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PHOTOVOLTAIC REMOTE INSTRUMENT APPLICATIONS: ASSESSMENT OF THE NEAR-TERM MARKET

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16. Abstract

A preliminary assessment of the near-term market for photovoltaic remote instrument applications is presented. Among the potential users, two market sectors are considered: government and private. However, the majority of the remote systems studied are operated by or for the federal, state, or local governments. Two types of remote instrument systems, environmental monitoring and surveillance, are discussed. Based on information obtained in this preliminary market survey, a domestic, civilian market of at least 1.3 MW_{pk} (cumulative through 1985) is forcast for remote instrument systems. This estimate is exclusive of several potentially large-scale markets for remote instruments which are identified but for which no hard data is available.

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ASSESSMENT OF THE NEAR-TERM MARKET

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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 700-1000 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.

E-9492

Due to the complexity of getting photovoltaic systems into the marketplace, the government has an important role to fill. This is 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. A category of applications termed Remote Instrument Applications is discussed herein which appears potentially attractive for the introduction of photovoltaic power sources. This category includes environmental monitoring instrument systems and surveillance instrument systems, defined below.

This category was originally selected (1) because photovoltaics appears cost-effective relative to alternative sources for instrument systems in remote areas, (2) because users have indicated interest in cost-sharing experiments, and (3) because such experiments could assist in promoting a general awareness of photovoltaics as a power source for other potential applications. Based on the above considerations, preliminary experiments were initiated with the National Weather Service of NOAA to demonstrate photovoltaics for powering Remote Automatic Meteorological Observation Systems, RAMOS, (appendix A) and with the Agricultural Research Service of U.S.D.A. for powering insect survey instruments (appendix B). Prior to these ERDA-sponsored experiments, NASA LeRC conducted tests with NOAA, beginning in 1973, of photovoltaic-powered remote weather stations at Mammoth Mountain, California and Sterling, Virginia (ref. 1).

It is appropriate now to further assess the potential for such applications in terms of the expectant market penetration and the need for additional experiments to accelerate commercial adoption. Accordingly, a preliminary market assessment of the Photovoltaic Remote Instrument Application category was made and the results reported herein.

DEFINITIONS AND TERMINOLOGY

Remote Instrument Systems

For this report remote instrument systems are defined as either environmental monitoring instrument systems or as surveillance in-

strument systems. Remote implies that the instrument is located such that it cannot be operated economically by utility power.

Environmental Monitoring Instrument Systems

Environmental monitoring instrument systems provide in situ measurements and data germane to areas of interest such as:

Agriculture	Hydrology
Environmental Quality	Meteorology
Forestry	Oceanography
Geology	Seismology

Surveillance Instrument Systems

Surveillance instrument systems sense and signal or provide data for applications such as:

Pipeline and oil or gas well status
Security (e.g., intrusion sensors and perimeter surveillance)
Traffic (e.g., vehicle number and rate)
Failure detection
Insect control surveys

USER CATEGORIES

Users of environmental monitoring and surveillance systems include both the government and private sectors. However, the majority of the systems are operated by or for the federal, state or local governments. These users are varied and generally insular. Hence, technology diffusion is slow or nonexistent among the different agencies and, in many instances, even within the same agency. A partial list of federal and state government users is shown in table I reproduced from reference 2. Private sector potential users include manufacturers, commercial firms, and universities.

PRELIMINARY MARKET ASSESSMENT

The preliminary market assessment presented here is based on (1) information from several published or preliminary reports (refs. 2 to 6), (2) telephone contacts with users and manufacturers in May and June 1977 (appendix C), and (3) the results of earlier LeRC user solicitation surveys.

Potential Domestic Markets

Environmental Monitoring Instrument Systems. - Photovoltaic power sources have already penetrated the market for environmental monitoring instrument systems. Reference 4 and telephone contacts with manufacturers both indicate a 1976 market of approximately 1-1.5 kW_{pk} for solar cells for environmental monitoring instruments. Predictions of future photovoltaic penetration of the market range from about 9 kW_{pk} annually (ref. 5) to 30 kW_{pk} annually (ref. 4) in 1985. The cumulative peak power by 1985 is predicted by reference 5 to be on the order of 40 kW. The forecast given in reference 5, however, is undoubtedly low, as it is based on information from only a portion of the potential users in the federal sector. Not included, for example, were potential users in the Bureau of Reclamation, TVA, and EPA. Also not included were state and local government users, private sector users, and potential foreign markets.

Reference 2 has identified about 50 government data collection "networks" consisting of approximately 100,000 environmental monitoring stations. A telephone contact with a co-author of the cited reference indicates that 15,000-20,000 of these stations are probably remote. Pertinent findings from reference 2 are summarized in table II

Earlier solicitation efforts by LeRC have uncovered a substantial interest in photovoltaic power for environmental monitoring instrument systems among users. One of these, the Department of Environmental Protection of the State of New Jersey, in consultation with LeRC, has redesigned their air quality monitoring system to require less power

and thus make it more amenable to the use of photovoltaic power. This particular application type is of some consequence to market considerations, since it would require about 300 or more peak watts of array for each air quality monitoring system, as compared to 4-10 peak watts for most of the other known environmental monitoring instrument systems.

Also contacted earlier were several producers and lessors of environmental monitoring instrument systems, such as Wright Associates, North Electric Company, and COMSAT. In general, much interest was expressed in using photovoltaic systems. This interest manifested itself into action, when Wright Associates subsequently opted to use a photovoltaic power supply for a micrometeorological monitoring system at a shale oil reclamation site near Vernal, Utah (fig. 1). In addition, Wright now offers its customers a photovoltaic power option for its instrument line.

In recent telephone discussions, COMSAT General Corporation has indicated that a network of 10,000 satellite data collection platforms (DCP) is being planned. COMSAT is considering using photovoltaic power systems with the remote DCPs. Similarly, the U.S. Geological Survey indicated that they were considering powering seismic detectors and tiltmeters with solar cells. Further, if Congress acts favorably on currently pending legislation, the total number of seismic detection stations will be increased from the present 500 to as many as 5,000.

No data could be obtained during the present assessment on the size of the private sector market for environmental monitoring instrument systems. Definition of this area is needed. Additionally, further study is required to define the size of the DoD market, although some data is given in reference 3.

Surveillance Instrument Systems. - No hard data is available on the overall market size for instrument systems in this category. However, it is known that a multiplicity of users and applications exist in all levels of government (including DoD, ref. 3) and in diverse elements of the private sector. Based on consideration of a limited number of users and applications, reference 5 forecasts a cumulative market for

photovoltaic-powered intrusion detection systems of 1.3 MW_{pk} by 1985, with 1985 annual sales of 120 kW_{pk}. Photovoltaics have already achieved modest penetration of the surveillance instrument system market. For example, reference 4 reports that of 1,000 intrusion alarm systems sampled, 5 percent were powered by solar cells.

Several potentially sizeable applications for photovoltaics exist in the surveillance instrument system category that were not included in the reference 5 forecast mentioned above. Among these are approach sensors (railroad and highway), and failure detection (railroad hot-boxes and pipeline monitoring). Recent telephone contacts with manufacturers indicate a number of applications underway or planned, for example, traffic counters (Motorola), iceberg tracking (Western Union), status of pipelines, oil and gas wells (Motorola), and power flow in networks (EG&G).

All of the above information indicates that the potential market for the surveillance instrument system category is well in excess of the 1.3 MW_{pk} cited earlier.

Potential Foreign Markets

Markets exist for both environmental monitoring and surveillance instrument systems outside the U.S. However, little hard data is available. One estimate obtained for the existing number of environmental monitors globally was 250,000 (ref. 6). This would imply approximately 150,000 systems outside the United States. The number of markets throughout the world, the extent to which they will expand by 1985, and potential penetration by photovoltaics needs further study.

CONCLUDING REMARKS

Photovoltaic power sources have already penetrated the remote instrument application market to a small extent. However, the highly varied and insular nature of the user groups poses a significant barrier to the rapid diffusion of this technology.

Based on limited information currently available, a domestic, civilian market of a least 1.3 MW_{pk} (cumulative by 1985) is forecast for remote instrument systems. This estimate is based largely on selected surveillance applications and does not include several potential large-scale applications, for example, pollution monitoring, fire detection, industrial surveillance, and insect survey, for which no forecasts exist. Additionally, military and foreign remote instrument application markets should increase estimates substantially.

REMOTE MICROCLIMATOLOGICAL MONITORING SYSTEM
VERNAL, UTAH

FIGURE 1.

APPENDIX A

SOLAR POWERED WEATHER STATIONS

Solar cells are now powering six RAMOS (Remote Automatic Meteorological Observing System) for the National Weather Service (NWS). RAMOS is the latest in a series of automatic weather stations developed by the NWS and used in a network of about 1000 manned and unmanned reporting stations located coast to coast.

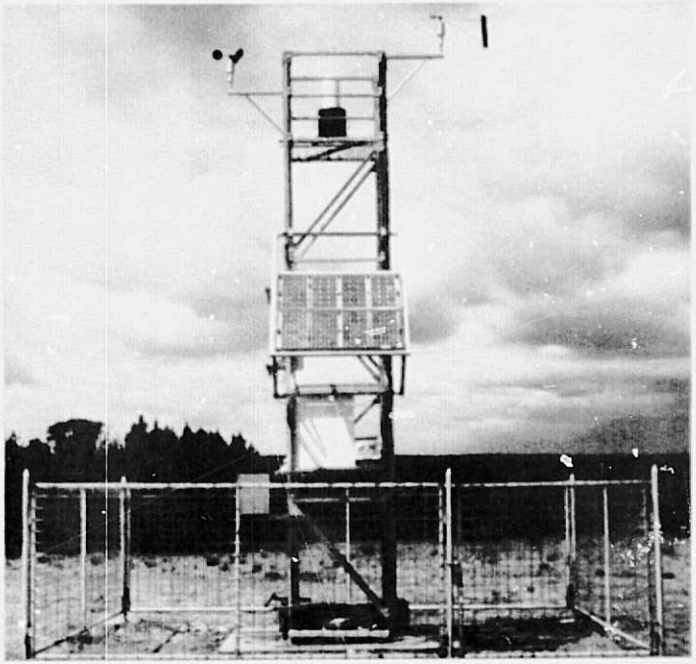
The solar-powered RAMOS experiment is one of several applications now under tests as part of the DOE/NASA Tests and Applications Project to stimulate the use of photovoltaic solar power.

Several sites were selected to evaluate the applicability of photovoltaics under a variety of climatological conditions. Solar cell power systems are located at Stratford Shoals; New York (a small island in Long Island Sound), Clines Corners, New Mexico, South Point, Hawaii, Point Retreat, Alaska, Halfway Rock, Maine, and Loggerhead Key, Florida. The power level of the RAMOS solar cell system varies from 74 to 148 peak watts depending on location.

The NWS has stated that in the most remote locations (such as Point Retreat, Halfway Rock and Loggerhead Key) the use of solar cells will save up to $150/year/site in fuel costs and up to $3000/year/site in fuel transportation and maintenance costs which would normally be required for the leading competitor, a thermoelectric generator (TEG) system. Even more impressive is a comparison of 10 year life cycle costs for solar cells vs TEG which yields a 2:1 cost advantage for photovoltaics.

NOAA RAMOS

STRATFORD SHOALS, LONG ISLAND SOUND



CLINES CORNERS, NEW MEXICO

FIGURE A-1

APPENDIX B

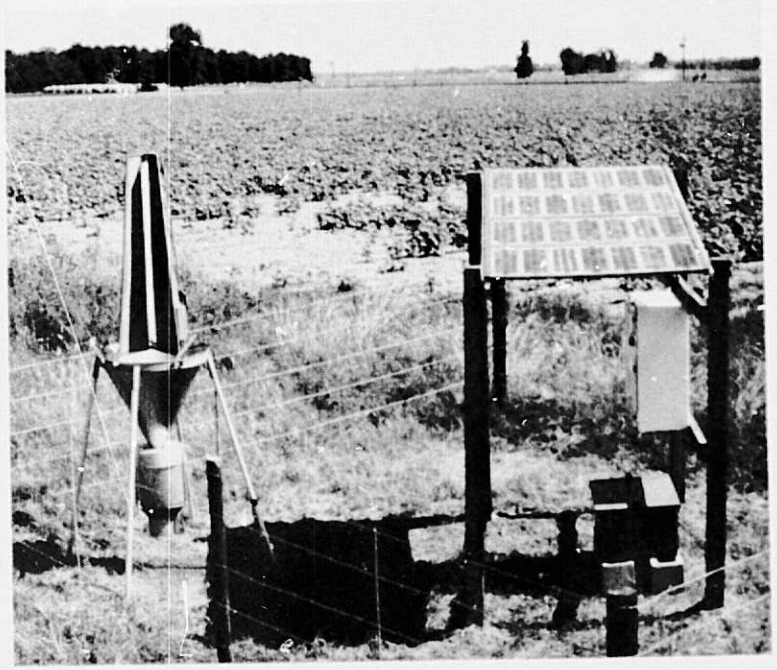
PHOTOVOLTAIC-POWERED INSECT SURVEY TRAPS

Solar cell arrays are now providing electric power for four insect survey traps near Texas A&M University in College Station, Texas. The traps were designed and built by the Agricultural Research Service (ARS-Cotton Pest Control Equipment and Methods Research Unit) of the U. S. Department of Agriculture at College Station. The photovoltaic power systems for this joint ARS-NASA-DOE experiment were designed by engineers at the NASA Lewis Research Center as part of the DOE sponsored Photovoltaic Tests and Applications Project.

Insect survey traps are used to determine population patterns of harmful insects so that effective pest control programs can be initiated thereby reducing damage to crops. One type of trap utilizes a fluorescent blacklight to attract insects; another kills the insects on an electric grid after they have been attracted by a synthetic pheromone (sex attractant). To date, a network of these types of traps have been utility-powered by means of long extension cords; consequently, flexibility of siting was greatly limited. Now, ARS scientists are not constrained in the conduct of insect studies; traps can be placed in the most advantageous and effective locations.

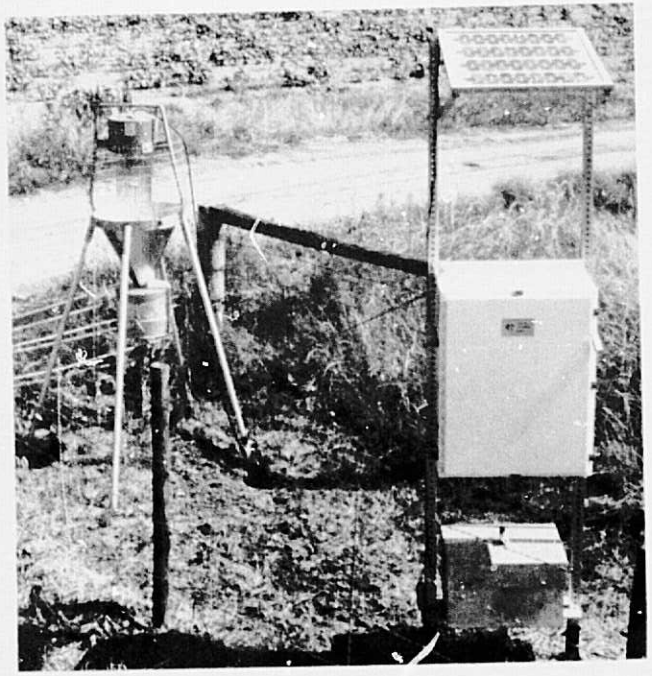
The data gathered on insects collected by the network of traps is used in computer programs which allows ARS scientists to predict future insect populations.

Although the insect survey trap network near Texas A&M is concerned particularly with the cotton boll weevil, similar traps are also used in many other locations for survey and/or control of other crop-destroying pests; consequently, the overall potential market for solar-powered units is believed to be significant.



BLACKLIGHT TYPE

(140 Peak Watt Array)



CHARGED GRID TYPE

(20 Peak Watt Array)

INSECT SURVEY TRAPS

FIGURE B-1

APPENDIX C

GOVERNMENT AND COMMERCIAL CONTACTS MADE FOR MARKET RELATED INFORMATION

Government

Arbesman, Paul
Director, Environmental Quality Division
N. J. Dept. of Environmental Protection
Trenton, NJ

Bilyeu, Jay
DOE, Savannah River Operations
Aiken, SC 29801

Burbank, Farnum
Fire Management Engr.
USDA/Forest Service
Roselyn, VA

Coats, Gregory
DOI/U. S. Geological Survey
Reston, VA

Morton, William
USDA/Forest Service
Washington, DC

Environmental Protection Agency
Washington, DC

Environmental Protection Agency
Las Vegas, NV

Environmental Data Service
Washington, DC

Environmental Data Service
Boulder, CO

National Oceanic & Atmospheric Administration
Bay St. Louis, MS

Commercial

Bernier, Robert
Earth Resources Marketing Mgr.
COMSAT General
Washington, DC

Brodhocker, John
ESB, Inc.
Cleveland, OH

Mr. Christianson
LaBarge, Inc.
Electronics Division
Tulsa, OK

Clifford, Tony
Solarex
Rockville, MD

Donnelly, Dick
Spectrolab
Sylmar, CA

Fox, William
Western Union
Government Systems Div.
McLean, VA

Hrin, Sharon
Operations Research, Inc.
Silver Spring, MD

Liers, Henry
Senior Engineer
InterTechnology Corp.
Warrenton, VA

McGinnis, Robert
Motorola Solar Systems
Phoenix, AZ

McGregor, Dennis N.
Operations Research, Inc.
Silver Spring, MD

Merchon, James
Vice President
Wright Associates, Inc.
Longmont, CO

Rattin, E. J.
Aerospace Corporation
El Segundo, CA

Wheatley, John
EG&G, Inc., Albuquerque Div.
Albuquerque, NM

American Society of Corrosion Engineers
Houston, TX

Electronic Industries Association
Washington, DC

El Paso Natural Gas
El Paso, TX

General Battery
Redding, PA

Globe Union
Milwaukee, WI

GTE Lenkurt
San Carlos, CA

Institute of Electrical and
Electronic Engineers
New York, NY

ITT
Raleigh, NC

McGraw Edison
Bristow, CT

National Climatic Center
Nashville, NC

Microwave Associates
Burlington, MA

Oil Pipeline Association
Washington, DC

Petroleum Institute of America
Washington, DC

Pollution Control News
Pittsburg, PA

Research Control News
Pittsburg, PA

Secode Electronics
Dallas, TX

Teledyne Energy Systems
Timonium, MD

Transcontinental Pipeline
Houston, TX

Wayne Broyles
Consulting Engineers
Houston, TX

REFERENCES

1. Forestieri, A. F.; and Ratajczak, A. F.: Terrestrial Applications of FEP-Encapsulated Solar Cell Modules. NASA TM X-71608, 1974.

2. Hrin, S.; and McGregor, D.: United States Data Collection Activities and Requirements. (ORI-TR-1124-Vols. 1 & 2, Operations Research, Inc.; NASA Contract NAS5-22467.) NASA CR-152523 and NASA CR-152524, 1977.

3. Technical/Cost Evaluation of Photovoltaic Energy Systems for DoD Applications. BDM/W-76-144-TR, BDM Corp., 1976.

4. BDM Corporation: "Photovolatic Power Systems Market Identification and Analysis - Task 1 Results." Oral presentation at ERDA Headquarters, April 8, 1977.

5. The Aerospace Corporation: "Mission Analysis of Photovoltaic Solar Energy Conversion - Volume II: Survey of Near-Term (1976-1985) Civilian Applications in the United States" (Contract No. E(04-3)-1101 for ERDA) Final Report (to be published).

6. Mercanti, Enrico: Satellite Data Collection Newsletter, no. 1, January 26, 1977. Satellite Data Collection Interagency Working Group.

TABLE I. - POTENTIAL DATA COLLECTION SYSTEM USERS

[Final Report Contract NAS5-22467, Vol. I, p. 3-5]

- Department of Agriculture
  - Forest Service
  - Soil Conservation Service
- Department of Commerce
  - National Bureau of Standards
  - National Oceanic and Atmospheric Administration
    - Environmental Data Service
    - National Environmental Satellite Service
    - National Marine Fisheries Service
    - National Ocean Survey
    - National Weather Service
- Department of Defense
  - Department of the Air Force
    - Air Weather Service
  - Department of the Army
    - Corps of Engineers
    - Defense Civil Preparedness Agency
  - Marine Corps
  - Department of the Navy
    - Naval Facilities Engineering Command
    - Naval Oceanographic Office
    - Naval Weather Service
- Department of the Interior
  - Bonneville Power Administration
  - Fish and Wildlife Service
  - Geological Survey
    - Water Resources Division-Office of Water Data Coordination
  - Bureau of Indian Affairs
  - Bureau of Land Management
  - National Park Service
  - Bureau of Reclamation
  - Bureau of Sport Fisheries and Wildlife
- Department of Transportation
  - Coast Guard
  - Federal Aviation Administration
- Office of Emergency Preparedness
- Energy Research and Development Administration
  - Nuclear Regulatory Commission
- Environmental Protection Agency
  - Office of Air Programs
  - Office of Water Programs
  - Office of Pesticide Programs
  - Office of Radiation Programs
- International Boundary and Water Commission
- National Aeronautics and Space Administration
- National Science Foundation
  - Office of Polar Programs
- Smithsonian Institute-Center for Short-Lived Phenomena
- States
  - Division of Forestry
  - Division of Water Resources
  - Department of Health
- Tennessee Valley Authority
- World Meteorological Organization

TABLE II. - A PARTIAL LIST OF POTENTIAL PHOTOVOLTAIC REMOTE INSTRUMENT USERS AND APPLICATIONS*

[Final Report Contract NAS5-22467, ref. 2]

Network identification	Number of stations	Application category	Geographical location
National Weather Service	9,445	Hydrology/Climatology Meteorology/Agriculture	Throughout the 50 states, Puerto Rico and several islands.
U.S. Geological Survey (Surface Water)	18,244	Hydrology	17,481 in 48 states, 14 in a small portion of Canada, 199 in Alaska, 238 in Hawaii and 312 outside the U.S.
U.S. Geological Survey (Water Quality)	7,826	Hydrology	7,407 stations in the 48 states, 177 in Alaska, 154 in Hawaii and 88 outside the U.S.
U.S. Geological Survey (Ground Water Level)	18,268	Hydrology	17,822 stations in the 48 states, 78 in Alaska, 165 in Hawaii and 143 outside the U.S.
Corps of Engineers	5,500	Hydrology	Throughout the U.S.
National Weather Service	1,090	Hydrology	Throughout the U.S.
Tennessee Valley Authority	1,155	Hydrology	Tennessee River Valley
Bureau of Reclamation	5,041	Hydrology/Agriculture	17 Western States
National Air Surveillance Network and EPA	320 (stations) 966 (monitors)	Environmental Quality	Throughout the U.S.
State and Local Air Quality Monitoring Networks	4,785 (stations) 8,358 (monitors)	Environmental Quality	Throughout the U.S., Puerto Rico and several Pacific Islands
Soil Conservation Service	1,704	Hydrology	Western U.S. and Columbia River Basin in British Columbia
Forest Service	2,000	Meteorology/Forestry	Throughout the U.S.
U.S. Geological Survey	635	Geology	Throughout the U.S., Alaska, Hawaii and Puerto Rico