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PHOTOVOLTAIC WATER PUMPING APPLICATIONS: ASSESSMENT OF THE NEAR-TERM MARKET

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

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by Louis Rosenblum, William J. Bifano, Larry R. Scudder,
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Lewis Research Center

SUMMARY

A preliminary assessment of the near-term market for photovoltaic water pumping 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. Water pumping applications represent 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 is defined in the government, commercial/institutional and public sectors. The foreign demand and sources of funding for water pumping systems in the developing countries are also discussed briefly. It is concluded that a near-term domestic market of at least 240 megawatts (peak) and a foreign market of about 6 gigawatts (peak) exists and that significant market penetrations should be possible beginning in the 1981-82 period.

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, that is, prior to 1986. 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.

In support of the Tests and Applications Project objectives, this report provides a preliminary market assessment of photovoltaic water pumping applications. For purposes of discussion, three categories of water pumping are considered, namely, (1) waste treatment and drainage, (2) potable water, and (3) crop irrigation.

DEFINITIONS AND TERMINOLOGY

Waste Treatment and Drainage

Applications within this category include waste treatment systems for recreational areas and highway comfort stations, and drainage pumping for land reclamation and other purposes. Remote industrial waste treatment and process pumping for aeration, sediment ponds and cooling towers are also included. Though not waste treatment, other pumping such as in fish hatcheries for water circulation and in mining operations for ore separator aeration may have merit as photovoltaic pumping applications and are included herein.

Potable Water

This category includes potable water pumping applications for small villages and public recreational and rest areas. Also included is potable water pumping for livestock watering both on the range and in feed lots, as well as power for water purification which is frequently required when surface water sources are used.

Crop Irrigation

This category takes in applications ranging from low lift pumping of surface water to deep well turbine pumping. Pump power needed for water distribution is also considered, covering power for low lift, low volume pumps for drip irrigation to high pressure, high volume pumps for sprinkler systems.

User Categories

Among domestic users, three sectors have been identified for consideration: (1) government, (2) commercial/institutional, and (3) general public. Within the government sector are the U. S. Department of Interior (National Park Service, Bureau of Outdoor Recreation, U. S. Fish and Wildlife Service, Bureau of Indian Affairs and Bureau of Reclamation), the U. S. Department of Health, Education and Welfare (Indian Health Service and Public Health Service), the U. S. Department of Agriculture (U. S. Forest Service, Agricultural Research Service and Cooperative State Research Service), and the U. S. Department of Transportation (Federal Highway Administration) as well as similar agencies on a state or local level.

Within the commercial/institutional sector are commercial crop farms, livestock ranges and feedlots, mining operatings, industrial effluent treatment facilities, and remote recreational operations (i.e., hunting and fishing lodges and campgrounds).

Within the public sector are potable water and sanitary systems for rural or vacation homes and drainage pumps.

Outside the U. S., the users would consist primarily of governments of developing countries who would purchase photovoltaic pumping systems for village domestic potable water, crop irrigation or for remote recreational facilities to enhance tourism.

MARKET ASSESSMENT

The market for photovoltaic water pumping 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 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 potential domestic market, a much larger near-term market for photovoltaic water pumping appears to exist in developing countries.

Energy Price

Competitive power systems for water pumping applications considered here are utility line extensions from central station plants, diesel generators, and photovoltaic power systems using flat-plate-type solar cell modules. In figure 1, photovoltaic module price is plotted against utility line extension distance for system break-even conditions assuming, for purposes of discussion, a continuous power level of 1 kW. This plot is based on the simplified economic break-even cost analysis given in reference 1. Both commercial and noncommercial (user-provided labor) photovoltaic system 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/mile, a 1-kW continuous (5.5 kW peak) photovoltaic system is cost-effective at module prices of about $6/watt, based on 1977 dollars and assuming noncommercial photovoltaic system installation (e.g., labor provided by the user). Using the DOE price of solar cell modules (present and projected to 1986), such a system is seen to be cost-effective today for utility line extension lengths of about 7 miles or more. A similar system commercially installed is estimated to be cost-effective for utility line extensions of about 10 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.

Using the methodology of the Aerospace report (ref. 1) with some modifications of assumptions (see appendix C), photovoltaic systems were compared with small diesel generators on the basis of energy price, 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 2 presents the price per kWH for a small diesel generator and a photovoltaic power system plotted against year and photovoltaic module price assuming, for purposes of discussion, continuous operation at 1 kW. (It should be noted that for some applications, a more favorable energy price would be realized for photovoltaic pumping systems which operated primarily during daylight periods allowing storage of pumped water rather than electric energy.) For the photovoltaic system, energy price is presented for both a commercial and a user-provided 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 1981-82 period for the high fuel price case assuming user-provided labor type installation. Further, a commercially installed, photovoltaic system becomes competitive relative to a low fuel price diesel generator system in about the 1985-86 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 (1981-86) as for the U. S.

For lower power water pumping applications in the range of a few hundred watts, a similar comparison was made for a photovoltaic system against a small gasoline motor-generator. The results indicate that the photovoltaic system becomes competitive with the gasoline motor-generator in the 1978-79 period, or 2 to 3 years sooner than for the diesel generator.

Potential Domestic Demand

Waste treatment and drainage. - Three applications for waste water pumping emerge from this preliminary assessment: (1) sanitary systems, (2) land drainage, and (3) industrial waste and process water systems.

- Sanitary Systems:

The first reported introduction of photovoltaics to this market was made in 1975 in a U. S. Forest Service sanitation project in Custer National Forest, Montana where an eight-fixture comfort station was installed at Rock Creek Vista Point powered by a 360-watt (peak) solar cell array (see fig. 3). A new type of sanitary system was required in this situation because water, commercial electricity, and suitable drainage conditions were not available at the site. Contacts with state park directors in several states and with the DOI-Bureau of Outdoor Recreation indicate that in a growing number of states, stringent requirements are being placed upon new and existing comfort stations to prevent untreated effluents from entering surface and ground water supplies. These regulations will necessitate retrofitting existing systems and providing new systems with waste treatment equipment similar to the Custer National Forest installation.

At present 320 000 campsites are in use in 5500 public parklands throughout the United States (ref. 1). Most of these sites do not have power available. In addition, 640 000 private campsites are in use. The majority of these, however, are thought to have commercial power available. The Federal-Aid Highway System has 7600 rest areas of which about 25 percent are in need of remote power (ref. 1). Based on available information (refs. 1 to 3), if 20 percent of the remote sanitary sites employed a photovoltaic power system, they would require about 110 megawatts (peak).

Competitive power for remote comfort stations appears to be primarily small gasoline engine generators. Based on energy price (see above), photovoltaic system market penetration for this application should be feasible almost immediately.

Currently, there are about 20 companies engaged in manufacture of remote sanitary facilities (ref. 4). One of these, Monogram Industries, provided the sanitary system for the U. S. Forest Service at Custer National Forest (ref. 5). LeRC contacts with three other manufacturers indicated that they were not aware of the existence of the system nor of the potential of solar power for their own product line. They did, however, indicate interest in learning more of the benefits of photovoltaic power.

● Land Drainage:

Census data published by USDA (ref. 6) shows 378 major drainage projects within the United States. The land area drained by each project varies from 3000 to 20 000 acres giving a total of 1.6 million acres. This data does not include pumping plants in states listed by USDA as county-drain states, irrigation enterprises that have installed their own drainage pumping plants, or individual farm drainage pumps. Major locations needing drainage are river bottom land, lake and coastal plains, peat land, and irrigated land. Largest state needs are in California (694 000 A), Illinois (315 000 A), Florida (293 000 A), and Louisiana (180 000 A). With the exception of California, most pumping is diesel/gasoline-engine powered with annual operation costs of about $20 per acre. Pumping requirements vary from 10 to 20 gpm per acre with working heads of 8 to 25 feet. Photovoltaic power for drainage pumping would require 150 to 700 watts (peak) per acre. If it were assumed, for example, that 500 watts (peak) per acre is required and that 20 percent of the 1 million acres under drainage powered by diesel and gasoline engines would constitute the potential photovoltaic market, the market size would be about 100 MW peak.

Solar cell power should be cost competitive for drainage applications, in some locations, within the next year. As module price decreases by the mid-1980's, photovoltaic systems should be in a position to compete for a major segment of the market.

- Industrial Waste and Process Water Systems:

Another application in the waste treatment category is water pumping for certain industrial applications. Water pumping for industrial waste sediment ponds and effluent treatment facilities and fish hatcheries and mining operations in remote areas may offer potential for photovoltaic power. No data was found in this preliminary survey which would indicate market size or cost-effective dates for these applications. The only reference to such systems is a BDM cost estimate for air and water effluent treatment of an ammonia plant (ref. 2). The study indicated that 1986 would be the photovoltaic system cost-effective date due primarily to a large battery capacity required for 24 hour/day operation.

Potable water. - There are two major potable water pumping applications: human and livestock. The water pumping needs for Indian reservations in the southwestern United States is estimated at several thousand units by the Aerospace study (ref. 1). Also, many more pump sites exist on privately owned lands. The pumping requirements for some typical Indian reservation sites are about 3000 gallons per day from a well depth of about 100 feet. This requirement can be met by a 400-watt (peak) photovoltaic system. Based on the estimated number of sites and power requirements, the market size for the Indian reservation potable water pumping segment alone - not considering private lands - is $\simeq$ 800 kW (peak).

Potable water pumping is also needed in some remote fire lookout towers and camps operated by the Forest Service and National Park Service. Two fire tower photovoltaic power system applications (shown in fig. 4) have been in operation since May 1977 as a cooperative activity between the U. S. Forest Service and the DOE/NASA-LeRC Photovoltaic Tests and Applications Project. For this application 300-watt (peak) photovoltaic arrays were architecturally integrated into two newly designed U. S. Forest Service fire lookout towers located on Antelope Peak in the Lassen National Forest and Pilot Peak in the Plumas National Forest (both in northern California). In addition to water pumping, the photovoltaic system also provides power for a refrigerator, lights, and a two-way radio.

The Forest Service is estimated to have a total of 1500 towers, camps, etc. nationwide. A similar situation exists for the National Park Service. The total number of Forest Service and Park Service remote towers and camps that may be suitable for photovoltaic-powered water pumps is not known. Further study is needed to define the market in this area. It should be noted that the Director of the National Park Service has issued a position paper which calls for the serious consideration of solar power for all new installations.

Livestock watering represents another potential application for photovoltaic-powered water pumps. An example of a photovoltaic system in such an application is shown in figure 5. Water consumption of cattle varies with animal size, ambient temperature and feed ration. Grazing cattle require about 5 gallons of water per day on a maintenance ration and 10 gallons per day on a fattening ration. Recent USDA figures (ref. 7) indicate 116 000 000 head of cattle on range lands and 12 000 000 head in feed lots. Hence, cattle demand for water is about 600 million gallons per day on the range and about 120 million gallons per day in feed lots. If only 5 percent of the range water need were assumed to constitute the photovoltaic market potential, the market size would be about 10 MW peak. However, further study is needed to adequately define the market in this area.

Crop irrigation. - Crop irrigation appears to have the largest potential as a photovoltaic water pumping application area for both the near-term and beyond. USDA (1969 figures, ref. 8) indicate 39 million acres of croplands under irrigation in the United States. In 1974, 35 million acres were irrigated by on-farm water pumps - 60 percent of these pumps were powered by fossil-fueled engines, the other 40 percent by electric utility power. Fifty-four million acre feet of ground water and 15 million acre feet of surface water were pumped by fossil-fueled engines. More recent information (ref. 9) indicates a significant number of new irrigation wells are being placed in service. In Nebraska, for example, the number of registered irrigation wells has more than doubled in the last decade. At present, between eight and nine new sprinkler irrigation systems are being added daily.

Irrigation systems may be divided into four main classes: sprinkler, surface, subirrigation, and drip. Sprinkler systems require a high pressure water supply (up to 125 psi) at the nozzle and pump capacities up to several thousand gallons per minute (refs. 10 to 12). Most sprinkler systems do not appear cost effective for near-term photovoltaic applications because of the high power required.

Some surface and subirrigation methods appear to have near-term potential for photovoltaic power since water distribution occurs at modest pressures and with gravity assistance. A particularly promising irrigation method gaining rapid adoption in the agricultural sector is drip irrigation. In 1975, 133 000 acres were irrigated by this method; 1976 statistics indicate an increase to 188 000 acres. Present estimates expect 500 000 acres to be under drip irrigation by 1980, increasing to 1 800 000 acres by 1985. States adopting drip irrigation are California, Washington, Oregon, Colorado, New Mexico, Arizona, Texas, and Florida. Photovoltaic power for drip irrigation, including modest water lifting of about 20 feet, would require about 200 watts (peak) per acre. The Aerospace Corp. study (ref. 1) reports a market size estimate of 22 MW (peak) for drip irrigation based on 60 watts/acre (i.e., no lift pumping included). Aerospace Corp. indicates (private communication with E. J. Rattin) that the reported value was derived by assuming a capture potential of 20 percent of the total drip irrigation acreage expected by 1985 (1.8 million acres), with no consideration of the market potential beyond 1985. Lacking more definitive information, at this time, the Aerospace estimate will be used.

Potential Foreign Demand

The market potential for photovoltaic-powered water pumping in non-U.S. markets is estimated to be very large; the bulk of this market being in the developing countries. Only two water pumping application categories are examined herein: irrigation and domestic potable water. Other possible application categories, such as sanitation pumping and water pumping for recreational facilities and game parks to enhance tourism, are left for a more detailed assessment.

Steve Allison, a groundwater specialist with the World Bank, has estimated that the developing countries have need for at least 100 million small (1/3 to 1/2 HP) pumping systems for irrigation. Photovoltaic power to operate such systems would require on the order of 300 watts (peak) each. On this basis, the near-term demand for photovoltaic power for irrigation applications in developing countries, assuming a 20-percent capture potential, is estimated at 6 gigawatts.

The World Bank (ref. 13) estimates that about 500 million people currently live in villages without electric power. We have estimated that the per capita use of water for drinking, cooking, and personal hygiene in rural villages is about 5 gallons per day. Assuming a 100-foot well depth, good insolation conditions, and a 20-percent market capture, leads to a projected near-term photovoltaic market size of about 70 megawatts (peak) for domestic potable water pumping in developing countries.

Foreign Market Penetration

Penetration of markets for photovoltaic-powered applications in developing countries will be paced by cost, awareness of the photovoltaic option, and availability of funds.

- <u>Cost</u>:

From the energy price analysis presented earlier, photovoltaic water pumping systems for developing countries should begin to be cost competitive against diesel or gasoline generator systems in the 1981-82 period. Further, compared with the cost of utility line extension of about 7 miles or more the photovoltaic systems examined are estimated to be competitive at present.

- <u>Awareness of the Photovoltaic Option</u>:

It is clear from contacts made with potential users and with manufacturers of water pumps during the course of this investigation that most were unaware of the potential benefits of solar cell power and the proximity to cost effectiveness of this class of power system. This situation should improve as the unfolding DOE Photovoltaic Program activities are publicized. Nevertheless, it is likely that many potential users will desire experimental or pilot tests of photovoltaic systems in order to satisfy concerns about geographic compatibility and economic and social acceptability in their specific setting. In this even' we estimate the total test time - for planning, implementation, and evaluation - will require about $3\frac{1}{2}$ to 4 years. Thus, from the point of view of confidence, many potential users may not be ready to enter the market before 1981.

● Availability of Funds:

It is our understanding, based on informal discussions, that substantial funding for photovoltaic pumping systems could be made available to developing countries by international development institutions, for example, World Bank, Asian Development Bank, Inter-American Development Bank, Agency for International Development, and the United Nations. It is a matter of record that the total value of developing country agricultural projects undertaken under World Bank sponsorship alone in 1976 was $3594.5 million (ref. 14). Of this amount, the World Bank financed $1519.4 million, the remainder was advanced by the client countries. Almost half, $743.4 million, of World Bank funds were for projects associated with irrigation. In another project area, water resources and sewage - also involving water pumping - the total value of projects undertaken with World Bank sponsorship in 1976 was put at $808.3 million. The World Bank financed $346.6 million of this amount. In addition, we estimate that funds from the other international development organizations for water-related projects exceed $1 billion annually in recent years.

Moreover, several developing countries who are also petroleum exporters, such as Saudi Arabia, Iran, Indonesia, Nigeria, and Venezuela, are in a good position to purchase photovoltaic pumping systems entirely from their own funds. Although these countries have large petroleum reserves, they have great difficulty in getting refined products to remote villages on a continuous basis, and maintaining power generating equipment. 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 part of the explanation. 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 and the absence of skilled maintenance personnel are determining factors. Photovoltaic systems consequently offer an attractive alternative.

Thus, from the above brief evaluation of cost, awareness and fund availability, significant market penetration should be possible beginning in the 1981-82 period for photovoltaic water pumping applications.

CONCLUSIONS

From limited information available for this preliminary assessment, a near-term domestic market potential of at least 240 megawatts (peak) is estimated for photovoltaic water pumping applications. The application categories included in this estimate are pumping for sanitary system, land drainage, irrigation, and domestic potable water (limited to Indian reservations). The near-term overseas market potential in developing countries is estimated to be about 6 gigawatts (peak), considering only irrigation and domestic potable water pumping applications.

Based on comparative energy price analysis with competitive power supplies and other considerations, significant market penetration should be possible beginning in the 1981-82 period.

APPENDIX A

LISTING OF GOVERNMENT AND COMMERCIAL CONTACTS MADE

Government

Allison, Steve
World Bank & Monetary Fund
Washington, DC

Altman, Landy
Solar Energy Specialist
Department of Agriculture
Washington, DC

Anderson, Carl
Water Management/ Irrigation Specialist
Department of Agriculture
Washington, DC

Aughenbauch, D. M.
National Park Service
Sante Fe, NM

Buquoi, Gerald
Louisiana State Park and Recreation Commission
Baton Rouge, LA

Casula, Pat
Department of Agriculture
Washington, DC

Falls, John
National Marine Fishery Service
Washington, DC

Glenn, P. M.
U. S. Department of Interior
Bureau of Outdoor Rec.
Albuquerque, NM

Handly, Rolland B.
Regional Director
Bureau of Outdoor Rec.
Albuquerque, NM

Hodgkins, Edward
Chief, Engineering, Location & Design Group
Federal Highway Adm.
Washington, DC

Holeman, John
Sedimentation Engineer
Department of Agriculture
Washington, DC

Krug, Eugene
National Park Service
Washington, DC

Levintow, David
Department of State-AID
Washington, DC

Lien, John
Department of Commerce
Washington, DC

Lund, Victor E.
Bureau of Indian Affairs
Phoenix, AZ

Matz, David
U. S. Forest Service
Ogden, UT

Miller, William
Chief, Division of Industrial Affairs
Department of Interior
Washington, DC

Myer, Donald G.
Director, Sanitary Engineering
Indian Health Service
Window Rock, AZ

Palmer, Larry
Bureau of Indian Affairs
Washington, DC

Rood, Ms. R. Fenton
Office of Outdoor Rec. and Planning
Oklahoma City, OK

Warner, Ms. Jean
National Park Service
San Francisco, CA

Commercial

Bier, Charles
Virginia Fiberglass Products, Inc.
Roanoke, VA

Brown, George
Civil Engineer
Pioneer Mill Company
Lahaina, Hawaii

Burkhardt, Harry F.
President
Lake Shore Equipment & Supply Company
Elyria, OH

Byg, Delbert
Agricultural Extension Service
Ohio State University
Columbus, OH

Cambell, Priscilla
Water Systems Council
Chicago, IL

Clifford, Tony
Solarex Corporation
Rockville, MD

Clock, John
ACE Pump Corporation
Memphis, TN

Cox, Rolly
F. E. Myers & Brothers Company
Ashland, OH

Daniels, William
Purdue University
Lafayette, IN

Donnelly, Richard
Spectrolab
Sylmar, CA

Fraser, Gordon
Director
International Drip Irrigation Assoc.
Colton, CA

Gunderson, Ralph
Hypro Engineering
St. Paul, MN

Halter, Harold
Farm Equipment Mfgs. Association
St. Louis, MO

Hesselbaum, Randy
Aurora Pump
Aurora, IL

Leturno, Conrad
Hypro Engineering
St. Paul, MN

Liers, Henry
Inter Technology Corp.
Warrenton, VA

Milligan, Clarence
Berkely Pump Company
Atlanta, GA

Palmer, Melville, L.
Department of Agricultural Engineering
Ohio State University
Columbus, OH

Mr. Price
Calvert Engineering
Los Angeles, CA

Rupar, Robert
Nelson Irrigation Corp.
Walla Walla, WA

Schierer, Mike
Rain Bird Sprinkler Mfg. Company
Glendora, CA

Schiltz, Tom
Sprinkler Irrigation Assoc.
Kensington, MD

Wherry, Allen
Hydraulics Institute
Cleveland, OH

Wilson, George
Professor of Transportation
Indiana University
Bloomington, IN

Yerkes, J. William
President
Solar Technology International
Chatsworth, CA

APPENDIX B

ASSUMPTIONS FOR PHOTOVOLTAIC POWER SYSTEM PRICE

COMPARISON WITH UTILITY LINE EXTENSION

The assumptions used to derive the break-even costs shown in figure 1 are given below. Utility line extension assumptions are based on reference 1 (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 (av.), \$30 000 (max)
- Connection Cost: \$250
- Transformer: \$150
- Annual Energy Cost: 1 kW_{cont} \$428
  5 kW_{cont} \$2100

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	2000
-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 PRICE COMPARISONS BETWEEN DIESEL GENERATOR AND PHOTOVOLTAIC POWER SYSTEMS

The assumptions used to derive the cost comparisons shown in figure 2 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]: $2100/Unit
- Specific Fuel Consumption[b]: 0.2 gal/kW 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]: $1315
- Annual Overhaul Cost[b]: $1629
- Installation Cost: Local, No Charge

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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. 1 (Aerospace).

[d]LeRC estimates.

Photovoltaic System[d]

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

	1977	1986
-Modules[e]	1[illegible] 000	500
-Batteries (40 kWh)	2 600	2000
-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)

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[d]LeRC estimates.

[e]Variable with year (DOE Goals - ref. 15).

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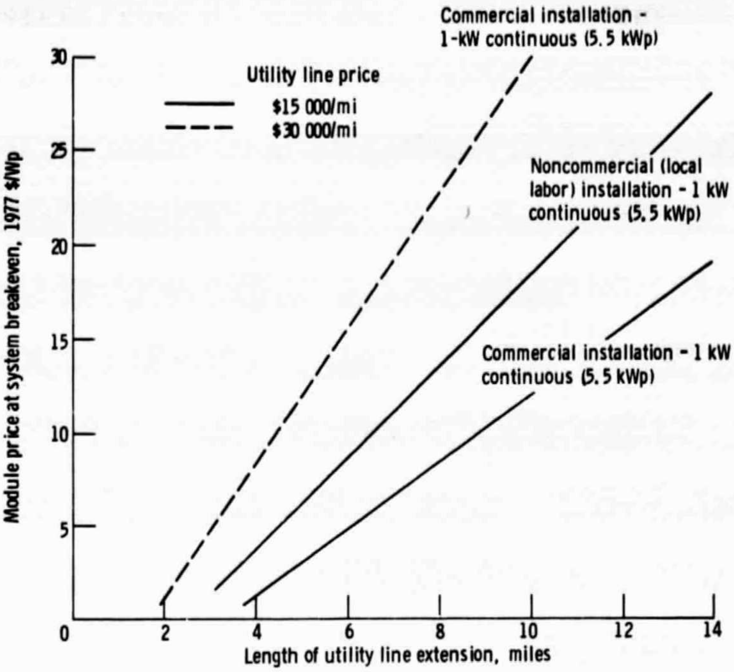

Figure 1. - Photovoltaic and utility line extension price comparison.

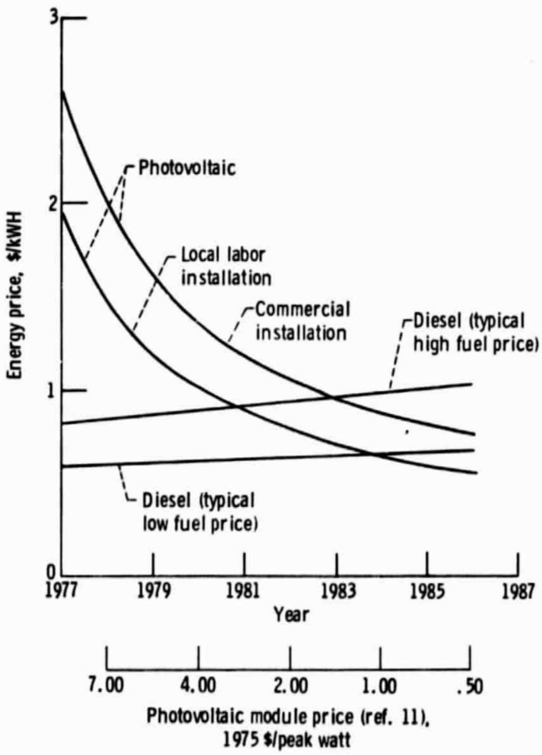

Figure 2. - Energy price comparisons for diesel generator and photovoltaic 1 kW continuous power systems.

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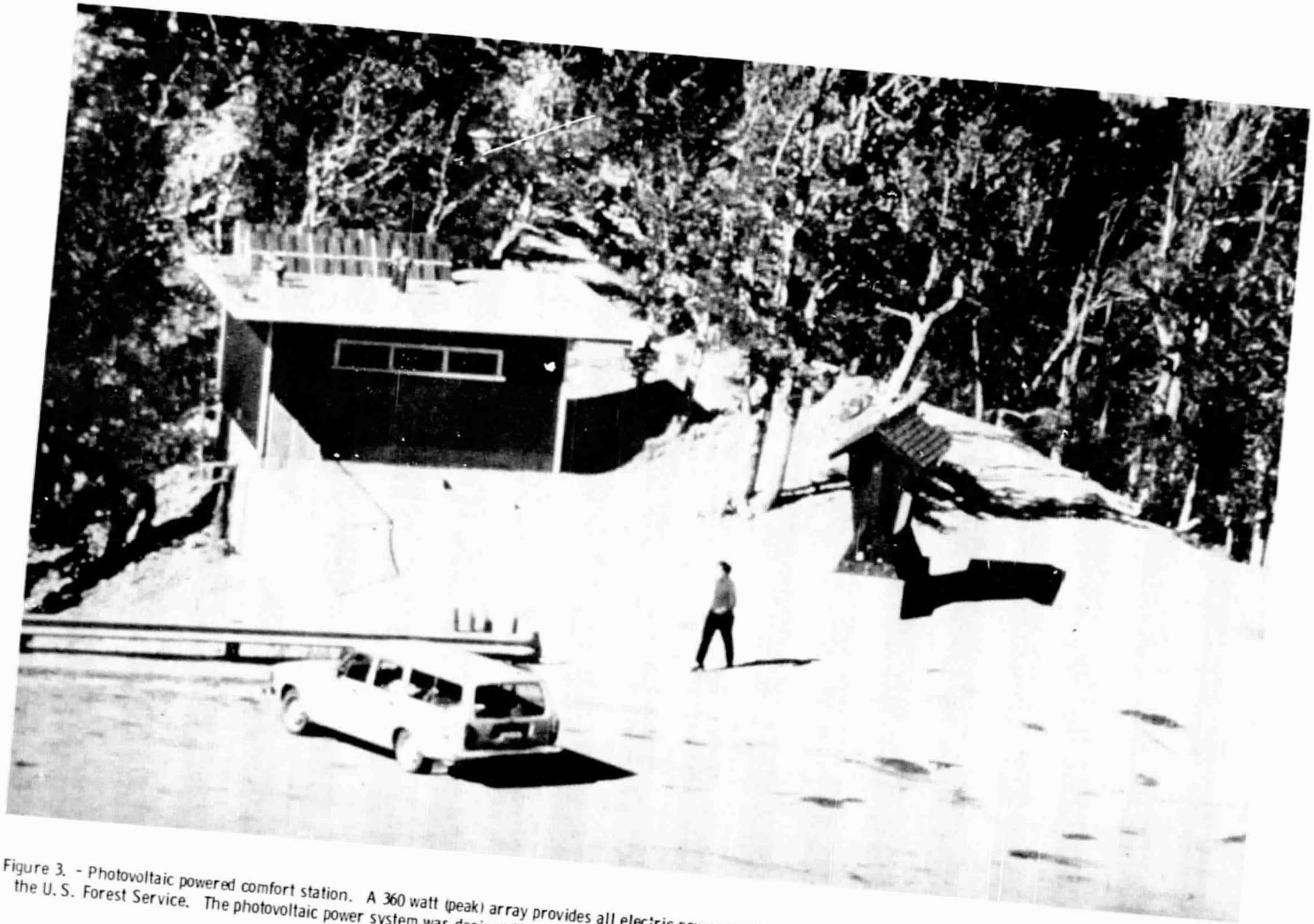

Figure 3. - Photovoltaic powered comfort station. A 360 watt (peak) array provides all electric power needs for a remote comfort station in Custer National Forest for the U.S. Forest Service. The photovoltaic power system was designed by Solarex Corp., the sanitary system by Monogram Industries.

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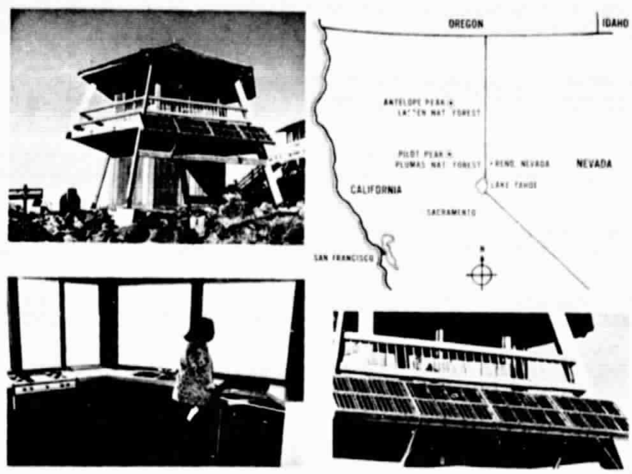

Figure 4. - Photovoltaic powered forest lookouts. Lassen and Plumas National Forests, California.

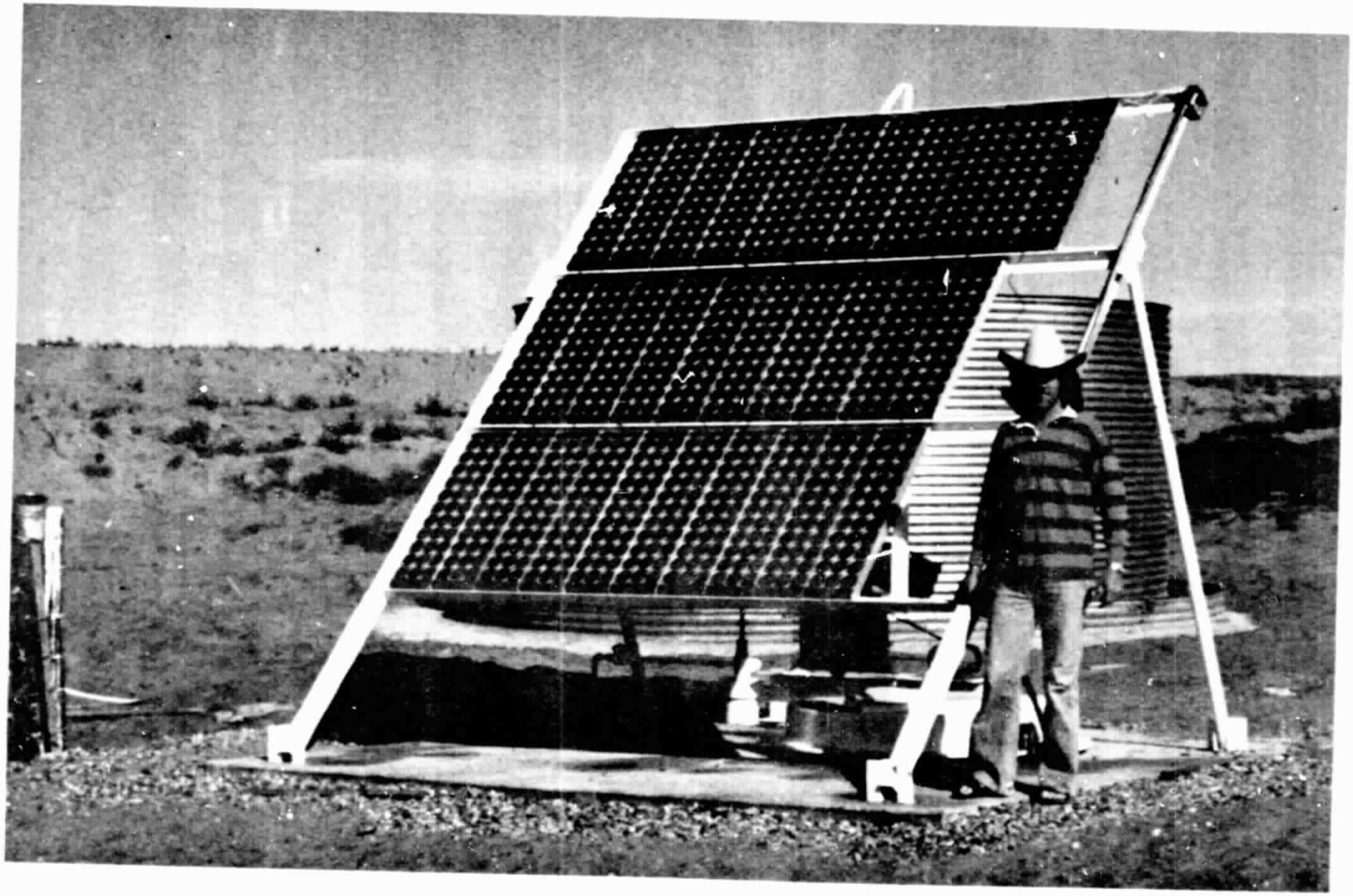

Figure 5. - Photovoltaic powered livestock watering system. This 700 watt (peak) array powers a 1/2 horsepower Jenson Jack water pump on the Isleta Indian Reservation, New Mexico. The system was built by Solar Technology International for the Bureau of Indian Affairs, U. S. Department of Interior.