production rate. In order to achieve these near-term goals, various markets for which photovoltaics can provide a viable power source need to be penetrated. For the most part, however, these markets are latent. Many potential users are unaware or unsure of the benefits and the readiness of solar cell power for their applications. Unless such users, and the manufacturers serving such users, are fully cognizant of the solar electric option, their entry into the solar cell market may be greatly delayed.

Due to the complexity of getting photovoltaic systems into the marketplace, the government has an important role to fill-namely, to share the risk of new venture development and to facilitate the transfer of technology to the users and manufacturers. In this endeavor it is a major objective of the Tests and Applications Project, managed by the NASA Lewis Research Center (LeRC) for the DOE National Photovoltaic Program, to identify and cooperatively test, with selected users, applications judged to be cost-effective in the near-term. These near-term applications experiments are structured to engage the active participation and interest of the private sector; they are intended to lead to commercial development and marketing of photovoltaic-powered products. It is also expected that these experiments will provide a flow of application-related information to the technical community, especially the DOE Photovoltaic Program participants and contractors.

This report provides a preliminary market assessment of photovoltaic village power applications.

DEFINITIONS AND TERMINOLOGY

Village

For purposes of discussion, a village is defined as a grouping of 25 to 3000 people living in a remote area, but in close enough proximity to interact with each other on a daily basis. Remote implies that the village is located such that it cannot be supplied economically with central station utility power.

An example of such a village is the Papago Indian village of Schuchuli in southwestern Arizona (fig. 1). No electric power service is available to Schuchuli's 95 inhabitants. Water for both human consumption and stock watering is pumped from two drilled wells using petroleum fuelled equipment. Food is generally purchased in Ajo, 20 miles from Schuchuli. The diet of the villagers is restricted, by lack of refrigeration, to items such as chili, beans, tortillas, and commercially available nonperishable vegetables and canned foods. Cattle raising and hunting wild game provides an occasional supplemental source of food. Most dwellings in the village are traditional adobe construction; a few are of masonry block modern construction. Lighting is provided by kerosene lamps.

Another example is the rural village of Tangaye, Upper Volta, Africa. Figure 2 shows scenes typical of rural Africa. Tangaye is located about 195 km east of the capital, Ouagadougau. It is a village of about 2400 people and is divided into several cartiers (modules). The inhabitants are members of the Mossi tribe. Many are farmers, agricultural activity being an important source of food for consumption and bartering. The diet of a villager consists basically of millet, prepared either as a paste, a semiliquid or a coarse bread. Milk, meat and cheese are also consumed. Cereal is ground by hand by women who meet in groups in a community center. Each woman spends from 1-1/2 to 2 hours per day at this task. Water is obtained from three tube wells. Each family spends about one hour a day drawing and transporting water.

Photovoltaic Village Power System

A photovoltaic village power system is an electrical power source designed for remote applications and consists of the following: a solar cell array and support structure; power monitoring, control and regulation equipment; and energy storage. The system also includes provisions for power distribution to locations within the village for operating local loads, for example, lighting, refrigerators, water pumps, educational TV, grain grinders, lathes, or other equipment.

An implicit feature of the photovoltaic village power system concept is modularity; the system is initially sized to provide power for basic needs (e.g., food processing, potable water pumping, lighting, refrigeration, educational television) with provisions for the addition of increments of power as required (e.g., cottage industry, communications). Figure 3 provides a schematic representation of a likely power system for a village of 250 people. The solar photovoltaic array for basic needs is estimated to be 3.5 kW peak. Additional capacity would provide for light industry and other needs. For purposes of discussion we assume a 6 kW peak village power system for a community of 250 people, that is, 24 watts (peak)/person.

User Categories

Among domestic users, two sectors have been identified for consideration: (1) government; and (2) commercial. Within the government sector are the Department of the Interior (National Park Service, Bureau of Outdoor Recreation, Bureau of Indian Affairs and the Office of Territorial Affairs), Department of Health, Education and Welfare (Indian Health Service and Public Health Service), Department of Agriculture (Forest Service), the Community Services Administration, as well as similar agencies at state and local levels.

Within the commercial sector, potential users are remote recreational operations (i.e., hunting and fishing lodges and campgrounds), construction and surveying camps, railroad blockhouse complexes, logging camps and ranches.

Outside the U.S., the user sector would mainly consist of governments of developing countries who would purchase photovoltaic power systems for villages or for remote recreational facilities to enhance tourism.

MARKET ASSESSMENT

The market for village power depends mainly on (1) potential demand, and (2) the energy price of the competitive systems.

The preliminary market assessment presented here is based upon (1) information from published reports (refs. 1 to 10), and (2) information from contacts with potential users, manufacturers and institutions (appendix A).

It should be noted that although the market assessment discussed hereafter deals primarily with the domestic market, by far the largest near-term market for photovoltaic village power appears to be outside the United States.

Energy Price

Competitive power systems for village power applications examined here are utility line extensions from central station plants, diesel generators, and photovoltaic power systems. In figure 4, photovoltaic module price is plotted against utility line extension distance for system break-even conditions assuming a continuous power level of 1 kW. This plot is based on the simplified economic break-even cost analysis given in reference 10. Both commercial and noncommercial (local labor) installations are considered. The specific assumptions used in generating this plot are given in appendix B. Assuming a peak watt rating to continuous load demand ratio of 5.5 (i.e., a relatively good solar insolation site), the 1 kW continuous curve corresponds to a 5.5 kW peak photovoltaic array.

According to this plot, for utility line extensions of more than about 5 miles at $15,000/per mile, a 1 kW continuous (5.5 kW peak) photovoltaic system is cost-effective at module prices of about $6.00/watt, based on 1977 dollars and assuming a noncommercial installation (e.g., labor provided locally by villagers). Using the DOE projected price of modules (ref. 11) such a system would be cost-effective for utility line extension lengths of about 5 miles or more in the 1979-1980 period. A similar system commercially installed would be cost-effective for utility line extensions of about 7 miles or more.

With a utility line extension price of $30,000/mile, which is the current cost in some areas with hilly or mountainous terrain, the commercially installed photovoltaic system is cost-effective for extension lengths of about 5 miles or more at present-day module prices again based on the assumptions given in appendix B.

Using the methodology of the Aerospace report (ref. 10) with some modifications of assumptions (appendix C), photovoltaic systems were compared with small diesel generators on the basis of energy price, again using the DOE projected price of modules. Diesel generator operating and maintenance costs were based on direct quotes recently obtained from the Onan Electric Power Systems Company and the Winpower Company, manufacturers of diesel generator sets; hence they reflect current typical expenses associated with these devices. Figure 5 presents the price per kWH for a small diesel generator and a photovoltaic power system plotted versus year and photovoltaic module price, assuming continuous operation at 1 kW. For the photovoltaic system, energy price is presented for both a commercial and a local labor type installation. For the diesel generator, a typical low and high value for the delivered fuel price is factored into the calculation, namely, $0.60/gal and $1.50/gal respectively. A 5 percent rate of escalation in fuel price is also assumed. The $0.60/gal and $1.50/gal represent current typical delivered fuel prices for Arizona Indian reservations and remote Alaskan villages, respectively. As can be seen, the photovoltaic system becomes competitive with the diesel generator system in about the 1981-1982 period for the high fuel price case assuming a local labor type installation. Further, a commercial photovoltaic system becomes competitive relative to a low fuel price diesel generator system in about the 1985-1986 period. Delivered fuel prices in developing countries are slightly higher than for the remote areas cited in the U.S., ranging from about $0.70/gal to $1.60/gal. Hence, photovoltaic systems would be competitive with diesel generator systems for foreign markets in about the same period (1981-1986) as for the U.S.

Potential Domestic Demand

The "domestic" market is defined here to include not only the 50 states of the Union, but other areas under the legal control of the U.S. Government, for example, the Commonwealth of Puerto Rico, the Canal Zone, the U.S. Virgin Islands, American Samoa, Wake and Midway Islands, Guam, and the U.S. Trust Territory of the Pacific Islands.

In a highly industrialized society like the United States, where rural electrification has made enormous gains, the number of "villages" not supplied with electricity is rather small. Most of these are on Indian lands, in remote parts of Alaska, and perhaps in areas such as Appalachia and the Mississippi Bayou. Outside the 50 states, there appear to be a significant number of villages in Puerto Rico, the U.S. Virgin Islands, American Samoa, Guam, and the U.S. Trust Territory of the Pacific Islands. Table I lists several domestic areas in which photovoltaic village power is believed to have the best potential, the total population of the areas, and the population living in villages of 25-3000 not presently provided with electricity. The list is not complete; certain villages or communities in special areas may be good candidates, but will require a more detailed study to identify.

Assuming a value of 24 watts peak/person, discussed previously, the total near-term domestic market for photovoltaic village power can be estimated at >5.7 MW peak. Based on the preliminary economic analysis given in the preceeding section, photovoltaic market penetration could begin as early as 1979 in some areas.

Indian reservations (contiguous 48 states). - A list of the federal and state Indian reservations is given in table II. The total population of these reservations is about 486,000. Complete information on the number of Indian villages presently without power and the number of Indians per village could not be readily obtained. From discussions with Indian representatives and experts on Indian affairs, however, the following incremental information was obtained:

A minimum of 40,000 Navajo and 5,000 Hopi Indians are presently living in areas where there is no utility power available.

The Papagos reported that about 30 villages on their reservation have no electric power.

The Navahos indicated that cottage industry, specifically jewelry making, would be enhanced by the availability of village power.

Alaska. - There are approximately 200 "villages" in Alaska consisting of 50 or more persons where half or more of the population are natives (Eskimo, Indian or Aleut). Of these villages, the largest has a population of about 600 people while the average population is about 200 people (Private Communication, Larry Kimball, Department of Community and Regional Affairs, State of Alaska).

The Alaska Village Electric Cooperative (AVEC) funded by the Rural Electrification Administration (REA) is currently servicing 48 of these villages with diesel generators. Villages are being added to the cooperative at the rate of about one per year. The electric rates for residential users of AVEC is $0.27/kWH. Delivered fuel costs vary with location. If fuel has to be flown in, it is as high as $3/gal. Both AVEC and REA review each village situation carefully to assure that the electricity provided is affordable. For example, to qualify for REA funds, AVEC serviced villages must be on a navigable waterway. Because of such criteria, Mr. Jerry Larson of AVEC estimates that approximately 100 to 125 of the villages that do not have electric power would not be eligible for AVEC service. Hence, between 20,000 and 25,000 people in Alaska live in villages without electric power and which are ineligible for AVEC service.

It should be noted that the general rules-of-thumb for array size and storage capacity cited in this report will not apply to Alaska because of its latitude. Therefore, the suitability of photovoltaics for this region would have to be determined on an individual basis depending on specific load requirements, local insolation conditions, cost of alternate systems, etc.

Puerto Rico. - Mr. Alberto Bruno, Head of the Electrical Planning and Research Division of the Puerto Rico Water Resources Authority, estimates that 4 percent of the population of the commonwealth are presently without power. The main island, which is about 100 miles by 30 miles in size, does have a central electrical utility grid system. Nevertheless, there are about 125,000 inhabitants living in remote farm areas inland and on off-shore islands who do not have access to the grid. According to Mr. Bruno, Puerto Rico is very interested in demonstrations involving solar electric energy sources.

U.S. Virgin Islands. - The U.S. Virgin Islands are an unincorporated territory administered by the Department of Interior. There are over 50 islands, with a total population of about 100,000. Most of the population lives on the three largest islands - St. Croix, St. Thomas and St. John, all of which have adequate electric supplies.

Of the total population living in the Virgin Islands, it is estimated that about 2,000 people live in remote villages without electricity, and represent a potential market for photovoltaic village power (Source: Richard Miller, Department of Interior, Office of Territorial Affairs.)

American Samoa. - American Samoa consists of six islands in the Pacific, with a total population of about 31,000. It is an unincorporated territory, administered by the Department of Interior. An estimated 3,000 people live in villages which do not have electric power at present. (Source: Richard Miller, Department of Interior, Office of Territorial Affairs.)

Guam. - Guam is the largest island in the Marianas, and was ceded by Spain to the United States in 1898. The island has an area of 209 square miles and a population of about 100,000. There is a central grid system supplying electricity to most of the inhabitants of Guam, and only about 2 percent of the population does not have access to electricity. The total market in Guam for photovoltaic village power is estimated at about 2,000 people. (Source: Captain Scott and Richard Miller, Department of Interior, Office of Territorial Affairs.)

U.S. Trust Territory of the Pacific Islands. - The U.S. Trust Territory of the Pacific Islands consists of 2141 islands scattered over 3 million square miles of Micronesia. There are 98 inhabited islands with a total population of 115,000. The islands are administered by the U.S. under a mandate from the United Nations. The small number of people living on any island (with a few exceptions), and the distances between the islands make centralized power generation impractical. About 35-40 percent of the total population lives in villages which do not have electric utility service. Some are served by very small diesel and gasoline generators, which operate unreliably and need continuous fuel shipment and storage. About a fifth of the total population lives in villages which presently do not have electricity from any source. There is considerable interest on the islands for the development of a totally self-sufficient energy system. (Source: James Berg and Richard Miller, Department of Interior, Office of Territorial Affairs.)

Other domestic markets. - Additional village power applications in the government sector are remote backcountry camps and fire lookout towers. For example, at present 320,000 campsites are in use in the 5500 public parklands throughout the United States and most of these sites do not have power available. This represents a cumulative power requirement of 6 MW peak for lighting, water pumping, etc. (ref. 10). In addition, the U.S. Forest Service is estimated to have over 1500 towers and camps nationwide (Jerry Hyde, U.S. Forest Service, Private Communication). The number of National Park Service and state-operated towers and camps could not be ascertained in this preliminary assessment.

The National Young Adult Conservation Corps (NYACC) Program, represents another potential market opportunity for village power systems. This program, administered by the USFS and NPS, will engage over 35,000 unemployed youths, ages 14-24, in conservation work on public lands. This project will establish term camps (1-1/2 to 3 years), of high mobility, as well as permanent camps of various size. Each facility will support a 24-hour, 7-day-a-week operation. Camp capacities will be nominal groupings of 25, 50, 100 and 200. Construction of the camps is expected to begin in FY'78.

Additional village power applications also exist in the commercial sector (e.g., remote recreation, construction, surveying, and logging camps). Further study is needed to determine the number of such sites for which photovoltaic village power systems might be needed.

Potential Foreign Demand

The largest market for photovoltaic village power lies abroad, primarily in the developing countries. Based on World Bank data (ref. 4), it is estimated that about 500 million people live in villages having a population up to 1000 each, which are presently without electric power. (This figure is in good agreement with the United Nation's estimate of about 3 million villages in the developing countries, each with 100-500 people, without electricity at the present.)

Some of the above villages are close enough to electric grids to be supplied economically from that source in the future. Excluding these and assuming a minimum power requirement of 24 watts peak/person, the near-term market for photovoltaic village power is estimated to be about 10 gigawatts (GW) peak (1 GW = 10^9 watts). The cumulative demand by the year 2000 is estimated to be in excess of 20 GW peak.

Funding for village power systems in the developing countries is available from several sources such as the World Bank, the Asian Development Bank, the Inter-American Development Bank, the United Nations and its affiliated organizations, and the U.S. Agency for International Development. Credits and loans made by the World Bank alone in the year 1975-1976 for electric power in the developing countries amounted to about $950 million, or about 15 percent of the total loans and credits made by the Bank. Additional World Bank loans to developing countries in 1975-1976 included $1,628 million for agriculture, $321 million for education, and $335 million for water supply and sewage (ref. 4). Since potential applications of photovoltaic village power systems exist within these categories, they may also be considered as possible sources of funding for such systems.

Preliminary information indicates that several countries, such as Saudi Arabia, Iran, Indonesia, Nigeria and Venezuela are in a good position to purchase photovoltaic village systems from their own funds. Indonesia, for example, a major exporter of petroleum, has a per capita consumption of energy less than one-sixtieth (1/60) of the corresponding number for the U.S. Lack of industrialization is only one part of the explanation. An important factor is the geographic nature of the country, with tropical forests hampering the building of a transportation system for the supply of fuel and the laying of electric transmission lines. The absence of skilled maintenance personnel, especially outside of Java, is also an important factor.

Even though the countries mentioned above have large petroleum reserves, their problems are associated with the difficulty of getting the refined products to the remote villages on a continuous basis, and maintaining the power generating equipment. Photovoltaic systems consequently offer an attractive alternative.

CONCLUSIONS

1. Based on the information available for this preliminary assessment, a near-term domestic market potential of at least 12 MW (peak) is forecast for photovoltaic village power applications. Based on energy price comparisons with competing systems, significant market penetration should begin in about the 1981-82 period.

2. Using population and rural electrification data from a World Bank study, the potential near-term foreign market for photovoltaic village power systems is estimated to be about 10 GW (peak). Based on energy price comparisons with competing systems, market penetration should begin in about 1981.

TABLE I. - PRIME DOMESTIC AREAS FOR PHOTOVOLTAIC VILLAGE POWER

Prime area for photovoltaic village power	Total population	Estimated population representing a potential market for P/V village power
Indian Reservations in the Contiguous 48 States	486,000	[a]>45,000
Alaska	300,000	[b]20,000
Puerto Rico	3,112,000	[c]125,000
Virgin Islands	100,000	[d]2,000
American Samoa	31,000	[d]3,000
Guam	100,000	[e]2,000
U.S. Trust Territory of the Pacific Islands	115,000	[f]42,000
Grand Total:	4,244,000	>239,000

[a]Source: Bernard Gagewski, Office of Environmental Health, HEW.
[b]Source: Jerry Larson, Alaska Village Electric Cooperative.
[c]Source: Alberto Bruno, Puerto Rico Water Resources Authority.
[d]Source: Richard Miller, Department of the Interior.
[e]Source: Captain Scott and Richard Miller, Department of the Interior.
[f]Source: James Berg and Richard Miller, Department of the Interior.

Source: U. S. Dept. of Commerce (data as of circa Dec. 1972)

State	No. of Reservations	Tribally-owned Acreage[1]	Alloted Acreage[2]	No. of Tribes[3]	No. of Persons[4]	Avg. Unemp. Rate %[5]	Major Tribes
Alaska	13	(2)	(2)	6	35 817	NA	Eskimo, Tlingit, Haida, Aleut, Athapascan[6]
Arizona	17	23 467 727	892 917	13	173 412	41	Navaho, Apache, Papago, Hopi, Pima
California	76	386 954	67 390	(7)	6 905	45	Quechan, Hoopa, Paiute, mission bands
Colorado	2	888 155	14 425	1	2 144	37	Ute
Connecticut	4	795	—	3	25	NA	Pequot, Mohegan[8]
Florida	5	183 319	—	2	1 511	31	Seminole, Miccosukee[9]
Idaho	4	274 428	36 723	5	4 849	36	Shoshone, Bannock, Nez Perce
Iowa	1	3 476	—	1	561	35	Sac and Fox[10]
Kansas	4	2 436	24 030	5	3 009	10	Potawatomi, Kickapoo, Iowa
Louisiana	1	262	—	1	268	NA	Chitimacha
Maine	3	27 546	—	2	1 077	45	Passamaquoddy, Penobscot
Massachusetts	1	12	—	1	1	0	Hassanamisco-Nipmuk[11]
Michigan	5	4 425	12 210	2	2 069	38	Chippewa, Potawatami
Minnesota	11	682 534	50 935	2	10 739	40	Chippewa, Sioux
Mississippi	1	17 381	209	1	3 294	10	Choctaw
Montana	7	1 792 383	3 279 926	10	24 137	38	Blackfeet, Sioux, Crow, Assiniboine, Cheyenne
Nebraska	3	27 193	45 467	3	2 601	62	Omaha, Winnebago, Santee Sioux
Nevada	23	1 133 529	32 691	3	4 784	46	Paiute, Shoshone, Washoe
New Mexico	24	3 329 270	119 877	7	30 125	43	Keresan, Zuni, Apache, Tanoan, Navajo[12]
New York	9	88 158	—	7	11 616	27	Seneca, Mohawk, Onondaga, Oneida[13]
North Carolina	1	56 573	—	1	4 880	21	Cherokee
North Dakota	4	375 936	996 744	5	16 735	41	Chippewa, Sioux, Mandan, Arikara, Hidatsa
Oklahoma[14]	(14)	56 741	991 715	27	80 994	24	Cherokee, Creek, Choctaw, Chicasaw, Cheyenne, Arapaho[14]
Oregon	4	495 842	165 778	8	2 718	41	Warm Springs, Wasco, Paiute, Umatilla
South Dakota	8	1 807 623	2 371 427	1	29 119	37	Sioux
Texas	2	4 400	—	3	1 000	30	Tigua (Pueblo), Alabama, Coushatta
Utah	4	1 095 531	48 095	3	1 961	36	Ute, Southern Paiute, Goshute
Virginia	2	925	—	1	110	NA	Algonquian
Washington	22	1 920 850	537 876	20	18 138	45	Yakima, Confederated, Lummi, Quinault
Wisconsin	10	61 911	82 977	6	7 497	38	Chippewa, Oneida, Winnegabo
Wyoming	1	1 776 136	109 344	2	4 435	47	Shoshone, Arapaho

Approximations. Ownership of reservation land is very complex. Most tribally-owned land listed here is owned by tribal organizations, but some of it is held in trust by the government and some is leased to or occupied by non-Indians. Government-owned land, even that held for the exclusive use of Indians, and non-Indian land formally included in reservations is not counted here.

Alloted land was land held by Indian individuals or families. The Department of Commerce data is not clear on whether all land listed as alloted is still securely held by Indians.

Alaskan Indian affairs are handled under the Native Claims Settlement Act (Dec. 18, 1971). The act provides for the establishment of regional and village corporations to conduct business for profit. There are 12 regional corporations. Within each regional corporation village corporations must be organized. These village corporations then receive title to lands previously held in reservations. There were approximately 2.5 million acres in reservations subject to the Settlement Act. Another 86,471 acres remain outside the Act in the Annette Island Reserve. Latest figures show that 5,687 acres have been assigned to village corporations, while an additional 13,490 acres have been surveyed but not yet assigned.

The concept of "tribe" is, in many cases, a white man's invention and, at first, was used to define loosely associated Indians with cultural similarities. Today, "tribe" is a formal status of Indians organized by law. Some present day "tribes," such as the Blackfeet, are really confederacies of smaller groups. The Alaskan natives are organized "on paper" into general linguistic groups.

Number of Indians living on or adjacent to reservations. When these figures are compared to 1970 census figures, it appears that nearly 64% of Indians are living on or near reservations.

Unemployment rate of Indian labor force living on or adjacent to reservations.

Aleuts and Eskimos are racially and linguistically related. Athapascans are related to the Navaho and Apache Indians.

Many California Indians are historically associated with groups which settled near Spanish missions where much of the traditional culture was destroyed. Many of these bands, however, still retain some of their Indian language and customs. Excluding the bands, there are 22 tribes represented on California reservations.

The Mohegan or Mohican are a branch of the Pequot.

"Seminole" means "runaways," and these Indians from various tribes were originally refugees from whites in the Carolinas and Georgia. Later joined by runaway slaves, the Seminole were united by their hostility to the United States. Formal peace with the Seminoles in Florida was not achieved until 1934. The Miccosukee are a branch of the Seminole; they retain their Indian religion and have not made formal peace with the U.S.

Once two tribes, the Sac and Fox formed a political alliance in 1734.

Reservation prior to 1728 consisted of 8,000 acres. The land was sold to whites who put the Indians' money in a bank. Over the years the money was "lost" or "borrowed." In 1848, the state granted 11.9 acres to one Indian family of which there are about 20 direct descendants today.

Tanoan, Keresan, and Zuni are all pueblo-dwelling Indians.

These 4 tribes along with the Cayuga and Tuscarora made up the Iroquois League, which ruled large portions of New York, New England, and Pennsylvania and ranged into the Mid-West and South. The Onondaga, who traditionally provide the president of the League, maintain that they are a foreign nation within New York and the U.S.

Indian land status in Oklahoma is unique and there are no reservations in the sense that the term is used elsewhere in the U.S. Likewise, many of the Oklahoma tribes are unique in their high degree of assimilation to the white culture.

APPENDIX A

GOVERNMENT AND COMMERCIAL/INSTITUTION CONTACTS MADE FOR MARKET RELATED INFORMATION

Government

Anderson, Dennis
World Bank & Monetary Fund
Washington, DC

Anderson, Donald
Facilities Management
Bureau of Indian Affairs
Juneau Area Office
Juneau, AK

Berg, James
Territorial Affairs Office
Department of Interior
Washington, DC

Bosken, Jerome J.
Off. of Science & Technology
Agency for International Development
Washington, DC

Bowman, Chuck
Off. of Environ. Health
Indian Health Service (HEW)
Albuquerque, NM

Bruno, Albert
Head, Electrical Planning & Research Division
Puerto Rico Water Resources Authority
San Juan, PR

Mr. Campbell
Appalachian Regional Comm.
Regional Economic Development Commission
Washington, DC

Conover, Nat
Dept. of Community & Regional Affairs
Rural Development Assistance Division
Juneau, AK

Diamond, Beatrice
United Nations
New York, NY

Esquivel, George
Office of Environmental Health
Indian Health Service (HEW)
Tucson, AZ

Friedman, Efran
World Bank & Montary Fund
Washington, DC

Gagewski, Bernard
Office of Environmental Health
Indian Health Service (HEW)
Phoenix, AZ

Goss, Roger
United Nations
New York, NY

Hogge, Ralph
Environmental Branch
Indian Health Service (HEW)
Washington, DC

Hyde, Jerry
Division of Engineering
U.S. Forest Service
P.O. Box 2417
Washington, DC

Kimball, Larry
Department of Community & Regional Affairs
Rural Development Assistance Division
State of Alaska
Anchorage, AK

King, Bill
Bureau of Indian Affairs
Washington, DC

Lovejoy, Derrick
United Nations Development Program
New York, NY

McAlister W. Bruce
Deputy Director, Marine Mammal Div.
National Marine Fisheries Service
NOAA, Seattle, Washington

Meyers, Don
Office of Environmental Health
Indian Health Service (HEW)
Phoenix, AZ

Miller, Bill
Office of Tribal Economic Development
Bureau of Indian Affairs (DOI)
Washington, DC

Miller, Richard
Territorial Affairs Office
Dept. of Interior
Washington, DC

Mrs. Pan
United Nations
New York, NY

Peters, Phyllis
World Bank & Monetary Fund
Washington, DC

Captain Scott
Territorial Affairs Office
Dept. of Interior
Washington, DC

Usmani, I. H.
Senior Energy Advisor
United Nations Environment Programme
United Nations
New York, NY

Walker, Lynn
Information Resources Dept.
VITA
Mt. Rainier, MD

Weiss, Charles
World Bank
Washington, DC

Wromble, Dick
Indian Health Service (HEW)
Washington, DC

Commercial/Institution

Cummins Diesel of Northern Ohio, Inc.
Walton Hills, OH

Delwood Generator Equipment Company
Cleveland Hts., OH

Gibson, Elizabeth
Harvard University
Cambridge, MA

Great Lake Diesel Company
Cleveland, OH

Jones, Loyal
Center for Appalachian Studies
Berea College
Berea, KY

Larson, Jerry
Alaska Village Electric Cooperative, Inc.
Anchorage, AK

Lee, Thomas H.
Group Strategic Planning Operation
Power Generation Group
General Electric Co.
Fairfield, CT

McDonald Equipment Company
Willoughby, OH

Power Equipment Company
North Royalton, OH

E. J. Rattin
Aerospace Corporation
El Segundo, CA

Shipman, James
Industrial Sales
General Electric Company
Cleveland, OH

APPENDIX B

ASSUMPTIONS FOR PHOTOVOLTAIC POWER SYSTEM

COMPARISON WITH UTILITY LINE EXTENSION

The assumptions used to derive the break-even costs shown in figure 4 are given below. Utility line extension assumptions are based on reference 10 (Aerospace). Assumptions for the photovoltaic system are based on LeRC estimates.

Both Systems

- Interest Rate: 10%

Utility Line Extension

- System Life: 20 yr
- Cost/Mile of Extension: \$15,000 (ave), \$30,000 (max)
- Connection Cost: \$250
- Transformer: \$150
- Annual Energy Cost: 1 kW_{cont} \$428
  5 kW_{cont} \$2,100

Photovoltaic System

- System Life:
  - -Modules, Batteries: 10 yr
  - -Structure, Building, etc.: 20 yr
- Component Costs (\$/kW_{peak}):

	1977	1986
-Modules	15,000	500
-Batteries (40 kWh)	2,600	2,000
-Power Reg., Control	500	250
-Battery/Control Enclosure	140	140
-Wiring	750	750
-Frames	1,000	500
-Support Structure	1,000	750

- Overhead and Fee
  - -Local Labor 10%
  - -Commercial 50%
- Spares (PV Modules, Battery Charge Regulator, Diodes): $500 (1977), $250 (1986)

APPENDIX C

ASSUMPTIONS FOR ENERGY COST COMPARISONS BETWEEN DIESEL GENERATOR AND PHOTOVOLTAIC POWER SYSTEMS

The assumptions used to derive the cost comparisons shown in figure 5 are given below.

Both Systems

- Interest Rate: 10%
- System Life: 10 yr
- Inflation (Fuel Only): 5%

Diesel System

- 3.0 kW[a] Unit Run at 1 kW Continuous
- Backup: 3.0 kW Unit
- Diesel Cost[b]: $2,100/Unit
- Specific Fuel Consumption[b]: 0.2 gal/kWh at 1 kW
- 1977 Fuel Costs, Delivered: $0.60, $1.50/gal
- Equipment Housing Cost[c]: $31.50/ft^2
- Equipment Housing Size[d]: 40 ft^2
- Annual Maintenance Cost[b]: $1,315
- Annual Overhaul Cost[b]: $1,629
- Installation Cost: Local, No Charge

Photovoltaic System[d]

- 5.5 kWp Array = 1 kW Continuous
- Component Costs ($/kW$_{peak}$):

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[a] A 3 kW diesel generator is the minimum size available for continuous operation for this application.

[b] Private communication with Onan Electric Power Systems and Winpower representatives.

[c] Ref. 10 (Aerospace).

[d] LeRC estimates.

	1977	1986
-Modules[e]	11,000	500
-Batteries (40 kWh)	2,600	2,000
-Power Reg., Control	500	250
-Battery/Control Enclosure	140	140
-Wiring	750	750
-Frames	1,000	500
-Support Structure	1,000	750

- Overhead and Fee
  - -Local Labor 10%
  - -Commercial 50%
- Spares (PV Modules, Battery Charge Reguator, Diodes): \$500 (1977), \$250 (1986)

[e]Variable with year (DOE Goals - ref. 11).

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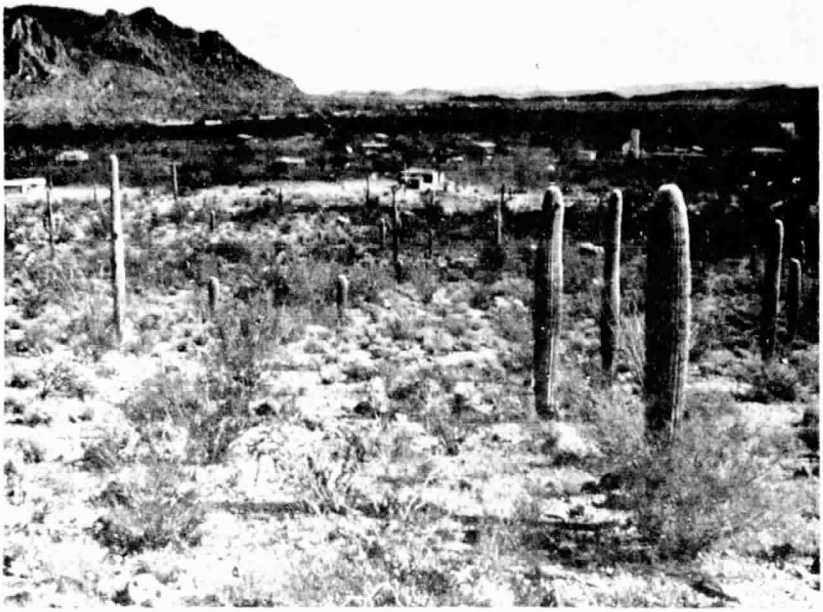

Figure 1. - The Papago Indian Village of Schuchuli Arizona.

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Figure 2. - Photographs depicting scenes typical of rural Africa.

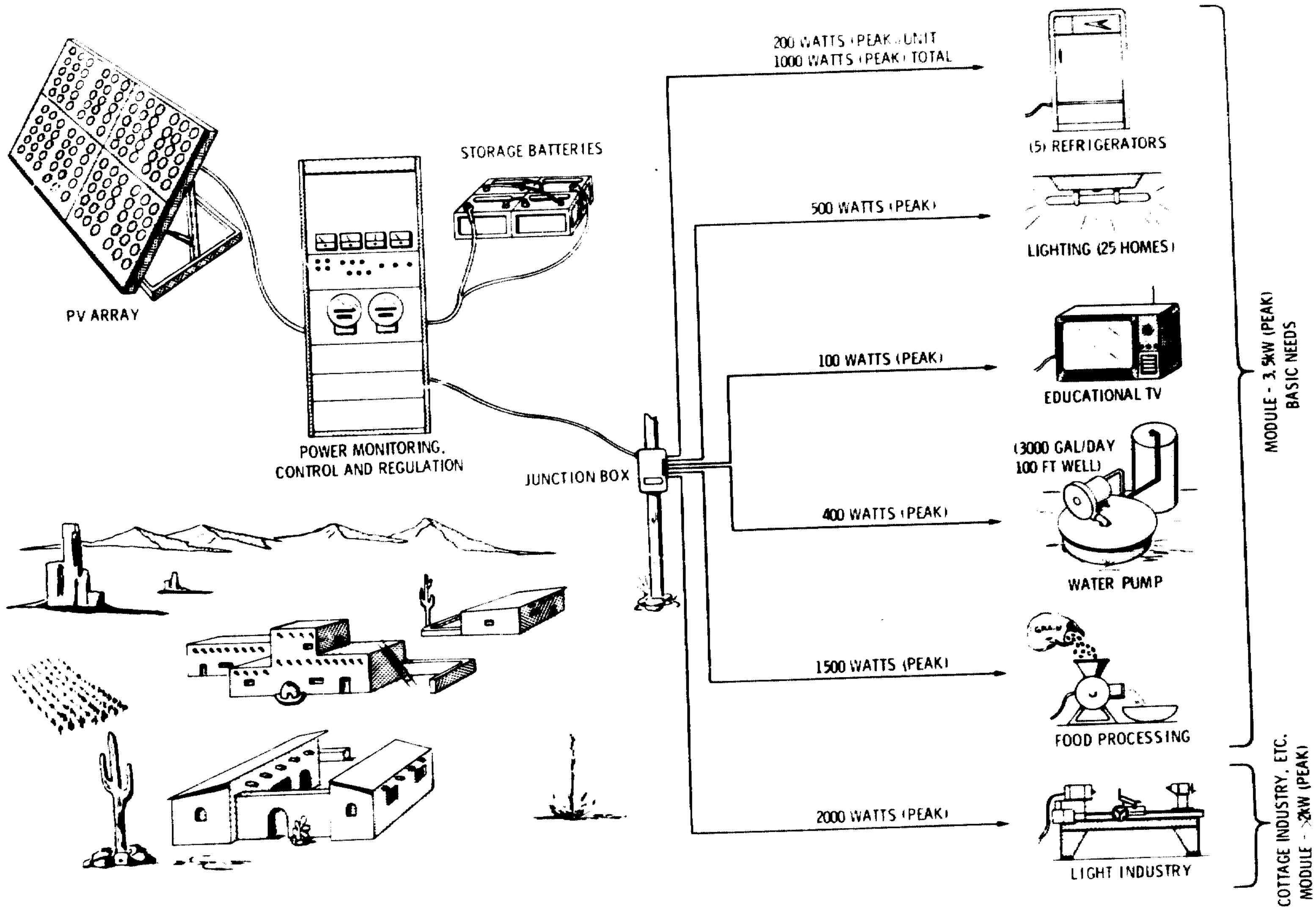

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Figure 3. - Representative photovoltaic village power system (pop. 250).

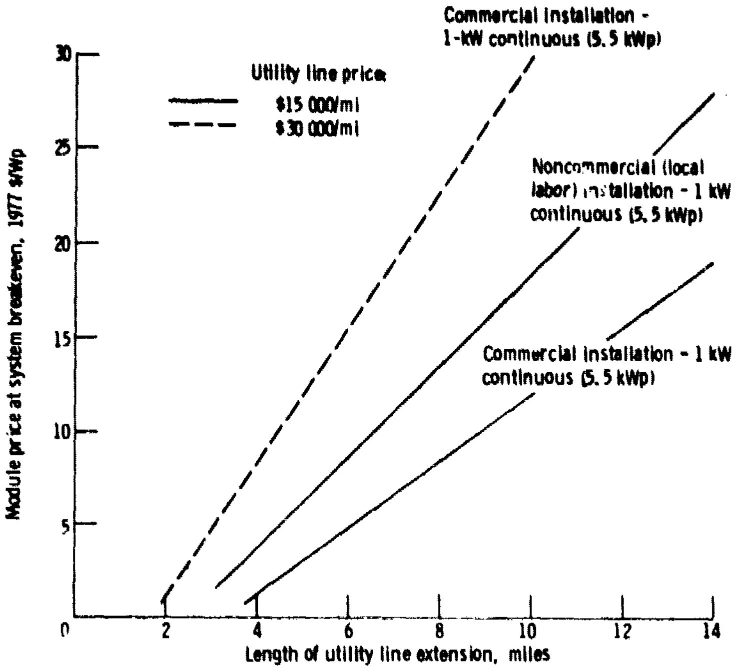

Figure 4. - Photovoltaic and utility line extension price comparison.

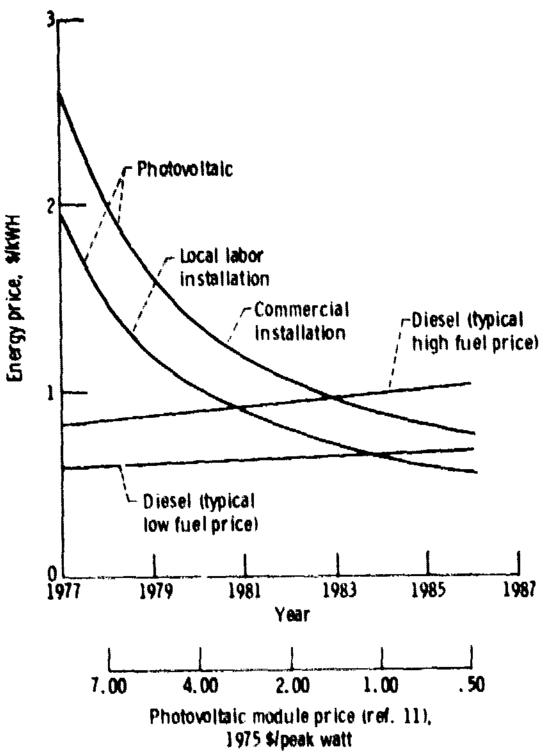

Figure 5. - Energy price comparisons for diesel generator and photovoltaic 1 kW continuous power systems.